EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

Gert Bijnens, John Hutchinson, Jozef Konings, Arthur Saint Guilhem

The interplay between green policy, electricity prices, financial constraints and jobs: firm-level evidence

No 2537 / April 2021

Abstract

Increased investment in clean electricity generation or the introduction of a carbon tax will most likely lead to higher electricity prices. We examine the effect from changing electricity prices on manufacturing employment. Analyzing firm-level data, we find that rising electricity prices lead to a negative impact on labor demand and investment in sectors most reliant on electricity as an input factor. Since these sectors are unevenly spread across countries and regions, the labor impact will also be unevenly spread with the highest impact in Southern Germany and Northern Italy. We also identify an additional channel that leads to heterogeneous responses. When electricity prices rise, financially constrained firms reduce employment more than less constrained firms. This implies a potentially mitigating role for monetary policy.

Keywords: environmental regulation, labor demand, employment, manufacturing industry, monetary policy

JEL Classification: E52, H23, J23, Q48

Non-technical summary

The EU has committed to tackling climate change and greenhouse gas emissions. To reach the ambitious goals, significant investment in clean electricity generation in combination with a meaningful carbon tax will be needed. There are, however, legitimate concerns that this will lead to higher electricity prices and more broadly energy prices. Previous research suggests that a $75 carbon tax is needed to keep global warming at 2 °C. This could increase electricity prices in Europe up to 20% depending on the emission intensity of generation. Whilst the overall impact of such a price increase is complex, an individual manufacturing firm faces higher input costs and lower competitiveness when electricity prices increase. This leads to reduced employment and investment, predominantly within firms active in sectors most reliant on electricity as an input factor.

In this paper we study over 200,000 manufacturing firms in Belgium, France, Germany, Italy, the Netherlands and the UK over the period 2009 - 2017. We find that an electricity price increase of 20% has a negative impact on employment of approx. 2% to 4% for the most impacted industries. A $75 carbon tax could therefore lead to 150,000 affected jobs in the countries we analyze. These jobs are either lost or need to be reallocated to other firms, industries and/or regions.

We also find this impact to be highly heterogeneous. The impact is highest for industries generally regarded as electricity intensive (e.g., chemicals, metals and paper). We find the highest (most negative) country-wide impact for Belgium and the highest local impact in Southern Germany and Northern Italy.

Should one worry about the 150,000 possible job losses in certain parts of the manufacturing industry in certain regions? In the past, Europe has successfully compensated millions of lost manufacturing jobs by jobs in the services industry. There is nevertheless no room for complacency. The impact could well reach beyond the 150,000 manufacturing jobs. One well paid manufacturing job indirectly also creates 1 to 2.5 jobs in non-tradable services (hospitality, food, retail, ...) in the immediate vicinity. Furthermore, the newly created services jobs are not necessarily in the same region nor for the same skill-set. Given the rigid labor markets in several European countries, increasing electricity prices could therefore have long-lasting negative labor market effects for the affected regions and workers.

To ensure a positive public sentiment towards environment related price increases, there will be a need for targeted assistance to firms, workers, and disproportionately affected communities. This is traditionally a role for fiscal policy makers. In this paper we also show there is a role for monetary policy makers to cushion the negative employment effect from rising electricity prices. We find indications that financially constrained manufacturing firms reduce employment more when electricity prices rise. This implies a potentially mitigating role for monetary policy.

1 Introduction

Many industrialized countries have committed themselves to tackling climate change and greenhouse gas emissions. The European Union has set itself a long-term goal to become climate neutral by 2050. To achieve these ambitious goals, the share of renewable energy sources (RES) in total electricity generation has to rise substantially. Whilst investing in RES can have important environmental and health benefits, it may increase electricity prices for firms and consumers by altering the electricity generating mix. RES subsidies are often recovered by levies and surcharges paid by the electricity consumer.[1] Furthermore, the introduction of a carbon tax, widely regarded as an efficient means to curb greenhouse gas emissions,[2] will most likely further increase electricity prices. Several recent studies found evidence of a high degree of pass-through of a carbon tax or emissions costs to wholesale electricity prices.[3] There are hence legitimate concerns that a climate neutrality objective could lead to increased electricity prices and more broadly energy prices.

For the manufacturing sector, energy and more particularly, electricity costs are an important component of total production costs. The EU defines energy intensive sectors as sectors where energy costs amount to at least 3% of production value. For the most energy intensive industries such as paper or metal production and processing the ratio can go up to 5–6% of production cost. Consequently, electricity prices can have important effects on employment and investment decisions as well. The impact of rising energy and more specific electricity prices on employment remains, however, complex, heterogeneous and dependent on the perspective taken (firm-level, sector-level, macro-level). When electricity prices rise, an individual manufacturing firm faces higher input costs and lower competitiveness. This can translate into lower output and thus lower employment. Furthermore, higher electricity prices make capital goods such as machinery more expensive relative to labor. Since labor and capital are to a limited extent substitutes (Henriksson et al. 2012), higher electricity prices can lower capital investment and increase employment. Alternatively, firms could also decide to invest in energy saving technology that

[1] Kreuz and Musgens (2017) calculate that Germany's "Energiewende" or energy transition incurred an annual gross costs in 2015 of €27.5 billion vs. a wholesale electricity value of €4.7 billion. The difference or RES cost is paid by electricity consumers. They calculate that ∼22% of the final electricity price for private households and ∼35% for industrial users is related to the Energiewende.

[2] See e.g., Stiglitz et al. (2017). Specifically for the EU Emission Trading System (ETS), Colmer et al. (2020) found that ETS regulated firms did reduce carbon dioxide emissions by 8-12% compared to unregulated firms.

[3] E.g., Fabra and Reguant (2014) for Spain, Hintermann (2016) for Germany and Lise et al. (2010) for 20 European countries.

ultimately makes them more productive.[4] This could lead to higher output and employment. Finally, a firm might simply decide to relocate (parts of) its production to a region or country with lower electricity prices.[5] Which of these heterogeneous effects dominate is an empirical question. The current literature suggests an employment elasticity as a function of energy and electricity prices of around -0.2.[6] This implies an electricity price increase of 10% has a negative impact on employment within manufacturing firms of approx. 2%.

When one takes a more aggregate view, the negative impact becomes less clear. Hafstead and Williams (2018) use a general equilibrium model and find that environmental policies lead to shifts in employment but have little effect on total employment. Recently, Metcalf and Stock (2020) found no support for the thesis that the EU emission trading system (ETS) had a negative impact on aggregate employment. The lack of aggregate movements often hides substantial heterogeneity under the hood. An example of underlying dynamics is given by Dussaux (2020). He shows that increasing energy prices have a negative effect on average firm-level employment, but a limited effect on aggregate sector-level employment. The reason is that jobs are shifted from less energy efficient to more energy efficient firms. Marin and Vona (2017) find negative effects from rising energy prices on French manufacturing establishments, but also find these effects are to a certain extent mitigated by job reallocation between establishments of the same firm. Subsequently Marin and Vona (2019) find that increasing energy prices lead to a higher demand for technicians and at the same time to a lower demand for manual workers. Hille and Möbius (2019) find positive net employment effects from increasing energy prices. Their intuition is that while there might be job destruction in energy-intensive industries, these losses are more than compensated in sectors producing, installing or consulting on energy saving or pollution abatement technologies.

Whilst the economy-wide impact remains debated, it is safe to say rising electricity prices will create some losers and these losers are likely to be active in electricity intensive manufacturing

[4] Even if firms increase investment in energy saving technology, this does not necessarily mean they increase overall investment. Weche (2018) found for Germany that environment related corporate investment crowds out other business investment.

[5] Saussay and Sato (2018) study the impact of energy prices on cross-border investment decisions and conclude that a relative price increase does lead to increased investment from companies in the higher priced country towards the lower priced country. They find an investment elasticity of -0.32.

[6] For the US, Kahn and Mansur (2013) find that energy-intensive industries tend to locate in low electricity price counties and estimate the elasticity between -1.65 to -0.17 depending on the sector with an average of -0.2. Deschênes (2012) finds a negative relation between US state level electricity prices and employment and find elasticity of -0.16 to -0.10. Cox et al. (2014) find, based on German data that higher input electricity prices lead to lower employment due to output contractions. They estimate the elasticity between -0.69 and -0.06 depending on the skill levels of the involved labor.

industries and lower skilled workers. Even if the aggregate economic impact of rising electricity prices is beneficial, there could be long-lasting negative and heterogeneous labor market effects for some workers and/or regions, similar to the long-lasting negative effects from Chinese import competition to the U.S. manufacturing industry, described by Autor et al. (2013, 2014).

To ensure a "just transition"[7] towards a carbon neutral world, there is hence an important role for fiscal policy makers. Recently, there is also an increased attention from monetary policy makers towards climate change.[8] Christine Lagarde, President of the ECB, stated that central banks need to devote greater attention to understanding the impact of climate change.[9]

In our case, rising electricity prices are part of risks associated with the transition towards a carbon neutral economy. Rising electricity and more broadly energy prices could e.g., cause negative supply shocks, lead to stranded assets, and be a burden to employment and overall economic activity in some parts of the economy.

In this study we confirm the negative and heterogeneous impact of rising electricity prices on firm-level employment and investment in the manufacturing industry.[10] The impact is highest for industries generally regarded as electricity intensive (e.g., chemicals, metals and paper) where we find employment elasticities between -0.1 and -0.2 and investment elasticities up to -1. We find the highest (most negative) country-wide elasticity for Belgium. Since different regions have different levels of specialization in the most affected industries, the impact from rising electricity prices is also geographically diverse within a country. We find the highest impact on employment in Southern Germany and Northern Italy.

Furthermore, we introduce a new source of firm-level heterogeneity. Firms that are more financially constrained, are more responsive (i.e. experience a higher elasticity) towards changes in electricity prices. These financially constrained firms will lower employment more when electricity prices rise compared to firms that experience less constraints. It is already established that firms expected to be more financially constrained react more to monetary policy shocks as frictions in financial markets amplify the effects of monetary policy on borrowers with lower access to external financial resources (e.g., Bernanke and Gertler 1995). We now also find

[7] Just transition refers to social assistance programs for workers who lost their jobs as a result of environmental policies, see e.g., Smith (2017).

[8] See e.g. Batten et al. (2020) for the relevance of climate change to monetary policy.

[9] Speech given at the launch of the COP 26 Private Finance Agenda, 27 February 2020.

[10] Whilst the impact on households is not the subject of this study, Green and Knittel (2020) recently showed that carbon taxes and more broadly climate policy also have an heterogeneous impact on households and could lead to both progressive and regressive redistribution between households and regions.

evidence that firms react more to carbon shocks in the form of rising electricity prices. This implies the credit channel of monetary policy could have a smoothing effect and absorb shocks from rising electricity and more broadly energy prices.

To come to these findings we use firm-level financial and employment data for Belgium, France, Germany, Italy, the Netherlands and the UK for the period 2008 - 2017. This selection of 6 countries has a comparable level of industrialization of its manufacturing sector and it includes both large and small countries. We estimate firm-level electricity prices based on the industry's firm size distribution. We use these prices as an explanatory variable in our econometric model of equilibrium labor demand across countries and estimate the electricity price elasticity of employment when the level of output can adjust as well.

The paper proceeds as follows. The next section explains the empirical estimation method and the data used. Section 3 presents the main econometric findings and performs a range of robustness checks. Section 4 discusses the policy implications and section 5 concludes.

2 Empirical data and method

2.1 Methodology

We are interested in the overall impact of changing electricity prices on employment and more specifically the electricity price elasticity of firm-level labor demand. This elasticity can be broken down into 2 components: the substitution and the scale effect (Hamermesh 1993). The substitution effect captures the fact that (under a given level of output) electricity consuming capital will be substituted for labor when electricity prices increase. The scale effect represents the reduction in employment driven by lower output when increased electricity prices lead to increased sales prices and/or lower profitability. We first use a reduced-form, static labor demand model that allows for multiple input factors (Hamermesh 1993). In section 3.4 we also explore a dynamic labor demand model. We focus on the impact on firm-level employment unconditional on output. This implies the overall effect includes substitution effects as well as scale effects. The model becomes:

$$emp_{it} = \alpha_i + \mu_1 price_{it} + \mu_2 wage_{it} + \xi X_{it} + \epsilon_{it} \tag{1}$$

Where emp_{it}, $price_{it}$ and $wage_{it}$ stand for the natural logarithm of employment (emp), the electricity price (*price*) and *wage* for firm i in year t. The advantage of using this log-linear model is that we can interpret the coefficient μ_1 as a price elasticity. Firm-level wage is defined as gross wage bill divided by the number of employees. Firm-level electricity prices are discussed in the next section. α_i is a firm-level panel fixed effect that accounts for firm-specific characteristics that impact employment and are constant over time. X_{it} represents a vector of control variables. In the most stringent specification this includes the natural logarithm of the firm's capital stock, country $\times$ year and sector $\times$ year fixed effects.

We also study the impact on firm-level investment. This is determined via a similar model where (the logarithm of) employment is replaced by (the logarithm of) investment. $price_{it}$ and $wage_{it}$ are replaced by their lagged values $price_{it-1}$ and $wage_{it-1}$ to account for the fact that investment in year t is decided on in year $t-1$.

2.2 Data

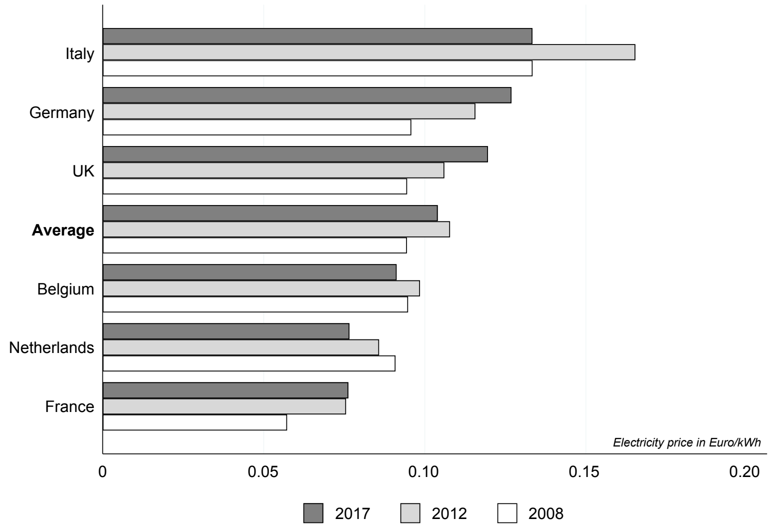
2.2.1 Background on electricity prices

The electricity cost for the end-user can generally be broken down into three parts that greatly differ between different consumer profiles and countries. First, the end-user has to pay for the electricity generation. Electricity is currently traded at electricity exchanges[11] where the commodity can be bought on a spot or future basis. The share of the actual commodity cost ranges from less than 50% to greater than 90% of the final price depending on the user profile and location. Second, the end-user price includes a network cost. Network costs are the charges for transmitting the electricity via the grid of transmission system operators (TSO) and distribution system operators (DSO). The breakdown of the transmission market is country specific. Generally, a DSO manages a medium- to high-voltage grid and a TSO manages a high- and very high-voltage grid. An end-user will pay a different network charge depending on the voltage used. Large consumers are directly connected to the high- or very high-voltage grid and hence pay reduced or no DSO charges. Network charges are regulated and for industrial users generally are the smallest part of the end price. Finally, there is a complex system of country specific tariffs, charges, levies and exemptions thereof. These charges are characterized by a large variance and in some cases can reach twice the cost of the underlying commodity.

When we refer to electricity price in this paper, this is the final cost towards an industrial

[11]Examples are the European Power Exchange (EPEX) and the European Energy Exchange (EEX).

Figure 1: Electricity prices for industrial users



Note: Electricity prices (€/kWh, excl. VAT and other recoverable taxes and levies) for industrial users with a yearly consumption between 2,000 and 20,000 MWh, ranked based on 2017 price (descending).
Source: Eurostat.

consumer, i.e. the sum of the commodity, network costs and all non-recoverable taxes and levies, excluding VAT.

Figure 1 shows the electricity prices for 6 European countries as well as the average price for the year 2008, 2012 and 2017 for a commonly used industrial consumption band. We see that prices can vary substantially.[12] Electricity prices in Italy are almost 3 times higher than in France.

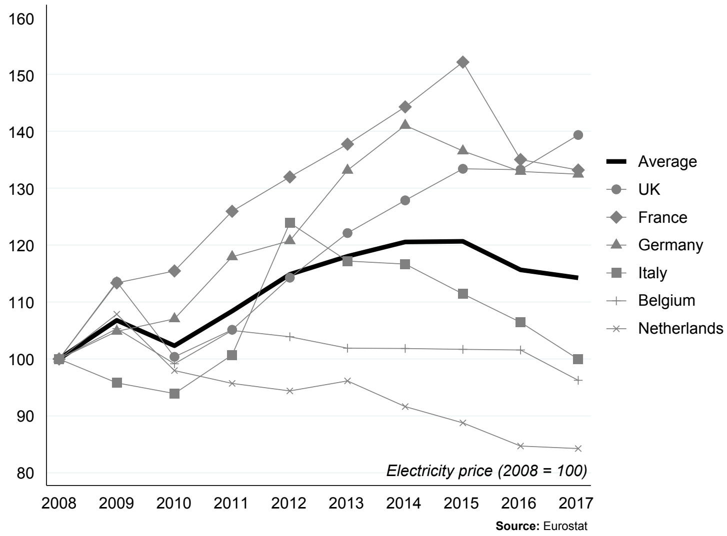
Figure 2 shows the relative evolution of the same electricity price between 2008 and 2017. While for France, Germany and the UK, the price has risen 30% to 40%, for Belgium and The Netherlands, the price was stable or even came down.

2.2.2 Data sources

We obtain information on firm-level employment and financials from Orbis maintained by Bureau Van Dijk. We include firms in the manufacturing sector of Belgium, France, Germany, Italy, The Netherlands and the UK for the period 2008 - 2017. Micro firms with less than 10 employees are excluded as these are generally not well reported in Orbis. Table 1 shows the summary statistics

[12] Price differences and changes are driven by differences and changes in the underlying commodity, network charges and/or taxes/levies and can vary for each consumption band and between different countries. The importance of taxes/levies and changes thereof has risen over the past decade.

Figure 2: Relative evolution of electricity prices for industrial users



Note: Relative evolution of electricity prices (excl. VAT and other recoverable taxes and levies) for industrial users with a yearly consumption between 2,000 and 20,000 MWh. While on average we see an increase, the evolution differs substantially between countries.
Source: Eurostat.

of firm-level employment per country. The UK firms that are included in our dataset are skewed towards larger firms compared to the other countries.

Electricity prices are gathered from the electricity price statistics for non-household consumers from Eurostat (2020a). It reports on a bi-annual basis weighted average prices for six electricity consumption bands up to 150,000 MWh and for a consumption band above 150,000 MWh. Prices are very well reported for the bands up to 150,000 MWh. Price data for consumption above 150,000 MWh is not available for all countries. Prices reflect the true cost to the end-user and hence exclude VAT and other recoverable taxes and levies. Yearly prices are calculated as the average over the 2 semesters.

The largest industrial electricity users, however, have a yearly consumption well over 150,000 MWh. For prices for these heavy users we rely on Deloitte (2018) who reports baseload and peakload prices[13] for Belgium,[14] the Netherlands, France and Germany for the period 2013-2018 for 10 consumption bands between 100,000 MWh and 1,000,000 MWh. We use these prices and how they compare to the Eurostat prices as the basis to extrapolate prices for the consumption

[13] We calculate the average as 35% peakload and 65% baseload. This corresponds with baseload hours on weekdays between 8h00 and 20h00.

[14] We calculate the price for Belgium as 70% Flanders and 30% Wallonia.

Table 1: Firm-level employment statistics

Country	# firms	Average employment				Total employment
		Mean	Median	p10	p90	
Belgium	7,268	67	22	11	119	486,083
Germany	61,591	82	27	12	129	5,077,617
France	32,402	81	23	11	137	2,630,678
Italy	86,496	40	17	11	67	3,501,006
The Netherlands	12,031	40	19	11	69	477,088
UK	12,688	164	67	17	270	2,083,127
TOTAL	**212,506**	**67**	**22**	**11**	**110**	**14,255,598**

Note: The number of firms refers to the number of unique firms appearing 1 or more years in the dataset. The employment statistics refer to the average number of employees over the years the firm appears in the dataset.

bands not reported by Eurostat. In practice the Deloitte prices reported for Belgium, France and the Netherlands for consumption of 100,000 MWh are comparable to the Eurostat prices for the highest consumption bands and then linearly decrease reaching a price that is 20% to 30% lower for the highest consumption band above 950,000 MWh. We assume prices for lower bands relate to higher bands in a similar way in Italy and the UK as they do on average in Belgium, Germany, France and the Netherlands. This brings us to electricity prices for 15 consumption bands per country. The exact definition of the consumption bands can be found in Appendix A.

We use the electricity consumption profile per sector for Belgium derived in Bijnens et al. (2018). Based on firm-level electricity consumption profiles, they derive a consumption matrix (given in Appendix B). This matrix shows for each manufacturing sector the share of electricity consumption taken by each of the 15 consumption bands. We assume this consumption profile to be similar across countries used in our study. This is a realistic assumption since technology levels in manufacturing (with respect to electricity usage) in the most industrialized countries in Europe are comparable.

This sectoral electricity consumption profile is used to estimate to which electricity consumption band a firm belongs. We assume that, within a sector, a higher amount of tangible fixed assets reflects a higher electricity consumption. We therefore rank, across countries, all firms in a sector based on the average value for tangible fixed assets over the period. This ranking is matched with the sectoral electricity consumption profile to determine the electricity price band for each firm. This firm-level price band is subsequently linked with the relevant electricity price valid for the firm's country in a certain year.

3 Results

3.1 Impact on employment

Table 2 estimates the impact of electricity prices on employment based on the model from Equation 1. We sequentially include more control variables. Columns (1) includes country × year and country × year fixed effects. Column (2) adds the wage and column (3) also controls for the capital stock. All columns include firm panel fixed effects.

Table 2: Impact on employment
OLS panel regression results estimating Equation 1

	(1) employment	(2) employment	(3) employment
electricity price	-0.0631***	-0.0395***	-0.0162*
	(0.00632)	(0.00730)	(0.00705)
wage		-0.0641***	-0.105***
		(0.000701)	(0.000702)
tangible fixed assets			0.0612***
			(0.000286)
Firm FE	yes	yes	yes
Country × year FE	yes	yes	yes
Sector × year FE	yes	yes	yes
N	1062182	836134	834172

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: The elasticity of employment in function of the price of electricity is given by the coefficient for *electricity price* and ranges between -0.02 and -0.06.

The coefficient of interest is μ_1 from Equation 1 detailing the unconditional elasticity of labor demand as a function of the electricity price. We find values in the range of -0.02 and -0.06 This implies an electricity price increase of 1% will, on average, reduce firm-level labor demand 0.02% to 0.06%. Cox et al. (2014) find unconditional demand elasticities between -0.06 and -0.69 depending on the skill levels of the involved labor.

The estimates for the employment – wage elasticity of -0.06 to -0.10 are on the lower side of the typical range of -0.15 to -0.75 reported by Hamermesh (1993) as we do not make a distinction between low and high skilled labor. In a more recent study Lichter et al. (2015) report, based on a meta-regression analysis, point estimates for medium-term elasticities of -0.114 to -0.243. As can be expected, the wage elasticity is higher (more negative) than the electricity elasticity as wage costs represent a higher share of input costs than electricity for most firms.

The above elasticity is the average for all manufacturing firms in our dataset. Clearly, not all firms will be impacted by changing electricity prices. Firms and sectors that do not significantly rely on electricity as an input will only be impacted to a limited extent by changing electricity prices. Furthermore, since the firm landscape will differ between countries, we also expect a different impact between countries.

We therefore interact the electricity price (*price* in Equation 1) with the country the firm is located and the sector the firm is active in. The detailed regressions results are included in Table 7 in Appendix C. We use 2 different specifications: a reduced form model (similar to column (1) from Table 2) and an extended model that controls for wages and tangible fixed assets (similar to column (3) from Table 2).

Figure 3 shows a graphical representation of the country specific elasticities. We clearly find a negative elasticity for Belgium, Germany and France with the highest impact in Belgium. For Italy the elasticity is very close to zero and for the UK the elasticity becomes positive, albeit not significantly different from zero. For the Netherlands, we find a negative elasticity only for the reduced form model. The elasticity estimated by the extended model shows a large confidence interval. A possible explanation of these differences between countries is a different sectoral composition. Figure 4 now gives the sector specific elasticities. Sectors are defined based on NACE 2-digit codes. We see a heterogeneous impact of electricity prices on firm-level employment based on the sector the firm is active in. For the sectors which are generally regarded as energy or electricity intense (e.g., chemicals, metals, paper) we find a negative elasticity.[15] For some industries, though, we find a positive elasticity. This suggests that the substitution effect, where machinery is replaced by human labor, outweighs the scale effect for these industries.[16]

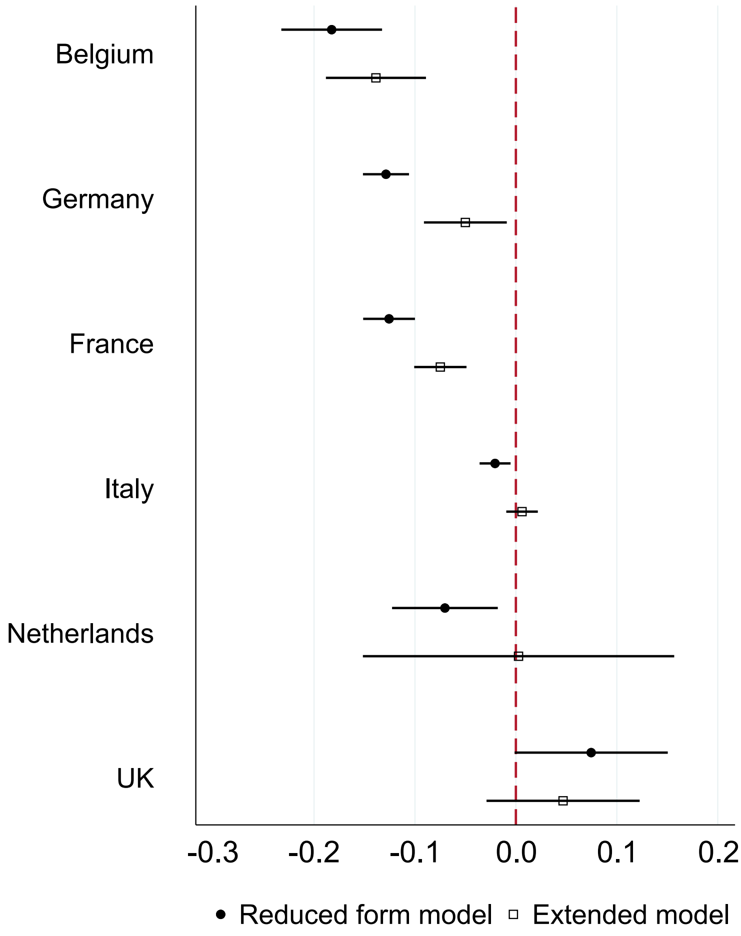
The heterogeneous sectoral impact leads to a heterogeneous geographical impact within a country since the manufacturing industry is not evenly spread across countries, nor within countries.[17] Figure 5 and Figure 6 highlight this geographical diversity. Figure 5 shows the

[15] An additional, though partial, explanation of sector-level differences for the elasticity is the level of competition in a sector. This is further explored in a later section of this paper.

[16] Other studies (e.g., Dechezleprêtre et al. 2017, Dussaux 2020) estimating sector level energy and electricity elasticities also find positive coefficients for some industries.

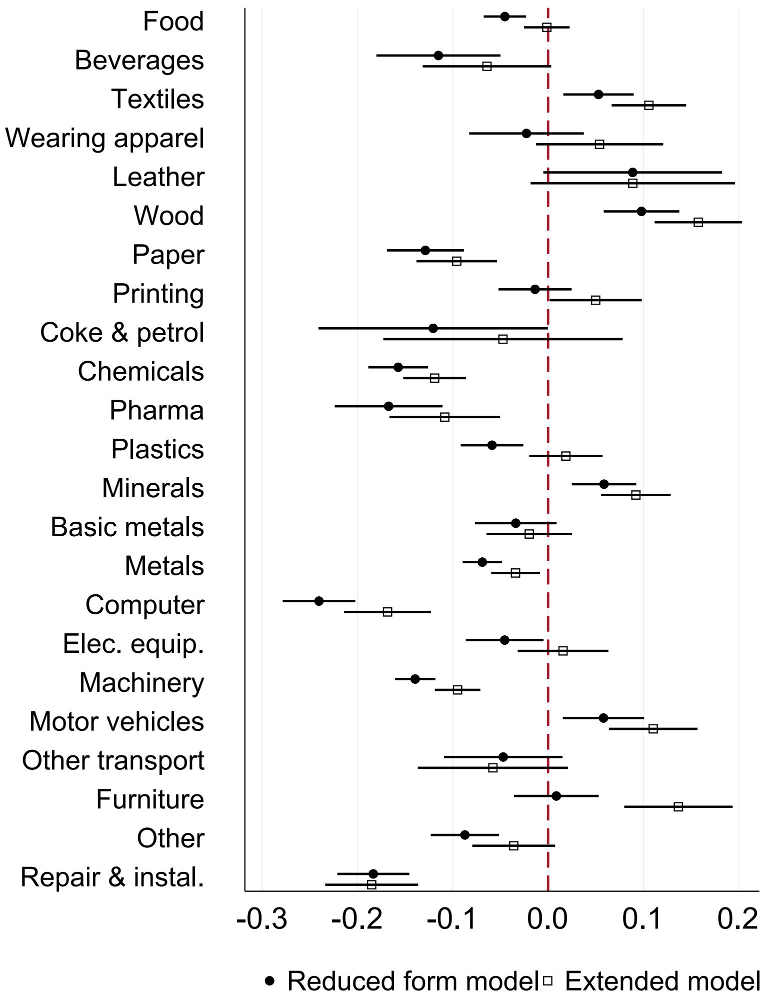
[17] Note that policy differences between countries that affect employment are absorbed by the country × year

Figure 3: Country specific elasticities of employment



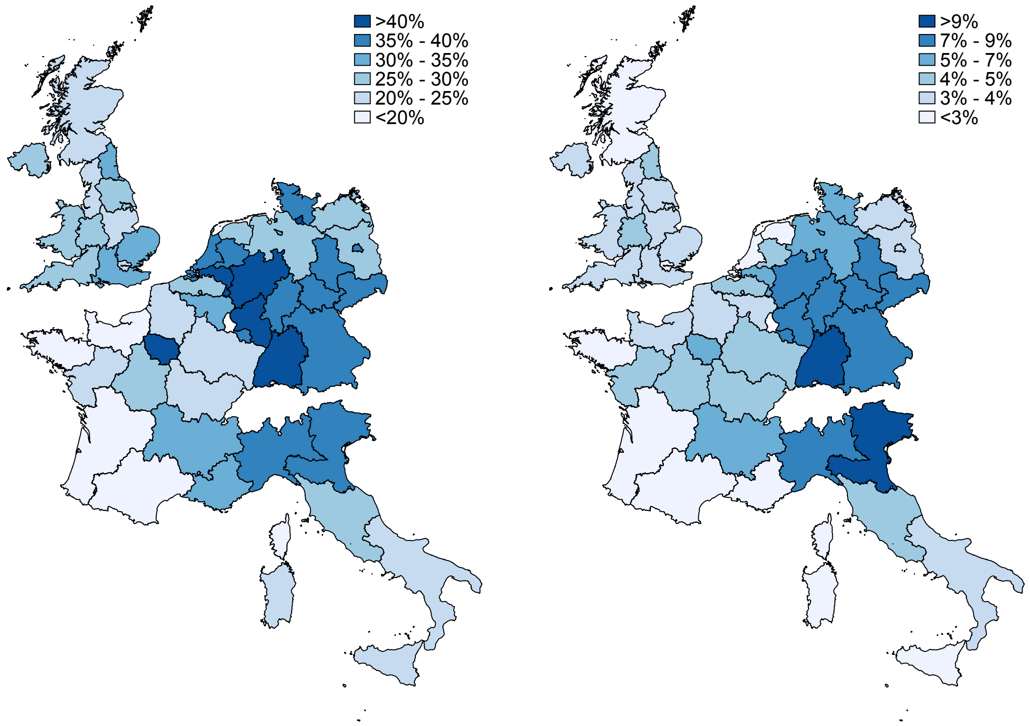
Note: Graphical representation for the coefficient of $price_it$ from equation (1) interacted with a country dummy. Detailed regression results can be found in Table 7 in Appendix C. The horizontal lines around the point estimate represent the 95% confidence interval.

Figure 4: Sector specific elasticities of employment



Note: Graphical representation for the coefficient of $price_{it}$ from Equation 1 interacted with a NACE 2-digit sector dummy. Detailed regression results can be found in Table 7 in Appendix C. The horizontal lines around the point estimate represent the 95% confidence interval. The coefficient for the tobacco industry (NACE 12) is omitted for graphical clarity reasons.

Figure 5: Relative employment in sectors where electricity prices have a negative impact on employment



(a) Share of electricity sensitive employment as share of *manufacturing* employment

(b) Share of electricity sensitive employment as share of *total* employment

Note: Geographical areas defined based on NUTS1 code. Employment figures for 2016.

relative importance of electricity sensitive employment vs. overall manufacturing employment (Figure 5a) and vs. total employment (Figure 5b).[18] Electricity sensitive employment stands for the employment in the manufacturing sectors for which we found a negative and significant elasticity in Figure 4, i.e. sectors that experience a negative impact from rising electricity prices.[19] Figure 6 shows the absolute employment in these electricity sensitive sectors.

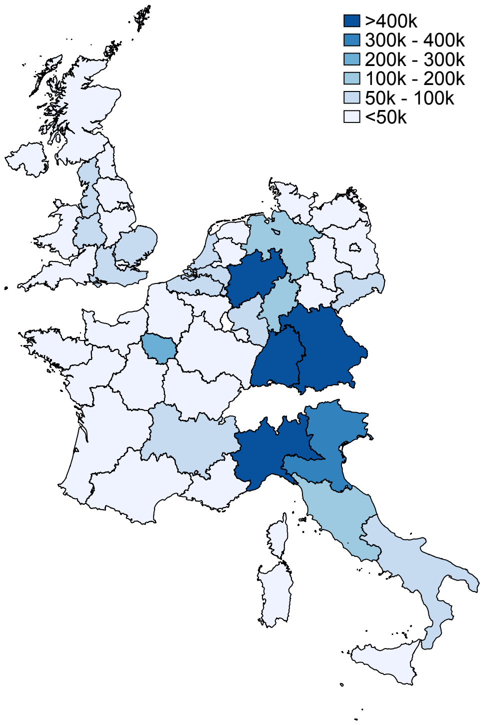
From Figure 5a we learn that these electricity sensitive sectors represent a high share of overall manufacturing employment in Germany, the Netherlands, Belgium and Northern Italy. Compared to total employment, the share of electricity sensitive sectors stands out in Germany

fixed effects. Country differences that affect the sectoral elasticity are not picked up as this requires the estimation of country – sector specific elasticities.

[18]We use the 2016 figures from Eurostat's regional Structural Business Statistics (sbs_r_nuts06_r2) that reports regional employment per NACE 2-digit sector. Missing data is replaced by data from our firm-level database. Aggregate employment is taken from Eurostat Labor Force Survey (lfst_r_lfe2en2).

[19]The sectors with negative and significant elasticity for both regression specification are tobacco (NACE 12), paper (NACE 17), chemicals (NACE 20), pharmaceuticals (NACE 21), metals (NACE 25), computers and electronics (NACE 26), machinery and equipment (NACE 28) and equipment repair (NACE 33).

Figure 6: Absolute employment in sectors where electricity prices have a negative impact on employment



Note: Geographical areas defined based on NUTS1 code. Employment figures for 2016.

and Northern Italy (Figure 5b). When we look at absolute employment numbers in these sectors (Figure 6), 5 regions stand out: Nordrhein-Westfalen, Baden-Württemberg and Bavaria in Germany and North-West and North-East in Italy. These regions could face substantial job losses and a high need for job reallocation driven by rising electricity prices.

3.2 Link with financial constraints

In the previous paragraph we showed that higher electricity prices will have a (substantial) negative effect on employment in certain industries. This also leads to a heterogeneous geographical impact. In this section we examine to what extent an additional source of firm-level heterogeneity, i.e. financial constraints, lead to a heterogeneous response to changing electricity prices. Over the past decades a large literature has been developed on how financially constrained firms have larger reactions to monetary policy shocks (e.g., Bernanke and Gertler 1995, Hutchinson and Xavier 2006) and how it affects corporate investment (e.g., Fezzari et al. 1987).

There are several possible explanations for the relevance of financial constraints. When electricity prices rise, firms experiencing liquidity issues might have to increase output prices quicker compared to their less financially constrained competitors.[20] This leads to a lower output and hence lower employment vs. the less constrained competitors. Financially constrained firms might have fewer possibilities to invest in electricity saving technology. In addition, De Haas and Popov (2019) showed that CO_2 emissions per capita are lower in economies that are relatively more equity-funded. Stock markets reallocate investment towards less polluting sectors and push carbon-intensive sectors to develop and implement greener technologies.

Figure 7[21] below examines if there is a disproportionate impact from rising electricity prices on firms that experience (possible) financial constraints. Since financial constraints are not directly measurable, the literature has resorted to proxies or indicators such as age, profitability, leverage and liquidity or combinations thereof that are easily observed (see e.g., Durante et al. 2020 for more detail). A shortcoming of firm financial data as a proxy clearly is the fact that they endogenously adjust to shocks. Age can therefore be regarded as the only exogenous proxy (Cloyne et al. 2018). Furthermore, unobservable characteristics such as management skills might well play a role.[22] For the purpose of our study we limit ourselves to several proxies

[20] A similar mechanism is explained in Amiti et al. (2019) who show that smaller firms have a higher cost pass through mechanism than larger firms.

[21] Detailed regression results can be found in Table 8 (Appendix C.)

[22] Chercheye et al. (2020) recently proposed a new measure that recovers financial constraints beyond observable

for financial constraints:[23]

- Age: young firms (less than 10 years) vs. older firms
- Gearing ratio : (total liabilities - equity) / equity
- Interest cover: EBIT / interest paid
- Return on equity (ROE) : (profit before tax + interest paid) / shareholder equity

We control for unobserved, time-invariant firm-level characteristics via firm-level fixed effects. Figure 7 shows how the elasticity changes based on different measures for financial constraints. We see that firms experiencing a higher (lower) level of financial constraints do experience a higher (lower) impact from changing electricity prices. From Figure 7a we learn that young firms face a higher elasticity than older firms.[24] Figure 7b shows that firms with a low level of gearing, i.e. a low level of debt vs. own equity face a lower elasticity. The more the debt level is increased, the higher the negative impact on employment stemming from increased electricity prices. Doubling the debt level increases (makes more negative) the elasticity with ~1.5 percentage points. Figure 7c indicates a similar mechanism. The elasticity becomes smaller (less negative) when the interest coverage (cash flow vs. interest payments) increases. Doubling the interest cover decreases (makes less negative) the elasticity with ~1 percentage point. Figure 7d finally shows that when profitability, measured via the return on equity, increases, the elasticity also decreases (becomes less negative).

3.3 Impact on investment

When it comes to investment, there are again several competing channels at play. The pollution haven hypothesis (McGuire 1982) predicts that firms will rather invest in areas with lower environmental compliance costs. The Porter hypothesis (Porter and van der Linde 1995), however, argues that environmental costs trigger innovation in cost-cutting technology. While there is certainly empirical proof that environmental regulation triggers innovation,[25] the literature suggests that the pollution haven effect outweighs the effects from the Porter hypothesis (see

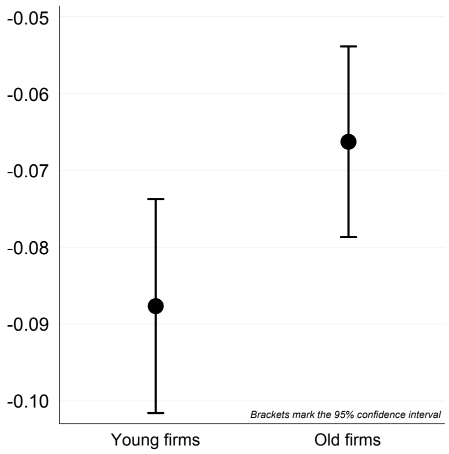
firm characteristics.

[23] Gearing, interest cover and ROE are log transformed.

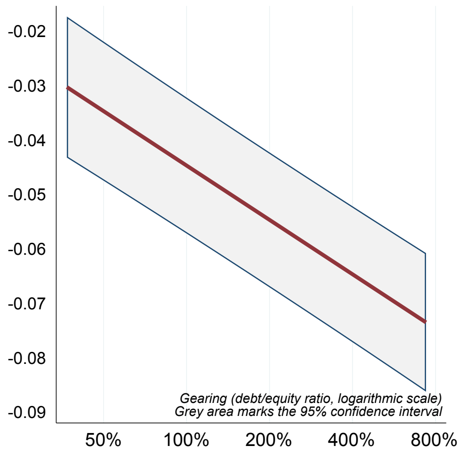
[24] Young firms are defined as firms that exist for 10 years or less.

[25] E.g., De Jonghe et al. (2020) recently showed that, when the price of emission allowances is sufficiently high, the EU ETS did lead to increased emission efficiency of highly polluting firms.

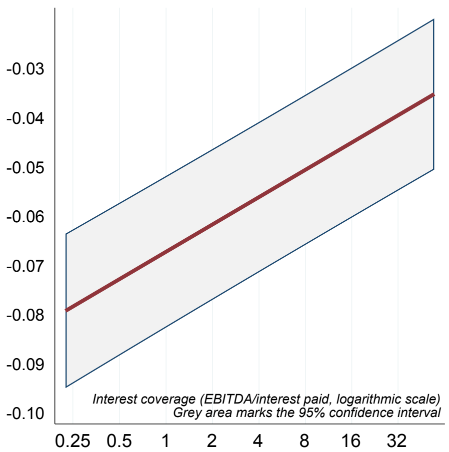
Figure 7: Elasticity of employment and financial constraints



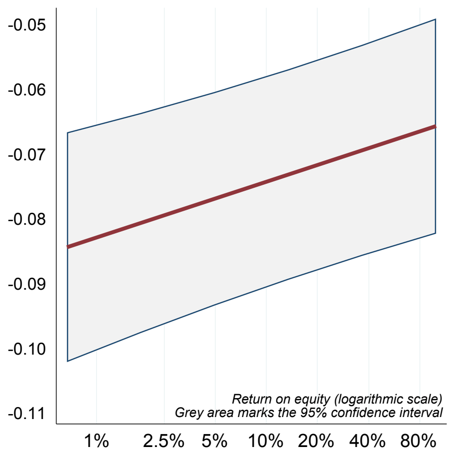
(a) Elasticity for young vs. old firms



(b) Elasticity and gearing



(c) Elasticity and interest coverage



(d) Elasticity and return on equity

Note: Graphs based on the reduced form model, i.e. columns (1), (3), (5) and (7) from Table 8 (Appendix C).

Dechezleprêtre and Sato 2017 for an overview). In addition, electricity prices can increase output prices and reduce output, which can lead to lower investment.

Table 3: Impact on investment
OLS panel regression results estimating Equation 1

	(1)	(2)	(3)
	$\text{investment}_{\text{t}}$	$\text{investment}_{\text{t}}$	$\text{investment}_{\text{t}}$
electricity $\text{price}_{\text{t-1}}$	-0.503***	-0.257*	-0.330**
	(0.0878)	(0.106)	(0.105)
$\text{wage}_{\text{t-1}}$		-0.603***	-0.302***
		(0.0119)	(0.0123)
tangible fixed $\text{assets}_{\text{t-1}}$			-0.467***
			(0.00530)
Firm FE	yes	yes	yes
Country × year FE	yes	yes	yes
Sector × year FE	yes	yes	yes
N	944857	664441	664441

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

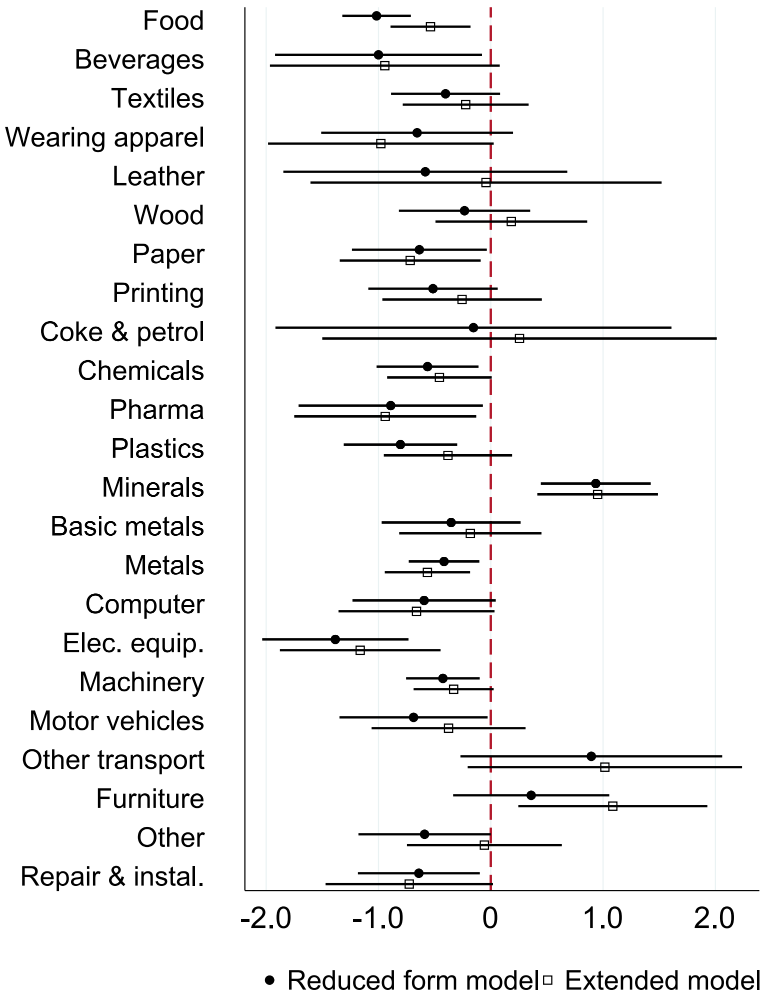
Note: The elasticity of investment in function of the price of electricity is given by the coefficient for *electricity price* and ranges between -0.2 and -0.4.

Table 3 gives the impact on investment[26] from changing electricity prices. Also for investment we find an elasticity that is higher (more negative) compared to the effect on employment. For investment we find a negative elastic between -0.2 and -0.5. This implies that a 10% rise in electricity prices reduces next year's investment with 2% to 5%. Our result is line with figures found in other studies. E.g., Saussay and Sato (2018) find that a 10% increase in the industrial energy price differential between two countries is associated with a 3.2% increase in the number of acquisitions of firms or assets located in the countries where the energy price is lower.

Figure 8 also shows the sector specific elasticities. Elasticities range between approx. -1 and +1, which is a broader range than we found for the sector level elasticities of employment (Figure 4). The confidence intervals are broader as well.[27] Nevertheless, the point estimates are predominantly negative. This indicates a negative impact on investment from rising electricity prices for most sectors.

[26]Investment in year t is calculated from the firm's financial accounts and is defined as the difference between tangible fixed assets in year t and year $t-1$ plus the amount depreciated in year t.
[27]Detailed regression results can be found in Table 9 in Appendix C. Table 9 also includes country specific elasticities.

Figure 8: Sector specific elasticities of investment



Note: Graphical representation for the coefficient of $price_{it}$ from Equation 1 interacted with a NACE 2-digit sector dummy. Detailed regression results can be found in Table 7 in Appendix C. The horizontal lines around the point estimated represent the 95% confidence interval. The coefficient for the tobacco industry (NACE 12) is omitted for graphical clarity reasons.).

Table 4: Impact on employment – dynamic effects
OLS panel and Arellano-Bond regression results estimating Equation 1

	(1) employment$_t$	(2) employment$_t$	(3) employment$_t$	(4) employment$_t$	(5) employment$_t$	(6) employment$_t$
employment$_{t-1}$	0.558***	0.581***	0.551***	0.686***	0.631***	0.602***
	(0.00153)	(0.00165)	(0.00162)	(0.00942)	(0.00846)	(0.00825)
electricity price$_t$	-0.0295***	-0.0286**	-0.0223*	-0.0245*	-0.0238*	-0.0209$^+$
	(0.00811)	(0.00908)	(0.00883)	(0.0107)	(0.0113)	(0.0109)
wage$_t$		-0.117***	-0.139***		-0.206***	-0.220***
		(0.00119)	(0.00117)		(0.00161)	(0.00158)
tangible fixed assets$_t$			0.0424***			0.0372***
			(0.000398)			(0.000521)
Firm FE	yes	yes	yes	yes	yes	yes
Country × year FE	yes	yes	yes	yes	yes	yes
Sector × year FE	yes	yes	yes	yes	yes	yes
N	379159	294521	293728	290132	229856	229143

Standard errors in parentheses
$^+$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Regression (1), (2) and (3) are OLS panel regressions; (4), (5) and (6) are Arellano-Bond regressions including 1 lag and treating electricity prices as endogenous. Included sectors are tobacco (12), paper (17), chemicals (20), pharmaceuticals (21), metals (25), computers and electronics (26), machinery and equipment (28) and equipment repair (33).

We also examine the impact of financial constraints (Table 10 in Appendix C). While we can confirm that financial constraints have a direct negative impact on the level of investment, we do not find that financial constraints amplify the negative employment effect from rising electricity prices. The coefficients for the interaction terms are not significant. If financial constraints would have an impact on the investment elasticity, the direct channel (the fact that financially constrained firms have less access to capital) clearly outweighs this potential impact.

3.4 Dynamic impact on employment

Table 4 shows the results when we include dynamic effects. We focus on the sectors where we previously found a negative elasticity.[28] In our empirical approach so far, we have estimated static labor demand. Static labor demand does not consider the existence of adjustment costs. Dynamic labor demand, on the contrary, explicitly accounts for the costs associated with changing the level of employment.

Adjustment costs may arise from either institutional (e.g., firing costs), economic (e.g., hiring

[28] These sectors are tobacco (NACE 12), paper (NACE 17), chemicals (NACE 20), pharmaceuticals (NACE 21), metals (NACE 25), computers and electronics (NACE 26), machinery and equipment (NACE 28) and equipment repair (NACE 33).

costs, training) or technological adjustment obstacles (e.g., capital stock is rather fixed). These costs may lead to the situation that firms do not change their demand for labor significantly after an exogenous shock (in our case a change of the electricity price) because the adjustment costs outweigh the benefits of a change of the level of employment. Furthermore, when a firm experiences an input price shock, it does not know yet to what extent this shock will be permanent. These factors make firms merely adjust their workforce slowly and employment will be rather persistent.

Empirically, dynamic effects are accounted for by including the lagged value of the dependent variable (employment) as an explanatory variable into the regression (Nickell 1986).

Table 4 retakes the specification from Table 2 and includes the lagged level of employment ($employment_{t-1}$) into the estimation. Column (1), (2) and (3) show the results for a standard panel fixed effects regression. Our estimates include the widest possible set of fixed effects. This allows to control for unobserved characteristics such as the fact that better managed companies are larger and hence employ more workers, but are also able to negotiate better electricity prices. Nevertheless, due to possible remaining issues arising from omitted variables, this fixed effects estimator might be biased downwards. We hence also include estimates based on Arellano and Bond's (1991) method in columns (4), (5) and (6). This is a generalized method of moments (GMM) method that also controls for reverse causality by instrumenting the lagged levels, as well as the lagged differences of the endogenous regressors. A firm experiencing a positive demand shock increases output (and employment) and hence electricity use. The increased electricity usage might lead to a lower electricity price. We therefore treat the electricity price as endogenous.

The results from the dynamic model confirm the negative elasticity. We find an average short run elasticity if -0.02 to -0.03 and a long run elasticity of approx. -0.07.[29] This means that a sustained increase of 10% of the electricity price will, after several years, decrease employment with 0.6%.

[29]The long run elasticity is calculated by dividing the coefficient for $electricity\ price_t$ by 1 minus the value of the coefficient for $employment_{t-1}$.

Table 5: Impact on employment – dynamic effects
OLS panel and Arellano-Bond regression results estimating Equation 1

	(1) employment	(2) employment	(3) Δ employment	(4) Δ employment
electricity price	-0.0763***	-0.00520		
	(0.0136)	(0.0137)		
Δ electricity price			-0.0312***	
			(0.00257)	
Δ electricity price (up)				-0.0405***
				(0.00456)
Δ electricity price (down)				-0.0201***
				(0.00519)
N	387418	469195	798427	798427

Standard errors in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Regression (1), (2) retake regression (1) from Table 2, but on a split sample where electricity prices go up (1) and electricity prices come down (2). Column (3) give the results for the first difference specification from Equation 2 and column (4) gives the results for the same Equation where $Deltaprice_{it}$ is interacted with a dummy that take the value 1 if the price goes up and 0 otherwise and a dummy that takes the value 1 if the price comes down and 0 otherwise.

3.5 Robustness checks and additional analysis

3.5.1 Symmetric price effect

So far we have assumed that the price effect on employment is symmetric. This implies that the size of the negative effect on employment from an electricity price increase is the same as the size of the positive effect on employment from a similar electricity price decrease. As we predominantly expect future price increases driven by, among others increasing carbon taxes, the results found in the previous paragraphs would not be useful if they were predominantly driven by price decreases.

The empirical analysis of this section therefore differentiates between a price drop and a price increase. We initially retake the base specification from column (1) in Table 2 and split the data sample between observations that saw an electricity price increase in year t vs. year $t-1$, this is given in column (1) from Table 5, and observations that experienced an electricity price decrease, this is given in column (2). From these results we learn that the negative elasticity found so far is predominantly driven by price increases.

To confirm this finding we specify a reduced form model written in first differences:

$$\Delta emp_{it} = \mu_1 \Delta price_{it} + \epsilon_{it} \tag{2}$$

Where Δemp_{it} and $\Delta price_{it}$ stand for $emp_{it} - emp_{it-1}$ and $price_{it} - price_{it-1}$. Taking first differences controls for all factors that affect firm-level employment that are fixed over time and is comparable to a panel fixed effect. This specification directly relates a year-on-year change in the price of electricity with a year-on-year change in employment. The coefficient of μ_1 is given in column 3 of Table 5 and confirms the negative elasticity found in the previous paragraphs. This specification allows to split the explanatory variable $\Delta price_{it}$ into a variable when the price goes up (and 0 if the price goes down) and a the same variable when the price goes down (and 0 otherwise). These results are given in column 4 of Table 5 and confirm as well the elasticity is certainly not predominantly driven by a price decrease.

3.5.2 Sector-level elasticities and competition

Next to the energy intensity of a sector, sector-level competition could also play a role in explaining the differences in elasticities across sectors given in Figure 4. In non-competitive sectors, producers might be able to pass-through the electricity price increase to their customers. In such a sector, a producer will predominantly defend its profit, rather than its output (and the employment associated with a certain level of output). In a very competitive sector, a producer does not have the ability to rise its output price and needs to absorb a price increase by lowering its profit. In such a case, employment will not change as the output price and the associated demand did not change. To account for sector-level competition we calculate the Herfindahl-index[30] for a sector in country in a certain year.[31] The Herfindahl-index takes a value from 0 to 1, moving from a huge number of very small firms to a single monopolistic producer.

We use the same specification as for the regressions from Table 2, but interact the electricity price with the Herfindahl-index. The regressions results are included in Table 6. We indeed find that a higher Herfindahl-index does increase (makes more negative) the elasticity. The median value for the index is approx. 0.02 and the 75$^{\text{th}}$ percentile value is approx. 0.6. From the coefficients for $electricity\ price \times Herfindahl - index$ from Table 6 we learn that if the

[30]The index is defined as the sum of the squares of the market shares of the firms within the industry. We use the share of employment of a firm vs. total employment in the sector.

[31]We hence regard the level of competition within a sector as country specific. If the level of competition is rather defined on a European level, i.e. when the market is predominantly global in stead of local, the level of competition is already accounted for by the country × year fixed effects included in the regressions of Table 2

level of competition within an industry decreases (i.e. the Herfindahl-index increases) from the median value to the 75th percentile value, the elasticity increases (becomes more negative) by 0.01 (result from column 1) to 0.02 (result from column 3). We hence do find an impact on the elasticity from the level of competition within a sector, but this plays only a minor role in explaining the different sector-level elasticities found in Figure 4.

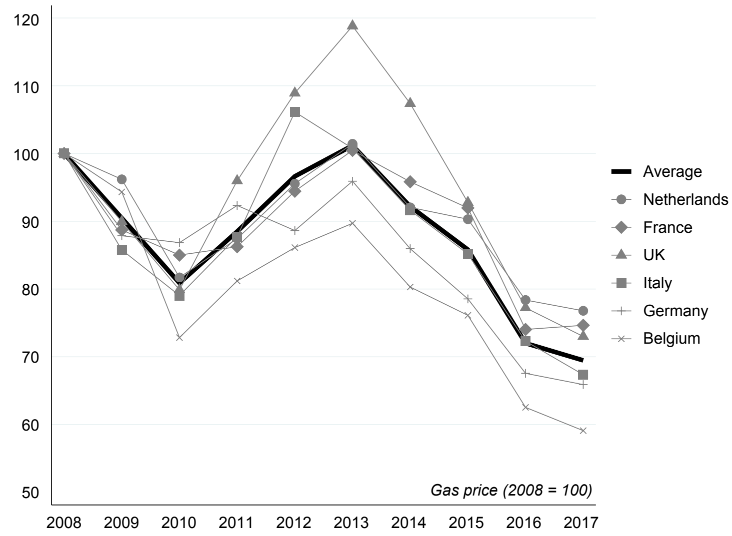
Table 6: Impact on employment
Role of level of competition in explaining sector-level elasticities

	(1) employment	(2) employment	(3) employment
electricity price	-0.0598***	-0.0337***	-0.00971
	(0.00637)	(0.00740)	(0.00714)
electricity price × Herfindahl-index	-0.240***	-0.454***	-0.508***
	(0.0508)	(0.0847)	(0.0820)
wage		-0.0641***	-0.105***
		(0.000701)	(0.000702)
tangible fixed assets			0.0612***
			(0.000286)
Herfindahl-index	-0.535***	-1.075***	-1.208***
	(0.124)	(0.213)	(0.206)
Firm FE	yes	yes	yes
Country × year FE	yes	yes	yes
Sector × year FE	yes	yes	yes
N	1062182	836134	834172

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: OLS panel regression estimating Equation (1) where the price of electricity is interacted with the Herfindahl-index. The Herfindahl-index measures the level of competition within a sector. We calculated the index based on the employment share of an individual firm vs. the total employment for each NACE 2-digit sector, country, year combination. The elasticity of employment in function of the price of elasticity increases (becomes more negative) if the Herfindahl-index increases (i.e. when the level of competition decreases).

Figure 9: Relative evolution of *gas prices* for industrial users



Note: Relative evolution of gas prices (excl. VAT and other recoverable taxes and levies) for industrial users with a yearly consumption between 100,000 GJ and 1,000,000 GJ. The evolution of gas prices shows similar trends across countries.
Source: Eurostat

3.5.3 High energy intensity and the use of gas

In the previous paragraphs (see Figure 4 with sector specific elasticities of employment) we have not consistently found lower (less negative) elasticities for sectors with high energy intensity.[32] Especially for the textiles, minerals and basic metals industries we found close to zero or even positive elasticities. This is counter-intuitive as these heavy users should be impacted the hardest when electricity prices increase. Next to the fact that these industries are very competitive, another possible explanation is that large electricity users can easily switch to gas to generate electricity in situ or to generate steam used in the production process. While electricity prices were on the rise over the period 2008-2017, gas prices have come down in the countries we study (Figure 9). This offers on incentive to substitute electricity by gas.

We analyze the impact of gas prices on employment in the sectors with highest electricity intensity, i.e. textiles (NACE 13), paper (NACE 17), coke and refined petroleum (NACE 19), chemicals (NACE 20), rubber and plastics (NACE 22), minerals (NACE 23) and basic metals (NACE 24). As we do not have the necessary data to construct firm-level gas prices, we base

[32] We regard textiles (NACE 13), paper (NACE 17), coke and refined petroleum (NACE 19), chemicals (NACE 20), rubber and plastics (NACE 22), minerals (NACE 23) and basic metals (NACE 24) as high energy intensity sectors. See e.g. OECD (2020) for sector level energy intensity for the French manufacturing sector.

ourselves on Eurostat (2020b) and use yearly, country specific gas prices.[33]

We use a similar model as Equation 1 where the firm-level electricity price is replaced by the country-level gas price. Note that since the gas price is country-year specific, we cannot include country-year fixed effects.

Table 11 in Appendix C gives the results of the econometric estimates. These indicate that the elasticity of employment as a function of gas prices is around -0.1. This is higher (more negative) than the elasticity we found for the electricity price. For the analysis of the gas price, we only include, however, the sectors that have the highest energy intensity. Firms in other sectors are not very likely to make the investment for in situ electricity production. The different elasticities for the different sectors are represented in Figure 10.

3.5.4 Firm-level electricity prices

We extrapolated the prices for the very high electricity consumption bands based on Deloitte (2018), which does not report on prices for the UK and Italy, nor for the period before 2013. Furthermore, we have allocated an electricity consumption band to each firm based on its amount of tangible fixed assets vs. other firms in the same industry.

We now change how we construct firm-level electricity prices based on the user profile of Appendix B. We assume that the electricity price for the consumption bands above band F (150,000 MWh) are the same as the price for band F. Band F is the highest consumption band for which Eurostat reports accurate data for all countries.

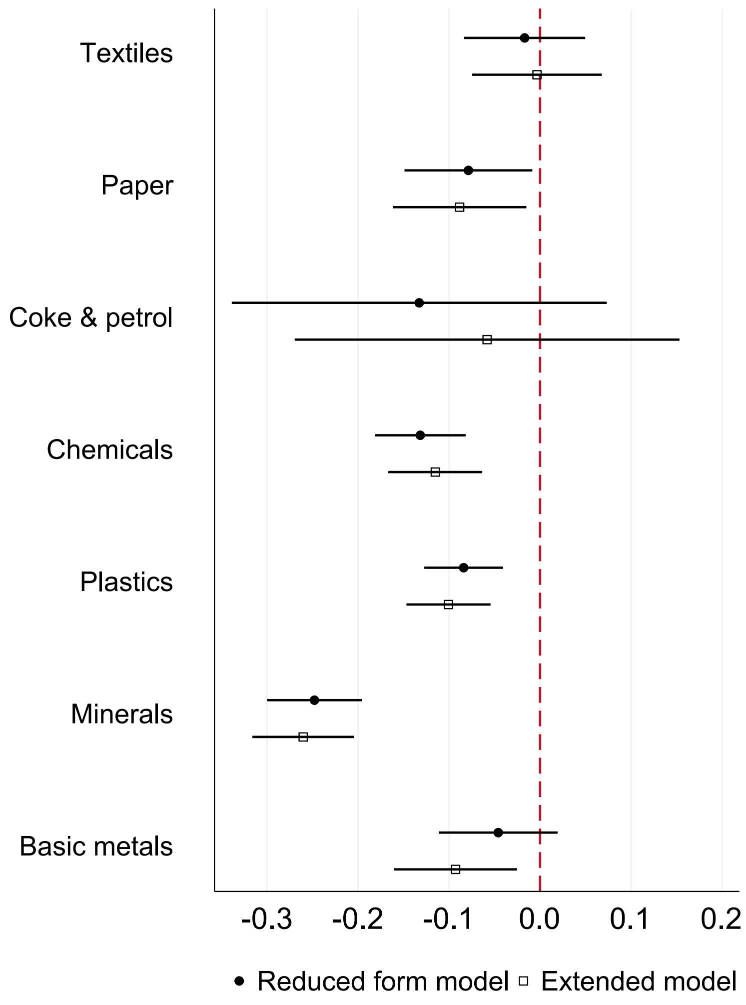
Table 12 in Appendix C shows the same regressions as Table 2, but with the electricity price calculated as described above. We find an elasticity estimate that is slightly higher (more negative) than the elasticity we found initially.

3.5.5 Serial correlation and clustering

Table 13 in Appendix C shows the same regressions as Table 2, but now standard errors are clustered at the frim-level. Clustering deals with concerns of serial correlation of the error term in panel time series (Bertrand et al. 2004). It is not illogical to assume that when Equation 1 e.g., underestimates employment for a certain firm in a certain year, it will make a similar

[33] We take the average of the 5 consumption bands that are well reported: consumption below 1,000 GJ, consumption between 1,000 GJ and 10,000 GJ, consumption between 10,000 GJ and 100,000 GJ, consumption between 100,000 GJ and 1,000,000 GJ and consumption 1,000,000 GJ and 4,000,000 GJ.

Figure 10: Sector specific *gas price* elasticities of employment



Note: Graphical representation for sector-level elasticity of employment as a function of the price for gas. The horizontal lines around the point estimate represent the 95% confidence interval.

underestimation for all subsequent years. While the confidence levels of the estimates reduce after clustering, we still find a negative and significant elasticity.

3.5.6 The impact of small firms

We also perform a weighted regression in Table 14. We weigh each firm by the square root of employment. A traditional regression does not distinguish between small and large firms. Potentially our initial results could be predominantly driven by small firms that have a relative unimportant share in aggregate employment. We take the square root as the absolute number would simply mean only the very large firms are taken into account as firm size shows large differences. The results remain comparable.

4 Policy discussion

In the previous section we have shown that rising electricity prices lead to a loss of employment in manufacturing industries, especially in that part of manufacturing that is most reliant on electrical energy. IMF (2019) estimates that an ambitious climate change scenario (i.e. keeping global warming at 2 °C) requires a carbon tax of $75 a ton CO_2.

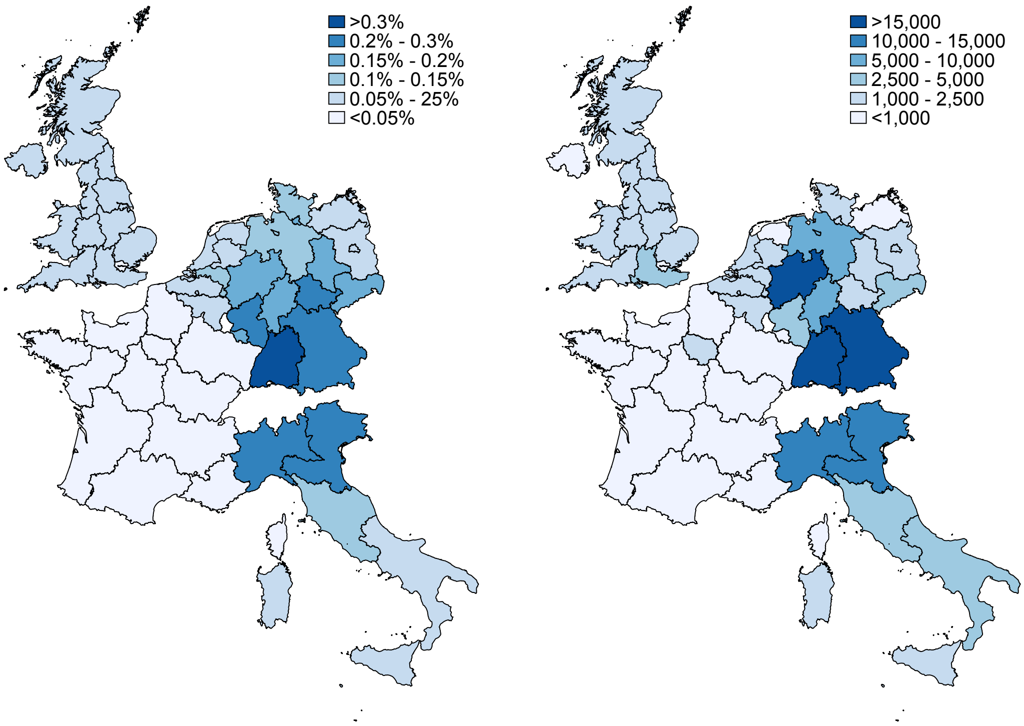
Under such a scenario, the IMF also estimate energy prices will rise considerably. Coal prices could typically rise by more than 200 percent as coal has a high carbon content. They expect electricity prices[34] to rise more modestly. Furthermore, the increase will vary across countries depending on the emission intensity of generation. With a $75 a ton CO_2 carbon tax, the IMF expects electricity prices to rise with 2% in France, 18% in Germany, 18% in Italy and 16% in the UK.[35] France will experience the lowest rise as a large part of its power generation is nuclear based.

Figure 11 shows the negative employment impact from the scenario with a $75 a ton CO_2 carbon tax and its country specific impact on electricity prices. We again focus on employment in electricity sensitive sectors and use the sector-level elasticities from the reduced form model as shown in Figure 4. We combine the IMF (2019) estimates on the electricity price increase, the sector-level elasticities and the regional employment numbers in these sectors. We subsequently

[34] IMF (2019) discusses the impact of a carbon tax on retail electricity prices. We assume the impact on industrial electricity prices to be similar. Since the underlying commodity price represents a higher share of the industrial price, this is likely to be a lower bound for the impact.

[35] IMF (2019) does not give an estimate for Belgium and The Netherlands. For our analysis, we assume the average of the 4 reported countries, i.e. 14%.

Figure 11: Negative employment impact on the manufacturing industry from rising electricity prices associated with a $75 a ton CO_2 tax



(a) Affected jobs as percentage of total employment

(b) Affected jobs in absolute numbers

Note: Geographical areas defined based on NUTS1 code. Employment figures for 2016. The total amount of affected jobs amounts to approx. 150,000.

estimate the potential job losses in these electricity sensitive sectors associated with a \$75 carbon tax. We only study the employment impact stemming from rising electricity prices. Via this method, we estimate the total number of affected jobs in the studied countries at approx. ~150,000.[36] These jobs are either lost or need to be reallocated to other more electricity efficient firms, industries and/or regions.[37]

This number, however, is again unevenly spread over different regions (Figure 11) with Germany (~80,000 affected jobs) and Italy (~35,000 affected jobs) experiencing the highest impact. Figure 11a shows the relative number of affected jobs as a percentage of the total workforce. We again see substantial regional variation. As expected, there is little impact on France as electricity prices are not expected to rise substantially. The highest impact can be found in Southern Germany and Northern Italy. Figure 11b shows the absolute number of affected jobs. Again the burden is highest for Southern Germany and Northern Italy and the German region of Nordrhein-Westfalen.

Should one worry about the 150,000 possible job losses in certain parts of the manufacturing industry in certain regions? Over the past decades, millions of manufacturing jobs have disappeared whilst unemployment rates did not rise.[38] Whilst the employment impact clearly seems manageable, there is, however, no need for complacency:

- The recent COVID-19 pandemic led to an unprecedented decline of economic activity and CO_2 emissions with 2020 emissions 4% to 7% lower than previously expected.[39] Yet, to keep global warming at the 1.5 °C or 2 °C temperature targets of the Paris Agreement, UN (2019) estimates that an emission reduction of respectively 7.6% and 2.7% is needed each year between 2020 and 2030. A \$75 carbon tax, used for our estimations and only roughly double the current price,[40] might well be a lower bound for the carbon tax needed

[36] One could argue that the firm-level elasticities we calculate do not hold anymore if all firms experience the same price shock from e.g., a carbon tax. Here it is important to note that the electricity price impact from a carbon tax will be highly heterogeneous between countries and firms differ substantially in electricity efficiency. Furthermore, in the short term the question remains to what extent non-EU countries will also adopt a carbon tax. In the past "carbon off-shoring" has been limited, but EU ETS carbon prices have also not been very binding yet.

[37] Note that even if the jobs created in green parts of the economy outweigh the jobs lost in energy intensive manufacturing, this will still require a potentially painful reallocation process as these jobs are unlikely located in the same area nor for the same skill-set.

[38] According to Eurostat's Labor Force Survey overall employment in the manufacturing industry in Belgium, France, Germany, Italy, Netherlands and UK declined from 27.5M (1992) to 22M (2008).

[39] Speech by Isabel Schnabel, Member of the Executive Board of the ECB, at a virtual roundtable on "Sustainable Crisis Responses in Europe" organized by the INSPIRE research network, 17 July 2020.

[40] The EU ETS price stands around €30/ton CO_2 (September 2020) despite the sharp contraction in energy consumption during the COVID-19 crisis. Bayer and Aklin (2020) estimate that the ETS system reduced CO_2

to trigger such a fundamental economic shift. A higher tax could well lead to substantially higher electricity prices and hence job losses.[41]

- Job losses in the manufacturing industry have historically been compensated by newly created jobs in services industries, albeit not necessarily in the same region nor for the same skill-sets. Goos and Manning (2007) have shown, however, that in the UK there was growth in employment for the highest-skilled and lowest-skilled services with declining employment in the middle of the distribution. This is the so called job polarization where we end up with only "lovely" and "lousy" jobs (Goos and Manning 2007). Clearly not all workers that shift from manufacturing to services will be better off.[42]

- The local job losses could well reach beyond the manufacturing industry. Well paid manufacturing jobs indirectly also create a higher demand for local non-tradable services in the immediate vicinity. Moretti (2010) estimates that 1 manufacturing job in a given city, creates 1 to 2.5 jobs in non-tradable sectors in the same city. As the number of workers and the equilibrium wage increase in a city, the demand for local goods and services increases. Goos et al. (2018) even estimate this effect to be as large as 5 for high-tech jobs.

These factors contribute to the fact that the impact from rising electricity and more broadly energy prices could well be similar to the "China syndrome". This refers to the insight from Autor et al. (2013) who show that different U.S. regions were exposed differently to Chinese import competition and "rising exposure increased unemployment, lowered labor force participation, and reduced wages in local labor markets." Exposure to Chinese competition affected not only local manufacturing employment but also numerous other factors. In Autor et al. (2014) they add "earnings losses are larger for individuals with low initial wages, low initial tenure, and low attachment to the labor force." Pressure on China exposed industries and regions led to the fact that a part of the labor force was worse off than before, even many years after the shock occurred. Possibly, drastically rising electricity prices -driven by increased (or properly

emission with 3.8% between 2008 and 2016, i.e. a reduction far below the levels needed for the Paris agreement targets. It has to be noted, though, that during 2012-2016 the ETS price was €5 - €10/ton CO_2.

[41]E.g., in a recent study, EnergyVille, a cooperation between Belgian universities, concluded that the Belgian wholesale electricity price would double in real terms by 2030 driven by an increased carbon price and investment in clean energy generation.

[42]E.g., Bijnens and Konings (2017) argue that in Belgium higher paying manufacturing jobs were predominantly replaced by lower paying services jobs. In absolute numbers, the so called less knowledge intensive services showed an increase in employment of 3-to-1 compared to the increase in employment of the knowledge intensive services during 1997-2013.

allocated) environmental costs- will create a similar result in the regions that are most affected. There clearly will be a need for targeted assistance to firms, workers, and disproportionately affected communities.

5 Concluding remarks

Increasing the share of renewables in the electricity generation mix is an important lever to reduce global warming and air pollution. This will require continued and large investment in clean electricity generation capacity. The costs associated with these investments are generally borne by the end user and result in a higher electricity price. These investments could go hand in hand with a carbon tax. A meaningful carbon tax could increase electricity prices with 20% depending on the carbon emission intensity of the electricity generation mix.

In this paper we have shown that such an increased price of electricity will lead to a reduced level of employment within manufacturing firms. We estimate the elasticity of employment with respect to the price of electricity and find values up to -0.2, depending on the industry. This implies a 10% increase of the electricity price can lead to a 2% reduction of firm-level employment in the hardest hit industries. These jobs are either lost or need to be reallocated to other firms, industries and/or regions. To come to this conclusion we analyze over 200,000 firms representing ~14 million employees in 5 countries over the period 2008-2017.

Manufacturing that is most reliant on electricity as an input factor is not evenly spread across countries nor regions. Therefore, the impact of rising electricity prices will also be unevenly spread. Especially Southern Germany and Northern Italy could experience significant job losses if electricity prices meaningfully rise. If the impact of past trade shocks serves as an example, the impact of rising electricity prices could have long lasting distributional consequences (similar to Autor et al. 2013). Although the overall benefits of environment related taxes are clear, some workers (especially manual workers, Marin and Vona 2019) in some regions could end up worse off even years after the price rise occurred. The labor market effects will be most negative countries and regions where labor mobility is insufficient.

To mitigate these heterogeneous effects and ensure a positive public sentiment towards environment related price increases there is hence clearly a role for fiscal policy makers. In this paper we also show there is a role for monetary policy makers to cushion the negative employment effect from rising electricity prices. We find that financially constrained firms react more to rising electricity prices. Doubling the debt level of a firm increases (makes more negative) the elasticity $\sim$1.5 percentage points. The credit channel of monetary policy could therefore have a smoothing effect to absorb shocks from rising electricity prices.

References

Amiti, M., Itskhoki, O., & Konings, J. (2019). International shocks, variable markups, and domestic prices. The Review of Economic Studies, 86(6), 2356-2402.

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. The Review of Economic Studies, 58(2), 277-297.

Autor, D. H., Dorn, D., & Hanson, G. H. (2013). The China Syndrome: Local Labor Market Effects of Import Competition in the United States. American Economic Review, 103(6), 2121-2168. doi: 10.1257/aer.103.6.2121

Autor, D. H., Dorn, D., Hanson, G. H., & Song, J. (2014). Trade adjustment: Worker-level evidence. The Quarterly Journal of Economics, 129(4), 1799-1860.

Batten, S., Sowerbutts, R., & Tanaka, M. (2020). Climate change: Macroeconomic impact and implications for monetary policy. In Ecological, Societal, and Technological Risks and the Financial Sector (pp. 13-38). Palgrave Macmillan, Cham.

Bernanke, B. S., & Gertler, M. (1995). Inside the black box: the credit channel of monetary policy transmission. Journal of Economic perspectives, 9(4), 27-48.

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates? The Quarterly Journal of Economics, 119(1), 249-275.

Bijnens, G., & Konings, J. (2017). An Enterprise Map of Belgium. KU Leuven - VIVES Policy Paper.

Bijnens, G., Konings, J., & Vanormelingen, S. (2018). The impact of electricity prices on jobs and investment in the Belgian manufacturing industry. KU Leuven - VIVES Policy Paper.

Cherchye, L., De Rock, B., Ferrando, A., Mulier, K., & Verschelde, M. (2020). Identifying Financial Constraints. ECB Working Paper 2420.

Cloyne, J., Ferreira, C., Froemel, M., & Surico, P. (2018). Monetary policy, corporate finance and investment (No. w25366). National Bureau of Economic Research.

Colmer, J., Martin, R., Muûls, M., & Wagner, U. J. (2020). Does pricing carbon mitigate climate change? Firm-level evidence from the European Union emissions trading scheme. Centre for Economic Performance Discussion Paper No. 1728.

Cox, M., Peichl, A., Pestel, N., & Siegloch, S. (2014). Labor demand effects of rising electricity prices: Evidence for Germany. Energy Policy, 75, 266-277.

Dechezleprêtre, A., Lovo, S., Martin, R., & Sato, M. (2017). Does climate change pose a risk to competitiveness? Global firm-level evidence. Working paper, London School of Economics and Imperial College London.

Dechezleprêtre, A., & Sato, M. (2017). The impacts of environmental regulations on competitiveness. Review of Environmental Economics and Policy, 11(2), 183-206.

De Jonghe, O., Mulier, K., & Schepens, G. (2020). Going Green by Putting a Price on Pollution: Firmlevel Evidence from the EU. National Bank of Belgium Working Paper No. 390.

Deloitte (2018). Benchmarking study of electricity prices between Belgium and neighboring countries.

Deschênes, O. (2012). Climate Policy and Labor Markets. In D. Fullerton & C. Wolfram (Eds.), The Design and Implementation of U.S. Climate Policy. Chicago: University of Chicago Press.

Dussaux, D. (2020). The joint effects of energy prices and carbon taxes on environmental and economic performance: Evidence from the French sector. OECD Environment Working Papers No. 154.

Eurostat (2020a). Electricity price statistics.

Eurostat (2020b). Natural gas price statistics.

Fabra, N., & Reguant, M. (2014). Pass-through of emissions costs in electricity markets. American Economic Review, 104(9), 2872-99.

Fazzari, S., Hubbard, R. G., & Petersen, B. C. (1987). Financing constraints and corporate investment (No. w2387). National Bureau of Economic Research.

De Haas, R., & Popov, A. A. (2019). Finance and carbon emissions. European Cental Bank Working Paper 2318.

Durante, E., Ferrando, A., & Vermeulen, P. (2020). Monetary policy, investment and firm heterogeneity. European Cental Bank Working Paper 2390.

Green, T. W., & Knittel, C. R. (2020). Distributed Effects of Climate Policy: A Machine Learning Approach. MIT Center for Energy and Environmental Policy Research Working Paper.

Goos, M., & Manning, A. (2007). Lousy and lovely jobs: The rising polarization of work in Britain. The review of economics and statistics, 89(1), 118-133.

Goos, M., Konings, J., & Vandeweyer, M. (2018). Local high-tech job multipliers in Europe. Industrial and Corporate Change, 27(4), 639-655.

Hamermesh, D. S. (1993). Labor demand. Princeton University Press.

Hafstead, M. A., & Williams III, R. C. (2018). Unemployment and environmental regulation in general equilibrium. Journal of Public Economics, 160, 50-65.

Henriksson, E., Söderholm, P., & Wårell, L. (2012). Industrial electricity demand and energy efficiency policy: The role of price changes and private R&D in the Swedish pulp and paper industry. Energy Policy, 47, 437-446.

Hille, E., & Möbius, P. (2019). Do energy prices affect employment? Decomposed international evidence. Journal of Environmental Economics and Management, 96, 1-21.

Hintermann, B. (2016). Pass-through of CO2 emission costs to hourly electricity prices in Germany. Journal of the Association of Environmental and Resource Economists, 3(4), 857-891.

Hutchinson, J., & Xavier, A. (2006). Comparing the impact of credit constraints on the growth of SMEs in a transition country with an established market economy. Small business economics, 27(2-3), 169-179.

IMF (2019). Fiscal Monitor: How to Mitigate Climate Change. International Monetary Fund. Washington.

Kahn, M. E., & Mansur, E. T. (2013). Do local energy prices and regulation affect the geographic concentration of employment? Journal of Public Economics, 101, 105-114.

Kreuz, S., & Müsgens, Fs. (2017). The German Energiewende and its roll-out of renewable energies: An economic perspective. Frontiers in Energy, 11(2), 126-134.

Lichter, A., Peichl, A., & Siegloch, S. (2015). The own-wage elasticity of labor demand: A meta-regression analysis. European Economic Review, 80, 94-119.

Lise, W., Sijm, J., & Hobbs, B. F. (2010). The impact of the EU ETS on prices, profits and emissions in the power sector: simulation results with the COMPETES EU20 model. Environmental and Resource Economics, 47(1), 23-44.

Marin, G., & Vona, F. (2017). The impact of energy prices on employment and environmental performance: Evidence from french manufacturing establishments. Technical Report, Observatoire Francais des Conjonctures Economiques (OFCE).

Marin, G., & Vona, F. (2019). Climate policies and skill-biased employment dynamics: Evidence from EU countries. Journal of Environmental Economics and Management, 98, 102253.

McGuire, M. C. (1982). Regulation, factor rewards, and international trade. Journal of public economics, 17(3), 335-354.

Metcalf, G. E., & Stock, J. H. (2020). Measuring the Macroeconomic Impact of Carbon Taxes. In AEA Papers and Proceedings (Vol. 110, pp. 101-06).

Moretti, E. (2010). Local multipliers. American Economic Review, 100(2), 373-77.

Nickell, S. J. (1986): "Dynamic Models of Labor Demand," in Handbook of Labor Economics, Vol(1), ed. by O. Ashenfelter, and D. Card, pp. 473–523, Amsterdam, NL. Elsevier North-Holland.

Porter, M. E., & Van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. Journal of economic perspectives, 9(4), 97-118.

Saussay, A., & Sato, M. (2018). The impacts of energy prices on industrial foreign investment location: Evidence from global firm level data. Centre for Climate Change Economics and Policy Working Paper 344.

Smith, S. (2017). Just transition: A report for the OECD. Just Transition Centre.

Stiglitz, J. E., Stern, N., Duan, M., Edenhofer, O., Giraud, G., Heal, G. M., ... & Shukla, P. R.

(2017). Report of the high-level commission on carbon prices.

UN (2019). United Nations Environment Programme. Emissions Gap Report 2019. UNEP, Nairobi.

Weche, J. P. (2018). Does green corporate investment crowd out other business investment?. Industrial and Corporate Change, 28(5), 1279–1295, https://doi.org/10.1093/icc/dty056

A Definition of electricity consumption bands

Band	***Yearly consumption range (in Mega Watt Hour, MWh)***
A	Below 20
B	20 – 500
C	500 – 2000
D	2,000 – 20,000
E	20,000 – 70,000
F	70,000 – 150,000
G	150,000 – 250,000
H	250,000 – 350,000
I	350,000 – 450,000
J	450,000 – 550,000
K	550,000 – 650,000
L	650,000 – 750,000
M	750,000 – 850,000
N	850,000 – 950,000
O	Above 950,000

B Sectoral Electricity consumption profile (% of electricity consumption in certain band)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
10 Food		3%	6%	32%	35%	13%	9%	2%							
11 Beverages		1%	3%	28%	51%	16%									
12 Tobacco		7%	25%	68%											
13 Textiles		3%	8%	46%	15%	12%	15%								
14 Wearing Apparel	6%	49%	20%	25%											
15 Leather	1%	6%	2%	90%											
16 Wood		4%	5%	15%	13%	28%	35%								
17 Paper		1%	2%	11%	19%	31%	10%	6%		10%	11%				
18 Printing	1%	15%	17%	46%	21%										
19 Coke and petrol				1%	6%									30%	63%
20 Chemicals				5%	11%	11%	15%	8%	7%	1%		6%		4%	31%
21 Pharma			1%	10%	22%	2%	32%	33%							
22 Rubber and plastic		2%	6%	55%	35%	2%									
23 Minerals		1%	2%	13%	22%	28%	30%	3%							
24 Basic metals				3%	2%	4%	10%	5%	3%	7%	4%	7%	4%	9%	41%
25 Metals	1%	22%	24%	47%	6%										
26 Computer		5%	8%	51%	37%										
27 Electrical equip.		5%	7%	46%	43%										
28 Machinery		6%	8%	21%	34%	23%	7%								
29 Motor vehicles		1%	2%	18%	30%	30%	19%								
30 Other transport		3%	2%	37%	58%										
31 Furniture	1%	25%	30%	43%											
32 Other	3%	18%	11%	29%	39%										
33 Repair and installation	1%	18%	18%	35%	27%										

C Detailed regression results

Table 7: Impact on employment
Country and sector specific elasticities

	(1) employment	(2) employment	(3) employment	(4) employment
wage		-0.105*** (0.000702)		-0.105*** (0.000702)
tangible fixed assets		0.0612*** (0.000286)		0.0612*** (0.000286)
electricity price × Belgium	-0.183*** (0.0255)	-0.139*** (0.0253)		
electricity price × Germany	-0.129*** (0.0116)	-0.0501* (0.0209)		
electricity price × France	-0.126*** (0.0131)	-0.0748*** (0.0132)		
electricity price × Italy	-0.0206** (0.00783)	0.00610 (0.00798)		
electricity price × Netherlands	-0.0703** (0.0267)	0.00262 (0.0787)		
electricity price × UK	0.0746+ (0.0387)	0.0468 (0.0387)		
electricity price × Food			-0.0453*** (0.0114)	-0.00133 (0.0122)
electricity price × Beverages			-0.115*** (0.0332)	-0.0642+ (0.0344)
electricity price × Tobacco			-0.291* (0.139)	-0.486** (0.153)
electricity price × Textiles			0.0529** (0.0189)	0.106*** (0.0199)
electricity price × Wearing apparel			-0.0227 (0.0307)	0.0540 (0.0341)
electricity price × Leather			0.0888+ (0.0479)	0.0889 (0.0547)
electricity price × Wood			0.0980*** (0.0202)	0.158*** (0.0234)
electricity price × Paper			-0.129*** (0.0206)	-0.0959*** (0.0216)
electricity price × Printing			-0.0137 (0.0196)	0.0499* (0.0247)
electricity price × Coke & petrol			-0.121* (0.0614)	-0.0473 (0.0641)
electricity price × Chemicals			-0.157*** (0.0160)	-0.119*** (0.0168)
electricity price × Pharma			-0.167*** (0.0289)	-0.108*** (0.0296)
electricity price × Plastics			-0.0588*** (0.0168)	0.0186 (0.0197)
electricity price × Minerals			0.0587*** (0.0172)	0.0921*** (0.0187)
electricity price × Basic metals			-0.0339 (0.0219)	-0.0198 (0.0229)
electricity price × Metals			-0.0690*** (0.0105)	-0.0342** (0.0131)
electricity price × Computer			-0.240*** (0.0194)	-0.168*** (0.0233)
electricity price × Elec. equip.			-0.0456* (0.0208)	0.0157 (0.0243)
electricity price × Machinery			-0.139*** (0.0108)	-0.0950*** (0.0122)
electricity price × Motor vehicles			0.0581** (0.0218)	0.110*** (0.0237)
electricity price × Other transport			-0.0471 (0.0317)	-0.0579 (0.0402)
electricity price × Furniture			0.00864 (0.0227)	0.137*** (0.0290)
electricity price × Other			-0.0873*** (0.0183)	-0.0361 (0.0222)
electricity price × Repair & instal.			-0.183*** (0.0193)	-0.185*** (0.0249)
Firm FE	yes	yes	yes	yes
Country × year FE	yes	yes	yes	yes
Sector × year FE	yes	yes	yes	yes
N	1062182	834172	1062182	834172
r2	0.0274	0.102	0.0278	0.103

Standard errors in parentheses
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: Impact on employment
Link with financial constraints

	(1) employment	(2) employment	(3) employment	(4) employment	(5) employment	(6) employment	(7) employment	(8) employment
electricity price	-0.0663***	-0.0212**	-0.0448***	-0.00475	-0.0673***	-0.0335***	-0.0658***	-0.0266***
	(0.00633)	(0.00706)	(0.00635)	(0.00699)	(0.00783)	(0.00745)	(0.00845)	(0.00808)
wage		-0.105***		-0.143***		-0.146***		-0.135***
		(0.000701)		(0.000787)		(0.000828)		(0.000877)
tangible fixed assets		0.0612***		0.0659***		0.0677***		0.0643***
		(0.000286)		(0.000312)		(0.000327)		(0.000348)
young=1 × electricity price	-0.0214***	-0.0116**						
	(0.00364)	(0.00382)						
electricity price × gearing			-0.0144***	-0.00807***				
			(0.00113)	(0.00123)				
electricity price × interest cover					0.00798***	0.00726***		
					(0.000509)	(0.000484)		
electricity price × ROE							0.00373***	0.00778***
							(0.00108)	(0.00104)
young=1	-0.0952***	-0.0752***						
	(0.00844)	(0.00885)						
gearing			-0.0332***	-0.0192***				
			(0.00266)	(0.00290)				
interest cover					0.0229***	0.0218***		
					(0.00120)	(0.00114)		
ROE							0.0119***	0.0261***
							(0.00252)	(0.00241)
Firm FE	yes	yes	yes	yes	yes	yes	yes	yes
Country × year FE	yes	yes	yes	yes	yes	yes	yes	yes
Sector × year FE	yes	yes	yes	yes	yes	yes	yes	yes
N	1062182	834172	993549	790792	758607	756266	646651	641734

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: Impact on investment
Country and sector specific elasticities

	(1) investment$_t$	(2) investment$_t$	(3) investment$_t$	(4) investment$_t$
L.wage$_{t-1}$		-0.301*** (0.0123)		-0.301*** (0.0123)
L.tangible fixed assets$_{t-1}$		-0.467*** (0.00530)		-0.467*** (0.00530)
L.electricity price$_{t-1}$ × Belgium	-1.842*** (0.385)	-1.826*** (0.374)		
L.electricity price$_{t-1}$ × Germany	-0.972** (0.347)	-1.039** (0.362)		
L.electricity price$_{t-1}$ × France	-0.858*** (0.126)	-0.810*** (0.200)		
L.electricity price$_{t-1}$ × Italy	-0.251* (0.106)	-0.141 (0.117)		
L.electricity price$_{t-1}$ × Netherlands	0.184 (1.607)	-0.690 (1.680)		
L.electricity price$_{t-1}$ × UK	0.0512 (0.552)	-0.0470 (0.540)		
L.electricity price$_{t-1}$ × Food			-1.017*** (0.156)	-0.537** (0.182)
L.electricity price$_{t-1}$ × Beverages			-1.000* (0.470)	-0.943^{+} (0.522)
L.electricity price$_{t-1}$ × Tobacco			-1.089 (2.294)	-3.296 (2.292)
L.electricity price$_{t-1}$ × Textiles			-0.403 (0.248)	-0.223 (0.286)
L.electricity price$_{t-1}$ × Wearing apparel			-0.656 (0.436)	-0.979^{+} (0.513)
L.electricity price$_{t-1}$ × Leather			-0.583 (0.645)	-0.0423 (0.798)
L.electricity price$_{t-1}$ × Wood			-0.234 (0.298)	0.183 (0.345)
L.electricity price$_{t-1}$ × Paper			-0.636* (0.306)	-0.717* (0.320)
L.electricity price$_{t-1}$ × Printing			-0.514^{+} (0.294)	-0.255 (0.362)
L.electricity price$_{t-1}$ × Coke & petrol			-0.154 (0.900)	0.256 (0.896)
L.electricity price$_{t-1}$ × Chemicals			-0.563* (0.232)	-0.457^{+} (0.238)
L.electricity price$_{t-1}$ × Pharma			-0.891* (0.419)	-0.940* (0.414)
L.electricity price$_{t-1}$ × Plastics			-0.804** (0.258)	-0.381 (0.291)
L.electricity price$_{t-1}$ × Minerals			0.935*** (0.250)	0.952*** (0.274)
L.electricity price$_{t-1}$ × Basic metals			-0.353 (0.316)	-0.182 (0.323)
L.electricity price$_{t-1}$ × Metals			-0.416** (0.160)	-0.564** (0.194)
L.electricity price$_{t-1}$ × Computer			-0.594^{+} (0.326)	-0.661^{+} (0.354)
L.electricity price$_{t-1}$ × Elec. equip.			-1.384*** (0.332)	-1.162** (0.365)
L.electricity price$_{t-1}$ × Machinery			-0.426* (0.167)	-0.331^{+} (0.182)
L.electricity price$_{t-1}$ × Motor vehicles			-0.688* (0.337)	-0.376 (0.350)
L.electricity price$_{t-1}$ × Other transport			0.895 (0.595)	1.016 (0.623)
L.electricity price$_{t-1}$ × Furniture			0.360 (0.355)	1.087* (0.429)
L.electricity price$_{t-1}$ × Other			-0.589^{+} (0.301)	-0.0570 (0.352)
L.electricity price$_{t-1}$ × Repair & instal.			-0.640* (0.277)	-0.726^{+} (0.380)
Firm FE	yes	yes	yes	yes
Country × year FE	yes	yes	yes	yes
Sector × year FE	yes	yes	yes	yes
N	944857	664441	944857	664441

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: Impact on investment
Link with financial constraints

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$investment_t$	$investment_t$	$investment_t$	$investment_t$	$investment_t$	$investment_t$	$investment_t$	$investment_t$
L.electricity $price_{t-1}$	-0.481^{***}	-0.322^{**}	-0.645^{***}	-0.362^{***}	-0.420^{***}	-0.232^{*}	-0.573^{***}	-0.321^{**}
	(0.0882)	(0.105)	(0.0893)	(0.106)	(0.0912)	(0.111)	(0.0990)	(0.119)
$L.wage_{t-1}$		-0.302^{***}		-0.343^{***}		-0.333^{***}		-0.385^{***}
		(0.0123)		(0.0127)		(0.0134)		(0.0147)
L.tangible fixed $assets_{t-1}$		-0.467^{***}		-0.493^{***}		-0.495^{***}		-0.497^{***}
		(0.00530)		(0.00551)		(0.00576)		(0.00610)
young=1 × L.electricity $price_{t-1}$	-0.128^{**}	-0.0872						
	(0.0469)	(0.0579)						
L.electricity $price_{t-1}$ × $L.gearing_{t-1}$			0.107^{***}	0.0105				
			(0.0162)	(0.0188)				
L.electricity $price_{t-1}$ × L.interest $cover_{t-1}$					-0.0204^{***}	0.00104		
					(0.00601)	(0.00709)		
L.electricity $price_{t-1}$ × $L.ROE_{t-1}$							-0.0293^{*}	-0.0121
							(0.0127)	(0.0149)
young=1	-0.300^{**}	-0.191						
	(0.113)	(0.135)						
$L.gearing_{t-1}$			0.0486	-0.140^{**}				
			(0.0390)	(0.0445)				
L.interest $cover_{t-1}$					0.0891^{***}	0.122^{***}		
					(0.0145)	(0.0167)		
$L.ROE_{t-1}$							0.0282	0.0591^{+}
							(0.0305)	(0.0348)
Firm FE	yes	yes	yes		yes	yes	yes	yes
Country × year FE	yes	yes	yes		yes	yes	yes	yes
Sector × year FE	yes	yes	yes		yes	yes	yes	yes
N	944857	664441	898959	639263	885773	609331	737827	515824

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11: Impact on employment from changes in gas price
OLS panel regression results estimating Equation 1 with electricity price replace by gas price

	(1) employment	(2) employment	(3) employment
gas price	-0.105***	-0.126***	-0.118***
	(0.0112)	(0.0127)	(0.0123)
wage		-0.0533***	-0.0982***
		(0.00143)	(0.00144)
tangible fixed assets			0.0662***
			(0.000609)
Firm FE	yes	yes	yes
Country × year FE	no	no	no
Sector × year FE	yes	yes	yes
N	229558	190146	189374

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: only firms from textiles (NACE 13), paper (NACE 17), coke and refined petroleum (NACE 19), chemicals (NACE 20), rubber and plastics (NACE 22), minerals (NACE 23) and basic metals (NACE 24) included.

Table 12: Impact on employment – robustness checks
Prices for electricity consumption bands F and above kept constant

	(1) employment	(2) employment	(3) employment
electricity price	-0.0853***	-0.0644***	-0.0467***
	(0.00711)	(0.00857)	(0.00828)
wage		-0.0642***	-0.105***
		(0.000702)	(0.000702)
tangible fixed assets			0.0612***
			(0.000286)
Firm FE	yes	yes	yes
Country × year FE	yes	yes	yes
Sector × year FE	yes	yes	yes
N	1062184	836135	834172

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13: Impact on employment – robustness checks
Standard errors clustered the firm level

	(1) employment	(2) employment	(3) employment
electricity price	-0.0631***	-0.0395***	-0.0162
	(0.00937)	(0.0109)	(0.0104)
wage		-0.0641***	-0.105***
		(0.00282)	(0.00301)
tangible fixed assets			0.0612***
			(0.00106)
Panel	yes	yes	yes
Country × year FE	yes	yes	yes
Sector × year FE	yes	yes	yes
N	1062182	836134	834172

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 14: Impact on employment – robustness checks
Weighted regression

	(1) employment	(2) employment	(3) employment
electricity price	-0.0460**	-0.0386*	-0.00918
	(0.0173)	(0.0184)	(0.0169)
wage		-0.0912***	-0.142***
		(0.00688)	(0.00739)
tangible fixed assets			0.0821***
			(0.00297)
Firm FE	yes	yes	yes
Country × year FE	yes	yes	yes
Sector × year FE	yes	yes	yes
N	1062182	836134	834172

Standard errors in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Acknowledgements

This paper should not be reported as representing the views of the European Central Bank (ECB) nor the National Bank of Belgium (NBB). The views expressed are those of the authors and do not necessarily reflect those of the ECB nor the NBB.

Gert Bijnens
National Bank of Belgium, Brussels, Belgium; KU Leuven, Leuven, Belgium; email: gert.bijnens@nbb.be

John Hutchinson
European Central Bank, Frankfurt am Main, Germany; email: john.hutchinson@ecb.europa.eu

Jozef Konings
KU Leuven, Leuven, Belgium; University of Liverpool Management School, Liverpool, United Kingdom;
Nazarbayev University Graduate School of Business, Astana, Kazakhstan; email: joep.konings@kuleuven.be

Arthur Saint Guilhem
European Central Bank, Frankfurt am Main, Germany; email: arthur.saint-guilhem@ecb.europa.eu

PDF ISBN 978-92-899-4537-0 ISSN 1725-2806 doi:10.2866/302949 QB-AR-21-028-EN-N