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DISCUSSION PAPER

// JENS HORBACH AND CHRISTIAN RAMMER

Energy Price Shocks and Short-Time Reactions of Firms: The Case of the German Energy Crisis in 2022

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Energy Price Shocks and Short-time Reactions of Firms: The Case of the German Energy Crisis in 2022

Jens Horbach[a], Christian Rammer[b]

Abstract

After the beginning of the war in Ukraine, energy prices in Germany increased drastically. The paper analyses responses of German firms to this energy price shock. A variety of measures and reactions at the firm-level are explored, such as substituting machinery and equipment by less energy consuming alternatives, a change of energy suppliers, the use of digital technologies to reduce energy consumption, the introduction of energy management systems, relocation or closure of energy intensive activities, or replacing fossil by other energy sources. The analysis is based on data from the German part of the Community Innovation Survey (CIS). The econometric results show that a high affectedness by the energy price shock in 2022 triggers the substitution of machinery and equipment by more energy efficient alternatives. This measure in turn is correlated to a decrease of electricity consumption and oil use, and it promotes the substitution of fossil energy sources by renewables. The results also show that high energy costs can lead to stopping or relocating energy-intensive activities. Furthermore, firms with high energy intensity show negative sales growth from 2022 to 2023.

JEL-Classification: C21, C25, L25, Q21, Q41

Key words: Energy price shock, green energy firm behaviour, probit and quantile regressions

a Technical University of Applied Sciences Augsburg, jens.horbach@tha.de

b ZEW - Leibniz Centre for European Economic research, rammer@zew.de

1. Introduction

From 2021 to 2022, energy prices increased drastically in Germany as a consequence of Russia's war against Ukraine, which lead to a discontinuation of natural gas and oil supply from Russia to Germany and a sharp rise in international energy prices. The price of natural gas increased by 89% between 2021 and 2022 (annual average, Destatis 2024), resulting in a huge price shock for the most important energy source of German manufacturing (in 2021, 30.5% of all industrial energy consumption was natural gas). Prices of other energy sources such as fuel oil, heat and electricity increased at a high rate, too. This unexpected and dramatic increase in energy cost hit many firms hard and called for counteraction. One natural reaction is to reduce energy consumption by increasing the energy efficiency of business activities or avoiding unnecessary energy consuming activities. In addition to smaller energy saving measures such as lower room temperature or reducing travel, more substantial reductions of energy cost may result from the substitution of machinery and equipment by less energy consuming alternatives, the use of digital technologies to increase energy efficiency such as smart meters, the implementation of energy management systems or the change of energy suppliers. However, the energy price shock may also undermine the economic viability of certain business activities, urging firms to either stop some energy intensive activities, or to relocate these activities to countries with lower energy price increases. A third type of reaction to the energy price shock might be a change in the structure of energy sources, particularly through substituting fossil energy sources by renewables.

There is extensive literature on the macroeconomic relationship between energy prices and growth (see Kilian 2008, Alexeev and Chih 2021, Sokhanvar et al. 2023), but rather limited evidence on how firms react on energy price shocks (see Fontagné et al. 2024, Henriques et al. 2024). Firm-level information on the specific responses regarding different energy related measures is important, however, for the design and fine-tuning of policy measures aiming at attenuating adverse economic impacts of energy price shocks. The present paper investigates the extent to which different possible reactions to the energy price shock in 2022 have been used by firms in Germany during 2022. Based on data from the German part of the Community Innovation Survey (CIS) conducted in 2023, we analyse the determinants of different energy price shock reactions as well as the impact of these reactions on firm performance (measured by the change in sales between 2022 and 2023). It is important to note that the present analysis focuses on short-term reactions of firms because the adaptation of energy and production systems need a much longer time frame.

The paper is organised as follows. In Section 2, the theoretical background and the relevant empirical analyses of the literature are discussed leading to our hypotheses for the empirical analysis. Section 3 presents descriptive statistics on energy sources, prices and consumption in the German manufacturing sector. Our estimation strategy and the results of econometric analyses of the three groups of responses of firms to the energy price shock are presented in Section 4. Section 5 discusses the key findings of our analysis.

2. Related literature and hypotheses

Literature overview

Firm level analyses on the consequences of energy price shocks are still rare, while there are many studies showing macro-economic evidence. One recent exception is the analysis of Fontagné et al. (2024) using firm level data from French manufacturing for 1996-2019. The authors find that "firms adapt quickly, strongly and through multiple channels to energy shocks" (Fontagné et al. 2024: 1). The authors observe that the firms reduced their energy demand supported by an increase in energy efficiency and an optimisation of energy use across different plants. But firms also increased the imports of intermediate inputs and were able to pass-through higher energy costs on export prices, while production, exports and employment slightly decreased. Interestingly, in the more recent period 2012 to 2019, the effects of higher energy prices on production and employment were close to zero whereas during the period 1996 to 2012, effects on these two variables were considerable. Marin and Vona (2021) use the same French firm level data from 1997 to 2015 and show that energy price increases reduce energy consumption and thus CO_2 emissions. These effects are accompanied by modest negative effects on employment and productivity.

Dussaux and Monjon (2023) use panel data from French manufacturing firms for 2001 to 2015 to analyse the effects of energy price shocks on export strategies of the companies. Using an instrumental variable approach, the authors detect that a 10% increase in energy costs is linked to a 3.6% decrease in total export value, while export prices increased by 2.3%.

Wolverton et al. (2022) analyse the response of the U.S. manufacturing sector to higher electricity prices. During the time period 1992 to 2015, regulation-driven higher electricity prices led to a decline of electricity use by 1.2% for all plants and 1.8% for energy-intensive plants. Consistent to the results of the before-mentioned studies for France, the effects on output and employment were small.

Martin et al. (2009) estimate the impacts of an energy tax increase on the manufacturing sector using panel data from the UK. An analysis of fuel choices at the firm level shows an increase in electricity use leading to less CO_2 emissions. The authors do not detect statistically significant effects on employment, output or productivity.

For Italy, Alpino et al. (2023) analyse the effects of the 2021 energy price increase on energy input choices of medium-sized and large industrial firms based on survey data. The authors find that the price elasticity of demand is very close to zero for electricity and natural gas, also due to fixed-price contracts subscribed before the crisis. Compared to other firms, the product price increases of energy intensive firms were disproportionally high.

Greve et al. (2023) analyse the reactions of small Mexican firms to energy price increases. The effects of higher fuel and electricity prices show potentially large short-term effects on profits. Furthermore, the authors find a substitution of energy by labour, and some firms succeed to pass on higher fuel costs to customers.

Bastos et al. (2024) analyse the effects of the 2022 global energy crisis on the diffusion of low-carbon technologies. The authors find an acceleration of these technologies in 2022 measured by job postings and earnings calls transcripts. Amaglobeli et al. (2024) also detect a positive effect of the 2022 energy crisis on the mitigation of greenhouse gas emissions, using firm-level data from the U.S. and Germany. German firms reacted particularly strong by investing in energy saving and energy efficiency measures, besides passing-through higher energy costs to consumers.

Manuel et al. (2024) explore the economic consequences of the 2022 energy crisis for the UK. They find that corporate profits declined since the beginning of 2022. Firms with a higher market power were able to maintain higher profit margins.

Ferriani et al. (2022) analyse the impact of the Ukraine war on energy prices and firms' financial performance for European firms listed in the Eurostoxx 600 index. The authors find that equity returns decreased disproportionally for energy and carbon intensive firms.

From a macroeconomic perspective, Hutter and Weber (2023) analyse the short-run production and labour market effects of the 2022 energy crisis for Germany. The authors use sector-specific energy intensity as indicator for the affectedness of firms by the energy crisis. Directly after the beginning of the Russia-Ukraine war and the strong increase in energy prices, the monthly production and real turnover declined by 4.1% and 2.6%, respectively. Interestingly, employment was not reduced at the same rate, but rather short-time work increased while vacancy postings were reduced.

For Germany, too, Bachmann et al. (2022) explore the economic effects of a stop of Russian energy imports. The authors show that in the short run, a stop of Russian energy imports would lead to a reduction of GDP between 0.5% and 3%. In a similar vein, Krebs and Weber (2024) show that the energy crisis in 2022 led to a one-year loss of 4% of German GDP, comparable to the short-run losses of the Covid-19 pandemics in 2020 and the financial crisis in 2008. Ruhnau et al. (2022) show that industrial consumers already reduced their demand of gas in 2021 when whole-sale prices for natural gas increased. Compared to household gas demand, the reactions of the industry were stronger and earlier.

Hypotheses

Based on the extant literature on firm-level impacts of energy price shocks, we derive three hypotheses that will guide our empirical analysis. The first hypothesis is related to the ways how energy price shocks may affect firm decisions related to how energy is used in a firm (see also Fontagné et al. 2024). Since energy is a main input for business activities, higher energy prices lead to an increase of input costs. These costs include both expenses on a firm's own energy consumption, as well as higher prices for intermediary products that use energy inputs, and higher costs of transport, logistics and other services that consume energy. If these higher input costs are passed through on (export) prices, the (international) competitiveness of the affected firms is likely to decrease. This can lead to lower demand and thus to a reduction in output and employment. For energy intensive firms in particular, measures to increase energy efficiency as well as energy saving measures are therefore crucial. Another strategy might be to move energy intensive activities to locations with lower energy costs, to (internationally) outsource energy intensive business activities, or to shut-down activities subject to high energy costs. These considerations lead to our first hypothesis:

H1: Firms that are strongly affected by increasing energy prices are more likely to invest in mitigating measures such as increasing energy efficiency and other measures to reduce energy consumption, but they may also be more likely to relocate or shut-down energy intensive activities.

In addition to reducing energy costs, energy price shocks may also motivate firms to adapt their wider energy strategy, although such changes may reduce energy cost often in a more medium-term than short-term perspective. For example, along with installing more energy-efficient equipment, firms may change the composition of energy sources consumed towards those sources that are less affected by price increases. In the specific situation of the year 2022 in Germany, such a strategy would focus on substituting fossil by renewable energy sources, since fossil sources showed the highest increase in energy prices (see Section 3). In the same vein, relocating or stopping energy intensive activities is also likely to result in a shift in the composition of energy sources, leading to our second hypothesis:

H2: Firms that engage in mitigating measures to increase energy efficiency and reduce energy consumption are more likely to substitute fossil energy sources by renewable ones.

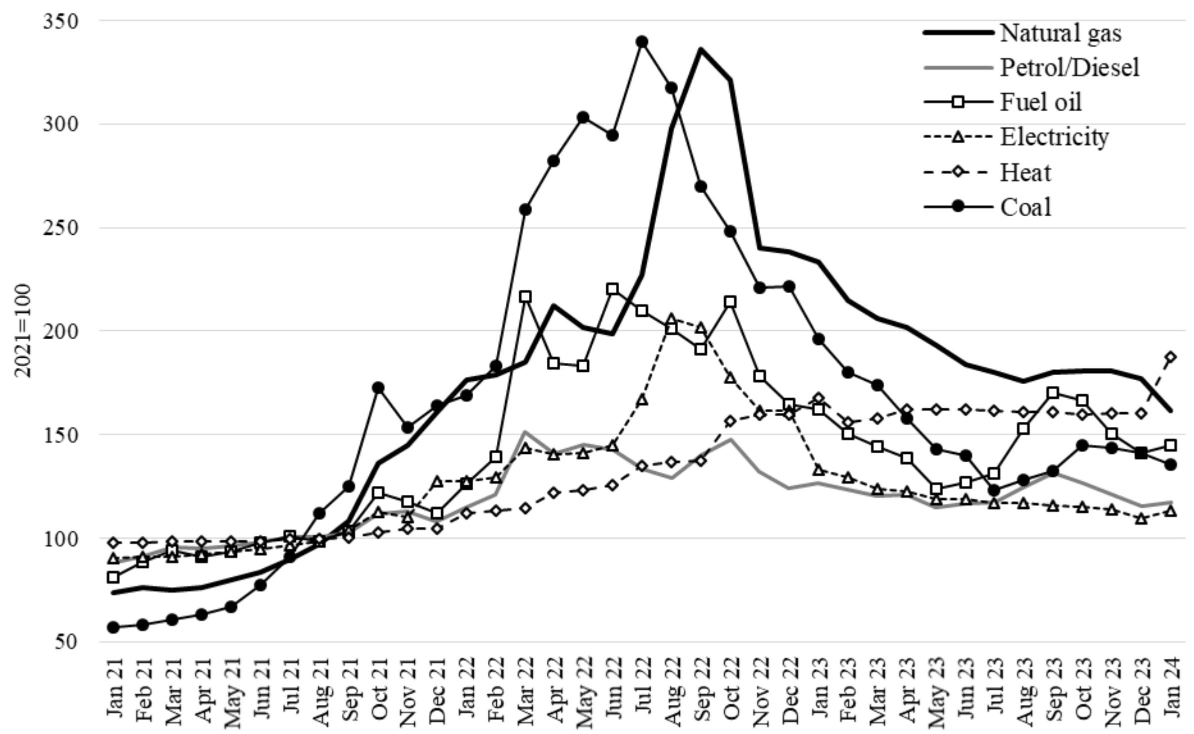
The existing literature strongly suggests that energy price shocks have adverse impacts on the economic performance of firms, particularly with respect to production volumes and sales, since higher energy costs reduce price competitiveness of energy-intensive firms subject to price shocks compared to competitors that do not experience a similar increase in energy cost. At the same time, firms immediately reacting to such price shocks by investing in energy saving and energy efficiency measures may be able to limit these adverse impacts as the cost increase will be lower for these firms, leading to our third hypothesis:

H3: The loss of competitiveness due to the energy price shock will be higher for firms with high energy intensity (H3a). For firms investing in mitigating measures, this negative link will be weaker (H3b).

3. Energy prices and consumption in the German business sector

The German economy experienced a dramatic increase in energy prices during 2022. Compared to the average price level in 2021, the prices for natural gas and coal peaked at 3.4 times the 2021 price level during summer 2022 (see Figure 1). Prices for other important industrial energy sources (fuel oil, electricity) doubled during 2022. The price increase started in late 2021, and strongly accelerated from March 2022 onwards, though at different pace for different energy sources. Prices started to fall in late 2022. During 2023, energy prices remained stable, though at a significantly higher level compared to 2021 (except for electricity).

Figure 1: Development of industrial energy prices in Germany 2021-2023



Note: all prices refer to business enterprise purchasers.
Source: Destatis (2024), own calculations.

The unprecedented increase in energy prices along with significant short-term price fluctuations, which were hardly predictable for any firm, posed enormous challenges for businesses. During 2022, the German business sector significantly reduced energy consumption across all energy sources. In manufacturing, which is particularly depending on energy as an input to production processes, energy consumption fell by 7.8% (Table 1). The substantial decrease in the consumption of coal (-11.9%), crude oil (-15.2%) and natural gas (-12.9%) were partially compensated by a significant increase in the use of renewable energy (+27.2%). In the business sector outside of manufacturing (trade and services including agriculture and construction, but excluding transport), energy consumption fell by 6.6%, with similar rates for most energy sources.

Table 1: Energy prices and consumption in the German business sector 2021 to 2022

Energy source	Energy price for business enterprises	Energy consumption	
		Manufacturing	Trade & services[a]
	% change 2021-2022		
Natural gas	+129	-12.9	-7.4
Crude oil	+57	-15.2	-4.7
Coal	+149	-11.9	-
Heat	+33	-6.8	-38.7
Electricity	+57	-5.5	-4.8
Renewables	-	+27.2	-1.2
Total	-	-7.8	-6.6

a: including agriculture and construction, excluding transport
Source: Destatis (2024), Arbeitsgemeinschaft Energiebilanzen (2024), own calculations.

Since the reduction in energy consumption of fossil energy sources and electricity was clearly much lower than the increase in energy prices for these sources, energy costs of firms drastically increased. Such a cost increase does not only challenge the competitiveness of firms. It also has macroeconomic implications, since the major share of total energy consumption in Germany is in the business enterprise sector (manufacturing, trade and services, see Table 2). Shifting financial resources towards financing of higher energy prices limits the economy's potential to invest in innovation, modernisation or expansion of productive assets, and to maintain the same level of output.

Table 2: Structure of final energy consumption in Germany by sector 2021 and 2022

Energy consumer group	2021	2022
Manufacturing	29.7	28.2
Trade & services[a]	26.7	29.5
Transport	14.2	13.7
Households	29.4	28.6
Total	100.0	100.0

a: including agriculture and construction, excluding transport
Source: Arbeitsgemeinschaft Energiebilanzen (2024), own calculations.

All in all, the effects of the energy price shock on the structure of energy consumption in the German business sector were only moderate because all energy sources were affected by price shocks. Furthermore, the elasticities for the substitution of energy sources are rather low in the short run as replacing energy sources requires time. A slight decrease of the use of natural gas can be observed leading to a moderate increase of electricity and renewable sources (Table 3).

Table 3: Composition of energy consumption in the German business sector 2021 and 2022 (%)

	Manufacturing		Trade & services[a]	
Energy source	**2021**	**2022**	**2021**	**2022**
Natural gas	31.9	30.1	32.0	31.7
Crude oil	3.7	3.4	16.0	16.3
Coal	17.1	16.3	0.0	0.0
Heat	6.6	6.7	4.1	2.7
Electricity	29.6	30.4	37.1	37.8
Renewables	4.5	6.3	10.9	11.6
Other	6.5	6.8	0.0	0.0
Total	100.0	100.0	100.0	100.0

a: including agriculture and construction, excluding transport
Source: Arbeitsgemeinschaft Energiebilanzen (2024), own calculations.

Despite the rather stable aggregate composition of energy consumption, many firms in Germany deliberately changed their energy mix during 2022. Results from the German CIS 2022 (see Section 3 for details on the data source) show that about 12% of firms decreased the use of natural gas, 13% reduced the use of electricity from suppliers, and 10% substituted the use of mineral oil by other energy sources (Table 4).

Table 4: Change in the consumption of energy sources in firms in Germany 2021-2022

Measure	**Decrease**	**Unchanged**	**Increase**	**Total**
	% of all firms[a]			
Electricity from suppliers	12.7	71.9	15.4	100.0
Renewable energy from own facilities	1.5	90.4	8.1	100.0
Natural gas	11.8	82.6	5.6	100.0
Fuels based on mineral oil	9.8	80.2	10.0	100.0
Others (coal, heat, etc.)	2.5	97.0	0.5	100.0

a: weighted results.
Source: German CIS 2023.

Along with the change in the use of different energy sources, firms in Germany implemented various measures to counterbalance the increase in energy prices. Further results from the German CIS 2022 reveal different short-time reactions of firms to the energy price shock. The most important measure was smaller energy saving measures such as the reduction of room temperature or fewer transport trips (Table 5). Another frequently used reaction was to substitute machines, vehicles and other equipment by less energy consuming alternatives. Further reactions included the change of energy suppliers, the use of digital technologies to optimise energy use, and the discontinuation of activities with a high energy use. Only few firms reacted on the energy price shock by introducing an energy management system or by relocating energy intensive activities to other countries.

Table 5: Energy-related measures in firms in Germany 2022

Measure	Manufacturing	Trade & services
	% of all firms[a]	
A. Substitution of machinery and equipment by less energy consuming alternatives	42.7	32.8
B. Optimization of energy use by digital technologies (e. g. smart metering)	16.6	12.4
C. Other energy saving measures (e.g., less transport, lower room temperature)	71.3	62.0
D. Relocation of energy intensive activities to other countries	2.2	1.0
E. Discontinuation of activities with high energy use	11.8	8.9
F. Change of energy suppliers	22.9	14.6
G. Introduction of an energy management system	7.3	2.3
At least one of measures A to G	84.0	72.8

a: weighted results.
Source: German CIS 2023.

4. Data and empirical model

In order to investigate the three hypotheses formulated in Section 2, we require data on firms' responses to the energy crises that emerged during 2022 along with data on factors that may have driven these responses, as well as firm performance measures that could have been affected by the responses. This section first describes the data source we use, followed by a description of the variables and a brief discussion of the econometric methodology.

Data

The empirical analysis rests on data from the German part of the Community Innovation Survey (CIS) of the European Commission, using data from the surveys conducted in 2023 and 2024, with the reference years 2022 and 2023, respectively. Differently to most other national CIS, the German CIS is designed as a panel survey (so-called Mannheim Innovation Panel - MIP, see Peters and Rammer 2023) and is conducted every year. The MIP also regularly includes questions that go beyond the standard question programme of the CIS. In the survey for the reference year 2022 ('MIP 2022'), three questions on energy use were included. First, data on the expenditure for energy in the years 2021 and 2022 were collected. Another question collected data on the energy sources used by the firm in the year 2021, and whether energy consumption by source decreased, increased or stayed the same between 2021 and 2022. A third question asked firms about measures implemented during 2022 related to energy use, distinguishing seven measures as shown in Table 5.

In addition to these energy-specific questions, the MIP 2022 included standard CIS questions on innovations with environmental benefits (see Horbach et al. 2012), including an item on the substitution of fossil energy sources by renewable ones, as well as a question on the affectedness of firms by climate change (see Horbach and Rammer 2025).

The MIP is a sample survey based on a stratified random sample. For the reporting year 2022, the total sample size was 37,980. 8,034 firms provided valid responses, resulting in a response rate of 21.1%. An extensive non-response survey covering 6,795 firms was conducted in order to identify a likely response bias between responding and non-responding firms with respect to innovation activities. More methodological details on the survey can be found in Peters and Rammer (2023). Descriptive results of the 2022 survey are reported in Rammer and Schubert (2024).

In order to analyse the link between short-term reactions to the energy crisis and firm performance, we complement 2022 MIP data by data from the following MIP survey on the reference year 2023. Although designed as a panel survey, not all firms in the panel sample participate in the MIP ever year. From the 8,034 firms in the 2022 data, 4,443 (55.3%) provided valid responses for 2023. The energy suppliers (coal mining, mineral oil processing, electricity, gas and district heating) are excluded from the analysis because it can be assumed that these firms show different motives concerning energy-related measures and energy sources compared to the rest of the sample.

Dependent variables

The empirical analysis to test the three hypotheses is organised in two parts. First, we analyse the determinants of firm activities undertaken in 2022 in response to the energy crisis, distinguishing (i) introducing energy-related measures and (ii) changes in the consumption of different energy sources. Secondly, we analyse the role of these activities for short-term changes (i.e. from 2022 to 2023) in firms' economic performance. For the first analysis, dependent variables represent the items of energy-related measures listed in Table 5: *energyequip* describes the replacement of equipment by less energy consuming alternatives, *digitalapps* the optimization of energy use through digital applications (e.g., smart-metering), *lessenergy* other (smaller) energy saving activities (e.g., less transport, lower room temperature), *relocstop* the closure or relocation of energy intense activities, *energysupp* the change of energy suppliers, and *enms* the introduction of an energy management system. In addition, we employ three variables that capture whether a firm decreased its consumption of electricity, gas and oil, respectively, from 2021 to 2022 (*eldecrease, gasdecrease, oildecrease*). A further dependent variable captures whether firms substituted fossil energy sources by renewables (*renewinno*). Firm performance is measured through the growth rate of sales from 2022 to 2023 (*grsales2223*), the growth rate of employment (*grempl2223*), and changes in the share of export sales in total sales (*chexpsh2223*).

Determinants of energy-related activities

Following the theoretical considerations, different factors may be linked to energy-related changes in firms. A key determinant is the relevance of energy as an input for a firm. The more a firm is relying on energy inputs for producing and delivering its products and services, the more relevant energy price shocks will be, and the stronger the need for reacting to energy prices increases. At first glance, it might be meaningful to use the change in energy costs from 2021 to 2022 as a determinant for energy-related measures. However, this may cause an endogeneity problem because the firm-level development of energy costs from 2021 to 2022 might be itself dependent from the choice of energy sources and the different energy-related measures. Secondly, the change in energy prices affects all firms so that the variance of this variable across the firms might be small. This argument is also true when using the sectoral energy cost development as an alternative. Therefore, we use the energy cost share on the total costs in 2021 (*encostshare21*) as an indicator for the affectedness of a firm by the energy price shock. This measure covers all costs of firms related to purchasing energy from external sources, including gas, oil and other fuels, electricity, and heat, but it does not include the costs of electricity produced in-house from renewable sources (e.g., through solar panels or water turbines). Since all external energy sources showed substantial price increases during 2022 (see Figure 1), the higher *encostshare21*, the more a firm will be affected by the energy price shock.

The variable *climaaffect* captures the climate change affectedness of firms. It has the value one if the firm is highly affected by climate policy, climate related costs, demand for products and services with positive climate related effects or by extreme weather events (see Horbach and

Rammer 2025 for a detailed discussion). We also expect that firms with innovative capabilities are more likely to implement new energy sources. We use an indicator variable for R&D activities (*rad*) which has the value one in case a firm performs research and development activities. *Cooperation* captures collaboration activities with other firms or institutions and reflects the openness of a firm towards knowledge from outside. The variable *subsidies* indicates whether a firm received government subsidies during 2020 to 2022. The competition situation is captured by *newentrants* describing a high threat to the market position of the firm whereas *pricecomp* indicates a high price elasticity of demand. In this case an increase of product prices as a reaction to higher energy costs is less probable. As an alternative measure of the competition situation, *compintensity* denotes the competition intensity by a scale from 0 to 24, considering different types of competition indicators (see Rexhäuser and Rammer 2014 for more details). As firms with a better financial situation are more likely to afford investment in new energy-related equipment, a firm's creditworthiness before the energy crisis (i.e. in 2021) as assessed by Germany's largest credit rating agency Creditreform is also included (*credrating*). As control variables, the *age* and the *size* of the firm as well as the share of highly qualified employees (*academic*) are also taken into account. For some of the econometric models, we also use the development of sales from 2021 to 2022 (*grsales2122*). In the analysed time-period, the Covid-19 crisis still affected the economic situation of firms, though at varying degrees. To represent the different levels of Covid-19 impacts on firms, we employ a dummy variable *covidneg,* which gets the value one if a firm experienced negative economic consequences on its business activities from the Covid-19 pandemics during 2022. In addition, we include industry dummies in all model estimations. The definition of all model variables along with descriptive statistics is shown in Table 10 in the Appendix.

Econometric modelling

The dependent variables on firms' responses to the energy crisis are measured in a binary way, i.e., whether a firm decided to implement a certain energy-related measure or change the composition of energy sources (Y=1) or did not engage in such an activity (Y=0). Probit models are hence adequate for model estimation. Following the theoretical considerations, different factors may affect these firm decisions, summarised by a vector **x**. Therefore, an estimation of the probability $Prob\ (Y = 1 \mid \boldsymbol{x}) = F\ (\boldsymbol{x}, \beta)$ is needed. The β parameter reflects the impact of changes in $\boldsymbol{x}$ on this probability (Greene, 2008:772). Average marginal effects for all covariates are calculated, allowing comparisons of the different climate change activities.

For the third group of dependent variables (on firm performance), we use quantile regressions (Koenker 2005). Quantile regressions are advantageous because they allow analysing the different role of energy related measures for shrinking, stable, slowly growing, or fast-growing firms. Furthermore, this estimation method is more robust against outliers, and no assumptions about the parametric distribution of the error term have to be made (Koenker 2005). Besides a median regression, with the objective to estimate the median of the dependent variable, conditional on the values of the independent variables, we also estimate regressions for the 10% and 90% quantiles.

The qth ($0 < q < 1$) quantile regression estimator minimises the objective function over β_q (see Koenker 2005, Cameron and Trivedi 2009: 207):

$$Q(\beta_q) = \sum_{i:y_i \geq x_i'\beta}^{N} q|y_i - x_i'\beta_q| + \sum_{i:y_i < x_i'\beta}^{N} (1-q)|y_i - x_i'\beta_q| \quad (2)$$

β_q instead of β is used, showing that different choices of q lead to different values of β. As the objective function is not differentiable, the simplex method is used for a solution.

Since we predominantly use cross-section data, the results of the econometric analysis should be interpreted in terms of correlation rather than causality.

5. Results of econometric analyses

The analysis of the determinants of energy-related measures adopted by firms (**Table 6**) shows that a high share of energy costs in total costs in 2021 (*encostshare21*), indicating a high affectedness by the energy price shock in 2022, triggers the substitution of equipment by less energy consuming alternatives (*energyequip*). The magnitude of the effect is rather low, however. An increase in the energy cost share by 1 percentage point is associated with a 0.3 percentage points higher probability of replacing equipment by more energy-efficient one. The mean value of *encostshare21* in the sample is 4.1 percent, while 42.5 percent of the sample have implemented this type of energy-related measure. Furthermore, affected firms are more likely to introduce energy management systems (*enms*). Per 1 percentage point of *encostshare21*, the probability for *enms* increases by 0.2 percentage points (with 7.6 percent of the sample having introduced an energy management system in 2022). A high energy intensity in 2021 is also associated with a higher probability of stopping or relocating energy-intensive activities. The marginal effect is 0.1 percentage points, while 7.0 percent of the firms in the sample reacted on the energy price shock in this way. All the three results support H1. The probability to introduce digital solutions for increasing energy efficiency (*digitalapps*) and to realise other (smaller) energy saving measures (*lessenergy*) are, however, not linked to the firms' energy cost share, while the link to changing energy suppliers is only weakly significant. These results show that energy-intensive firms focussed on particular measures to mitigate the strong increase in energy prices.

Table 6: Determinants of energy-related measures of firms

Correlates	Energyequip	Digitalapps	Lessenergy	Relocstop	Energysupp	Enms
Encostshare21	0.003**	0.001	-0.001	0.001**	0.002+	0.002**
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.000)
Climaaffect	0.031**	0.019**	0.027**	0.014**	0.014**	0.010**
	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
Cooperation	0.052**	0.040**	0.087**	0.004	-0.007	0.013
	(0.019)	(0.014)	(0.017)	(0.012)	(0.016)	(0.010)
Rad	0.062**	0.061**	0.053**	0.018	0.015	-0.004
	(0.019)	(0.015)	(0.018)	(0.012)	(0.017)	(0.009)
Newentrants	0.008	0.010	0.027+	0.026**	-0.005	0.016*
	(0.015)	(0.012)	(0.014)	(0.010)	(0.013)	(0.008)
Pricecomp	-0.010	-0.015	0.016	0.025**	0.028*	-0.002
	(0.016)	(0.012)	(0.015)	(0.009)	(0.014)	(0.008)
Subsidies	0.038*	0.031*	-0.020	-0.013	0.031*	-0.009
	(0.017)	(0.013)	(0.016)	(0.010)	(0.015)	(0.008)
Academic	-0.001*	-0.000	0.000	-0.000	-0.000	0.000+
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age	0.013	-0.006	0.036**	-0.011+	-0.004	0.001
	(0.010)	(0.008)	(0.009)	(0.006)	(0.008)	(0.005)
Credrating	0.026+	-0.012	-0.028*	-0.015+	0.010	0.001
	(0.015)	(0.011)	(0.014)	(0.008)	(0.013)	(0.008)
Size	0.074**	0.039**	0.029**	-0.008*	0.016**	0.039**
	(0.006)	(0.004)	(0.005)	(0.004)	(0.005)	(0.003)
# observations	4,157	4,158	4,158	4,174	4,156	4,156
Wald Chi^2	576^{**}(33)	351^{**}(33)	349^{**}(33)	193^{**}(33)	156^{**}(33)	384^{**}(33)
Pseudo R^2	0.11	0.11	0.07	0.07	0.04	0.25

Estimation results of probit models. Average marginal effects are reported. Robust standard errors in parentheses. ** p<0.01, * p<0.05, + p<0.1. Industry dummies are included but not reported.
Source: German CIS 2023.

If a firm is highly affected by climate change (*climaaffect*, including policy measures such as increasing CO_2 prices, high demand for climate friendly products, higher costs of resources, and extreme weather events), the probability to use any of the six energy-related measures increases. The introduction of new energy-friendly equipment, digital solutions or other energy saving measures such as logistics requiring less transport activities is positively associated to *cooperation* activities and R&D (*rad*) activities of firms. A highly threatened market position by *new entrants* significantly promotes a relocation or stop of energy-intensive activities. The same result holds for a market environment characterised by high price competition (*pricecomp*).

A weak financial performance (*credrating*) is also correlated with a relocation or discontinuation of energy-intensive activities as well as with smaller energy saving measures. *Subsidies* support the installation of new energy saving equipment and digitalization. The firm *size* is positively correlated to most of the energy-related measures except the stop and relocation of energy-intensive activities showing that particularly small firms have difficulties to compensate energy price shocks.

In a next step, the determinants of the choice of different energy sources as well as of environmental innovations to replace fossil energy sources by renewable ones are analysed (Table 7). Not surprisingly, the substitution of equipment by less energy consuming alternatives (*energyequip*) leads to a decrease in electricity, gas and oil consumption. The same holds for activities to reduce energy use by various smaller scale energy saving measures (*lessenergy*). The marginal effects for *lessenergy* are substantially higher for a decrease in electricity and gas use compared to *energyequip*. However, *lessenergy* is also a much more frequently used measure (68.5 percent of all firms in the sample). *Energyequip* also promotes the substitution of fossil energy sources by renewables, as digital solutions to increase energy efficiency (*digitalapps*) do, both supporting H2. *Digitalapps* is also positively linked to a reduction of gas consumption, which is a key energy source for the German enterprise sector and showed the highest price increase in 2022 among the intensively used energy sources.

Stopping or relocate energy-intensive activities (*relocstop*) is statistically significant for the reduction of electricity use, but not for changes in the use of other energy sources, whereas a change of energy suppliers (*energysupp*) is linked to the substitution of fossil energy sources by renewables. The introduction of energy management systems (*enms*) does not have statistically significant effects on the change in energy sources. R&D activities (*rad*) and *subsidies* trigger the substitution of fossil sources by renewables, but they are not highly significantly relevant for other energy sources. When considering energy-related measures as determinants for changes in the use of different energy sources and the substitution of fossil by renewable energy sources, a firm's energy intensity in 2021 (*encostshare21*) becomes insignificant, suggesting that a high energy intensity motivates firms to undertake energy-related measures, which result in changes in the composition of energy sources.

Table 7: Determinants of changes in the use of energy sources

Correlates	Eldecrease	Gasdecrease	Oildecrease	Renewinno
Energyequip	0.036**	0.035**	0.053**	0.036**
	(0.013)	(0.012)	(0.011)	(0.009)
Digitalapps	0.017	0.044**	0.011	0.045**
	(0.016)	(0.016)	(0.014)	(0.012)
Lessenergy	0.090**	0.105**	0.056**	0.017+
	(0.012)	(0.011)	(0.010)	(0.009)
Relocstop	0.048*	0.023	0.033+	0.014
	(0.021)	(0.019)	(0.018)	(0.013)
Energysupp	0.001	-0.020	0.013	0.041**
	(0.014)	(0.013)	(0.012)	(0.011)
Enms	-0.022	-0.017	-0.024	0.019
	(0.020)	(0.019)	(0.016)	(0.015)
Cooperation	-0.018	0.013	-0.000	-0.002
	(0.014)	(0.014)	(0.012)	(0.010)
Rad	0.022	0.025+	0.007	0.026*
	(0.015)	(0.014)	(0.013)	(0.010)
Encostshare21	-0.000	0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Grsales2122	-0.000	-0.000	-0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Climaaffect	-0.001	0.000	0.000	0.009**
	(0.002)	(0.002)	(0.002)	(0.002)
Newentrants	0.008	0.005	0.007	-0.013
	(0.012)	(0.012)	(0.011)	(0.008)
Pricecomp	-0.005	-0.015	-0.010	-0.003
	(0.012)	(0.012)	(0.011)	(0.008)
Subsidies	0.025+	-0.009	0.006	0.033**
	(0.014)	(0.012)	(0.012)	(0.010)
Academic	0.000	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Age	0.021**	0.022**	0.013+	0.003
	(0.008)	(0.008)	(0.007)	(0.005)
Credrating	0.010	0.009	-0.004	0.007
	(0.012)	(0.012)	(0.010)	(0.009)
Size	0.012**	0.015**	0.008+	0.001
	(0.005)	(0.005)	(0.004)	(0.003)
# observations	4,026	4,026	4,026	4,026
Wald Chi^2	202**(40)	259**(40)	146**(40)	296**(40)
Pseudo R^2	0.06	0.08	0.05	0.14

Estimation results of probit models. Average marginal effects are reported. Robust standard errors in parentheses. ** p<0.01, * p<0.05, + p<0.1. Sector dummies are included but not reported.
Source: German CIS 2023.

In a third step, we analyse the link between different energy related measures on the one hand and firm performance variables on the other, focussing on sales growth between the year in which energy-related measures were introduced (2022) and the following year 2023 (*grsales2223*), when energy prices fell to a closer to normal level. In order to investigate whether this relationship differs according to the level of affectedness by the energy crisis, separate estimations for all firms and for firms with a higher energy intensity (EI) are conducted and reported in Table 8. Energy intensive firms are those with an energy cost share of more than 1 percent (representing 63 percent of all firms in the sample). As robustness check, we also report results for a 4 percent energy cost share, representing highly energy intensive firms (26 percent of all firms in the sample).

For firms above the 1% and the 4% threshold, the energy cost share is significantly relevant for the sales development from the year of the energy crisis to the following year. For these firms, *encostshare21* is negatively correlated with sales growth in the range of the 10% quantile and the median, supporting H3a. For the full sample, too, the 10% quantile and the median show significant coefficients, though the coefficient values are lower compared to energy intensive firms. Therefore, the relationship between the affectedness by high energy prices and sales growth seems to be higher if the energy cost share of the firm exceeds a certain threshold.

For the different energy related measures, the results are quite mixed, and the link to the post-crisis sales development seems to be very weak, giving little support for H3b. Only for firms that replaced their energy suppliers in 2022, highly significant positive effects on sales growth 2022 to 2023 can be observed, though limited to the 90% quantile.

With respect to control variables, a high competition intensity (*compintensity*) is significantly linked to a reduction in sales for all quantiles except firms with very high sales growth (90% quantile). Not surprisingly, firms negatively affected by the Covid-19 (*covidneg*) show a stronger growth in sales after the end of the pandemics. R&D (*rad*) activities are positively correlated to sales growth for all firms except the 90% quantile.

In addition to sales growth, we also investigate possible links between the energy crisis on the one hand, and employment growth and changes in the share of exports in total sales from 2022 and 2023 on the other (see Table 9). Since there are no significant differences between all firms and energy-intensive firms, only the results for all firms are reported. The results show that the energy cost share in 2021 is not significantly related to employment growth. The substitution of energy-related equipment (*energyequip*) and digital applications (*digitalapps*, only for the 90% quantile) are accompanied by an increase in employment whereas the relocation or the stopping of energy-intensive activities (*relocstop*) is associated with a reduction in employment (but only for the 90% quantile). These findings are important as they suggest that the energy crisis did not result in severe short-term adjustments in employment and export activities. For the change in export share, a positive coefficient for *encostshare21* is found for the 10% quantile of the development of export shares, indicating that firms tried to compensate higher energy costs by increasing export activities. Firms that invested in smaller energy saving measures (*lessenergyuse*) experienced a positive development of export shares.

Table 8: Determinants of sales growth from 2022 to 2023

Correlates	All firms 10% qt	EI Firms > 1% 10% qt	EI Firms > 4% 10% qt	All firms median	EI Firms > 1% median	EI Firms > 4% median	All firms 90% qt	EI Firms > 1% 90% qt
Encostshare21	-0.245*	-0.252*	-0.365**	-0.053+	-0.075+	-0.052	-0.068	-0.081
	(0.121)	(0.105)	(0.110)	(0.029)	(0.039)	(0.069)	(0.090)	(0.079)
Energyequip	-0.022	2.978*	-0.309	0.478	0.863	1.283	-2.333	-5.001*
	(1.139)	(1.342)	(1.971)	(0.553)	(0.703)	(1.054)	(1.533)	(2.298)
Digitalapps	2.107+	1.085	-5.220	1.069	1.068	1.061	2.168	1.018
	(1.095)	(1.275)	(3.347)	(0.716)	(0.896)	(1.381)	(1.907)	(1.787)
Lessenergyuse	1.751	-1.558	0.799	-1.197+	-2.589**	-1.791	-5.518*	-5.882**
	(1.504)	(1.886)	(3.657)	(0.650)	(0.759)	(1.148)	(2.469)	(1.876)
Relocstop	3.130**	1.998	-0.406	1.225	0.549	2.300	-3.332+	-0.736
	(1.210)	(1.779)	(2.681)	(0.835)	(1.034)	(1.634)	(1.798)	(1.781)
Energysupp	0.959	0.695	-0.879	-0.257	0.039	-0.984	6.246*	6.393**
	(1.147)	(1.054)	(1.932)	(0.689)	(0.823)	(1.324)	(2.662)	(1.567)
Enms	-5.457*	-5.249**	-2.365	-1.500	-1.524	-2.661+	1.992	-0.573
	(2.161)	(1.403)	(2.915)	(0.963)	(1.101)	(1.504)	(3.196)	(1.767)
Compintensity	-0.747**	-0.728**	-0.472*	-0.337**	-0.266**	-0.182	-0.114	0.053
	(0.130)	(0.120)	(0.207)	(0.059)	(0.077)	(0.118)	(0.175)	(0.176)
Cooperation	0.575	-1.414	-3.982+	-0.631	-1.254	-0.905	-1.501	0.779
	(1.307)	(1.405)	(2.345)	(0.690)	(0.819)	(1.287)	(2.196)	(2.000)
Covidneg	2.904**	3.900**	5.826**	1.181*	0.900	1.278	2.036	6.029**
	(1.044)	(1.055)	(2.161)	(0.527)	(0.662)	(1.031)	(1.604)	(1.434)
Academic	-0.017	-0.037	0.059	0.031*	0.023	0.016	0.206**	0.266**
	(0.033)	(0.034)	(0.037)	(0.014)	(0.018)	(0.025)	(0.045)	(0.059)
Age	1.738*	2.232**	4.219**	-0.324	0.352	0.269	-2.293**	-1.378+
	(0.769)	(0.763)	(1.526)	(0.369)	(0.436)	(0.624)	(0.814)	(0.829)
Subsidies	-0.255	0.703	1.458	0.296	0.008	-0.336	0.693	-1.458
	(1.068)	(0.959)	(2.517)	(0.651)	(0.784)	(1.030)	(1.512)	(1.502)
Rad	1.837	4.536**	9.566**	2.335**	2.039*	1.998+	2.842	4.488*
	(1.349)	(1.456)	(2.934)	(0.672)	(0.836)	(1.207)	(1.901)	(1.778)
Credrating	0.106	-0.169	-3.310	-0.282	-0.518	-2.544*	-3.052**	-2.188
	(1.374)	(1.378)	(3.031)	(0.583)	(0.689)	(1.184)	(1.007)	(1.914)
Size	1.641**	0.988+	0.854	0.932**	0.918**	0.333	-1.379**	-0.642
	(0.449)	(0.515)	(0.937)	(0.215)	(0.264)	(0.397)	(0.532)	(0.534)
Constant	-27.545*	-37.190*	-30.350	4.531	7.318+	9.524*	52.234**	40.72**
	(13.255)	(18.434)	(32.842)	(5.417)	(3.828)	(4.334)	(6.141)	(9.711)
# observations	2,539	1,612	664	2,539	1,612	664	2,539	1,612

Estimation results of quantile regressions. Robust standard errors in parentheses. ** p<0.01, * p<0.05, + p<0.1.
Industry dummies are included but not reported.
Source: German CIS 2023.

Table 9: Determinants of employment growth and change in the export share from 2022 to 2023

Correlates		Grempl2223			Chexpsh2223	
	10% qt	Median	90% qt	10% qt	Median	90% qt
Grsales2122	0.035+	0.009+	0.077**	-	-	-
	(0.020)	(0.005)	(0.022)	-	-	-
Encostshare21	0.012	-0.000	0.167	0.483*	-0.026	-0.742
	(0.022)	(0.002)	(0.220)	(0.213)	(0.052)	(1.374)
Energyequip	3.291**	0.033	2.479*	4.423+	1.454	-22.712*
	(0.875)	(0.070)	(1.129)	(2.411)	(1.314)	(10.585)
Digitalapps	0.263	0.130	3.496**	-4.054	1.147	10.750
	(0.985)	(0.149)	(1.242)	(3.128)	(1.438)	(20.251)
Lessenergyuse	1.201	-0.073	-0.256	16.190**	0.673	27.231*
	(1.002)	(0.075)	(1.415)	(4.138)	(1.569)	(10.875)
Relocstop	-2.049	-0.049	-5.629**	-1.953	-2.659	-26.496
	(1.408)	(0.149)	(1.416)	(6.407)	(1.659)	(19.771)
Energysupp	-0.391	0.009	3.230*	2.020	-1.955	5.640
	(0.848)	(0.089)	(1.320)	(2.664)	(1.248)	(13.391)
Enms	-0.046	0.036	2.688	-9.882	-0.603	1.763
	(1.225)	(0.231)	(1.809)	(7.393)	(1.575)	(23.378)
Compintensity	0.018	-0.012	-0.169	-1.650**	-0.323+	-0.757
	(0.099)	(0.008)	(0.127)	(0.445)	(0.166)	(1.642)
Cooperation	1.093	0.117	1.999+	3.253	1.384	18.221
	(1.013)	(0.112)	(1.179)	(3.489)	(1.376)	(11.332)
Covidneg	-3.372**	-0.150+	-1.599	-5.535+	-0.186	8.924
	(0.913)	(0.080)	(0.974)	(3.285)	(1.161)	(9.751)
Academic	0.042+	0.004*	0.083**	-0.180**	-0.038	-0.178
	(0.023)	(0.002)	(0.029)	(0.055)	(0.033)	(0.290)
Age	0.243	-0.077	-2.495**	-1.100	-0.512	-18.022*
	(0.571)	(0.052)	(0.651)	(2.422)	(0.812)	(7.719)
Subsidies	0.627	0.151	-1.942*	-1.358	0.128	2.519
	(0.866)	(0.118)	(0.949)	(3.411)	(1.352)	(10.700)
Rad	-0.165	0.081	1.819	3.379	-0.193	-10.490
	(1.009)	(0.106)	(1.421)	(3.902)	(1.551)	(13.987)
Credrating	4.996**	0.116*	-1.340	-9.742*	-0.747	-2.467
	(1.115)	(0.055)	(0.827)	(4.499)	(1.001)	(8.350)
Size	1.815**	0.023	-3.405**	9.030**	0.426	-4.853
	(0.322)	(0.037)	(0.407)	(1.409)	(0.431)	(5.203)
Constant	-44.531**	-0.119	68.890	3.526	44.065	97.824*
	(4.428)	(0.621)	(82.206)	(37.663)	(59.617)	(49.140)
# observations	2,472	2,472	2,472	1,152	1,152	1,152

Estimation results of quantile regressions. Robust standard errors in parentheses. ** p<0.01, * p<0.05, + p<0.1. Sector dummies are included but not reported.
Source: German CIS 2023.

6. Summary and conclusions

This paper aimed to analyse the way how firms reacted on the huge increase in energy prices during 2022 in Germany by looking at two mitigation strategies. First, the determinants of six possible energy-related measures are analysed, including investment in more energy-efficient equipment, smaller energy saving measures, digital applications to increase energy efficiency, stopping or relocating energy-intensive activities, changes of energy suppliers, and introducing energy management systems. Secondly, the paper investigated the drivers of changes in the use of different energy sources, with a focus on replacing fossil by renewable sources. Descriptive results show that a large share of firms in Germany engaged in energy-related measures during 2022, while the change in the composition of energy sources was rather moderate.

The results for the determinants of energy-related measures show that a high share of energy costs in the total costs in 2021 (indicating a high affectedness by the energy price shock) triggered the substitution of equipment by less energy consuming alternatives, as well as stopping or relocating energy-intensive activities and the introduction of energy management systems. For all three measures, the magnitude of the impact of energy intensity in the pre-crisis year is rather low, i.e. only a small fraction of the firms that engaged in these measures can be linked to differences in energy intensity. It seems that many firms with a rather low affectedness by the energy price shock also responded to price increases by mitigating measures. One reason may be that the uncertainty about the level and duration of price increases was very high during 2022, and many firms may have expected even higher or longer lasting price increases. Another reason for the rather small role of energy intensity may be linked to the fact that firms with high energy intensity are likely to have exploited most technical and organisational possibilities to increase energy efficiency, limiting their room for additional measures to cut energy costs in the short run.

With respect to the link between energy-related measures and changes in the use of different energy sources, the substitution of equipment by less energy consuming alternatives is associated with a decrease in the consumption of electricity, gas and oil, while innovations targeting the substitution of fossil by renewable energy sources are positively linked to this measure. Introducing digital solutions for increasing energy efficiency are also positively related to shifting energy consumption towards renewables and reducing the use of natural gas.

In addition to the drivers of mitigation strategies, we also looked at the link between the energy price shock and firm performance. We find evidence that firms with a medium to high energy intensity (energy costs of more than 1% of total costs) experienced a lower sales growth in the post-crisis period (2022 to 2023). At the same time, we do not see significant results for employment growth, suggesting that the energy price shock had negative short-term impacts on the competitiveness of highly affected firms, but did not result in a reduction of medium-term production capacities (which would be indicated by a decline in employment, since German employment law limits the possibilities of firms to short-term reduction in employment). This result has to be seen against the background of a lack of skilled labour in Germany (see Horbach and Rammer 2021), which incentivizes firms to keep their staff even in times of severe economic difficulties.

Compared to the existing literature (see Section 2), our analysis explores the role of the energy crisis for different energy-related measures and the choice of energy sources at the firm level. Up to now, there were only few analyses of this kind in the literature. Our results of quite modest effects of energy prices on employment and production confirm the work of Marin and Fona (2021) and Fontagné et al. (2024) for France and Martin et al. (2009) for the U.K. From a macroeconomic perspective, Hutter and Weber (2023) show quite strong effects of the energy crisis in 2022 for real turnover, but they also find that employment was not reduced at the same rate, which corresponds to our findings. Furthermore, our results confirm the analyses of Bastos et al. (2024) and Amaglobeli et al. (2024) detecting positive effects of the 2022 global energy crisis on the diffusion of low-carbon technologies such as renewable energies.

From an energy and environmental policy point of view, our results suggest that a temporary energy price shock can be advantageous for a shift of energy use towards higher levels of energy efficiency and less consumption of fossil energies. Both developments will positively contribute to mitigating climate change. Due to the strong impact of a price shock, many firms that otherwise would not have invested into more energy efficiency and a greener energy use decided to engage in energy-related measures. This holds both for firms that are highly effected by an increase in energy prices, and for firms with a low energy intensity.

However, these positive environmental results of energy price shocks come with negative short-term economic consequences, since firms strongly affected by energy price increases show a lower growth in sales. While lower output of energy-intensive firms will also reduce negative environmental impacts of these firms, macro-economic and global environmental consequences may by disadvantageous. The threat to the existence of such firms may not only result in a loss of output and employment for the national economy. In case the goods produced by these firms are replaced by goods from firms from other countries that have been less exposed to energy price shocks and producing at a lower level of energy efficiency, the impact on the environment at a global level will be negative. In the same vein, avoiding the relocation of energy-intensive activities to countries with lower energy prices might be disadvantageous for reducing global environmental pollution because of possible pollution haven effects.

Against this background, it seems justified to support firms, and particularly energy-intensive firms, during an energy price shock, provided that these firms invest in higher energy efficiency and a more sustainable energy use. This would call for targeted support measures that link subsidies for energy costs with investments in energy saving measures and the replacement of fossil by renewable energy sources. In the case of Germany and the 2022 energy price shock, the government did not establish such a link, however, but provided subsidies on gas and electricity costs for energy-intensive firms, regardless of any energy-related measures (see Bundesfinanzministerium 2022).

While this paper provided new insights into how energy price shocks are linked to changes in energy-related activities of firms, a number of relevant issues could not be tackled due to data limitations. First, we were only able to investigate the short-term reactions of firms and associated short-term economic performance implications. Future research could analyse whether the energy-related measures initiated by the energy crisis are longer lasting and shift firms on a more sustainable track of energy use. At the same time, medium-term economic consequences of energy price shocks could be investigated, as soon as more time has passed. A shortcoming of our analysis is the lack of a causal analysis, owing to the cross-section nature of our data. With panel data at hand, future research could establish real effects of the 2022 energy price shock on energy use and firm performance, instead of correlations, which were the focus of this paper.

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Table 10: Definition and descriptive statistics of model variables

Variable	Description of the variables	Mean	Std. D.
Energyequip	Substitution of machines, vehicles, equipment by alternatives with lower energy consumption in 2022 (1: Yes, 0: No)	.425	.494
Digitalapps	Optimization of energy efficiency using digital applications (e.g., smart-metering) in 2022 (1: Yes, 0: No)	.165	.372
Lessenergy	Other energy saving activities (less transport, lower room temperature) in 2022 (1: Yes, 0: No)	.685	.465
Relocstop	Re-location of energy-intensive activities to other countries or termination of activities with high energy use in 2022 (1: Yes, 0: No)	.080	.272
Energysupp	Replacement of energy suppliers in 2022 (1: Yes, 0: No)	.205	.404
Enms	Introduction of an energy management system in 2022 (1: Yes, 0: No)	.076	.265
Renewinno	Substitution of fossil energy sources by renewables 2020-2022 (1: Yes, 0: No)	.059	.236
Eldecrease	Decrease of electricity use from 2021 to 2022 (1: Yes, 0: No)	.123	.328
Gasdecrease	Decrease of gas use from 2021 to 2022 (1: Yes, 0: No)	.120	.325
Oildecrease	Decrease of oil use from 2021 to 2022 (1: Yes, 0: No)	.087	.283
Grsales2223	Growth rate of sales from 2022 to 2023	23.22	1110.2
Grempl2223	Growth rate of employment from 2022 to 2023	3.637	53.53
Chexpsh2223	Change in export share from 2022 to 2023 (in %)	254.6	2773.1
Encostshare21	Share of energy costs in total costs 2021 (in %)	4.098	7.537
Climaaffect	High affectedness by climate policy, climate related costs, demand for products and services with positive climate related effects or by extreme weather events 2020-2022 (scale from 0-12)	5.407	2.998
Cooperation	Cooperation with other firms or organizations 2020-2022 (1: Yes, 0: No)	.264	.441
Compintensity	Competition intensity (scale from 0 to 24)	10.31	4.557
Newentrants	High threat to the market position of the firm (1: Yes, 0: No)	.337	.473
Pricecomp	High price elasticity of demand (1: Yes, 0: No)	.390	.488
Grsales2122	Growth rate of sales from 2021 to 2022	19.37	328.8
Subsidies	Receipt of subsidies from public institutions 2020-2022 (1: Yes, 0: No)	.218	.413
Covidneg	Negative impacts of Covid-19 of on business activities in 2022 (1: Yes, 0: No)	.356	.479
Academic	Share of employees with a university degree in 2022 (%)	24.95	29.08
Age	Age of the firm (logarithm)	3.209	.820
Rad	R&D activities 2020-2022 (1: Yes, 0: No)	.345	.475
Credrating	Creditworthiness in 2021 (scale from 0 to 5)	3.602	.530
Size	Number of employees in 2021 (logarithm)	3.310	1.614
Sector dummies	1: Yes, 0: No (NACE codes in brackets)		
Sec1	Food products and beverages, tobacco (10-12)	.041	.199
Sec2	Textiles, clothing, leather products (13-15)	.024	.154
Sec3	Wood and paper products, printing (16-18)	.024	.154
Sec4	Chemical and pharmaceutical industry (20-21)	.024	.153
Sec5	Rubber and plastic products (22)	.025	.158
Sec6	Glass, ceramics and concrete products (23)	.019	.135
Sec7	Basic metals and fabricated metals (24-25)	.069	.254
Sec8	Electrical machinery, electronics, instruments (26-27)	.047	.212
Sec9	Machinery (28)	.057	.232
Sec10	Motor vehicles, other transport equipment (29-30)	.018	.132
Sec11	Medial products, furniture and other products (31-33)	.064	.245

Table 10: Contd.

Variable	Description of the variables	Mean	Std. D.
Sec12	Energy and water supply, mining (5-9, 19, 35-36)	.009	.094
Sec13	Recycling, waste and wastewater removal (37-39)	.048	.214
Sec14	Wholesale trade (46)	.048	.214
Sec15	Transport and logistics (49-53)	.081	.274
Sec16	Media services (58-60)	.042	.200
Sec17	Computer programming, IT services, telecommunication (61-63)	.035	.183
Sec18	Financial services (64-66)	.049	.216
Sec19	Technical and R&D services (71-72)	.081	.273
Sec20	Business consulting and advertising (69-70, 73)	.063	.244
Sec21	All other industries (1-3, 41-45, 47, 55-56, 68, 74-96)	.129	.335

Source: German CIS 2023 and 2024.

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ZEW – Leibniz-Zentrum für Europäische Wirtschaftsforschung GmbH Mannheim
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L 7,1 · 68161 Mannheim · Germany
Phone +49 621 1235-01
info@zew.de · zew.de