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The Many Channels of Firm’s Adjustment to Energy Shocks: Evidence from France

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The Many Channels of Firm's Adjustment to Energy Shocks: Evidence from France*

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Abstract

Based on firm level data in the French manufacturing sector, we find that firms adapt quickly, strongly and through multiple channels to energy shocks, even though electricity and gas bills represent a very small share of their total costs. Over the period 1996-2019, faced with an idiosyncratic energy price increase, firms reduce their energy demand, improve their energy efficiency, increase intermediate inputs imports and optimize energy use across plants. Firms are also able to pass-through the cost shock fully on their export prices. Their production, exports and employment fall. A consequence of these multiple adjustment mechanisms is that the fall in profits is either non-significant, small or concentrated on the most energy intensive firms. We also find that over time, the impact of electricity shocks has weakened, suggesting that only firms capable of adapting their production process to weather cost shocks have survived. We find some evidence that firms react less to large electricity and gas price shocks. These results shed light on the mechanisms of resilience of the European manufacturing sector in the context of the present energy crisis.

Key Words: Energy price, Employment, Electricity demand, Gas demand.
JEL Codes: .

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1 Introduction

"At the beginning of the conflict, when the risk of energy shortages became a serious threat, we analyzed our dependence on the price of gas and modified our production processes. We built propane tanks that could be filled by truck in case the gas ran out. It took a few months. Many companies did the same. They switched fuels or took energy efficiency measures, which lowered overall gas consumption." Karl Haeusgen CEO, HAWE Hydraulik (February,26 2023, Le Monde)

The concerns on the impact of the energy crisis following the post COVID reopening of the economy and the war in Ukraine on the European manufacturing sector have been strongly voiced by both politicians and industry lobby groups. This was especially the case in the spring of 2022 when a potential embargo on Russian gas and oil was discussed. BDI, Germany's main business lobby group, warned that cutting off Russian gas supplies to the EU would have "incalculable consequences" and cause "production disruptions, employment losses and, in some cases, massive damage to production facilities". The German chancellor said that "Hundreds of thousands of jobs would be at risk… Entire branches of industry are on the brink." Although a European embargo on Russian gas did not materialize, the fall of natural gas imports from Russia was still dramatic and quantitatively close to an embargo: compared to the same period in 2021, EU gas imports from Russia have been divided by more than 4 according to the data compiled by Bruegel. The increase in energy prices (gas and electricity) for European manufacturing firms was also very large. In France, for example, INSEE reports that between the end of 2020 and November 2022 gas and electricity prices for manufacturing firms almost tripled and doubled respectively.

In January 2023, the mood has changed as illustrated by the following quote by the German Ministry of Finance, Christian Lindner "The German industry and society are once again proving much more resilient and adaptable than certain people feared." Partial data for Germany and Belgium in the summer of 2022 show that the reduction in industrial gas demand induced by the price hikes was not associated with significant reductions in industrial production (McWilliams et al. 2023): from June to August 2022, industrial gas demand decreased by about 20 percent in both countries, with no significant reduction in industrial production, suggesting that the adjustment was not primarily through reductions in output, but through other channels of adjustment that can be loosely characterized as "substitution". An early and ex-ante analysis of the channels through which the European economy could adjust and adapt to an embargo was produced by **bachman˙2022** for Germany and by **bakaee˙2022** for Europe. Obviously, the crisis is not over and price spikes are only gradually phased in, so manufacturing firms has not felt their full force. Some companies are also protected by government subsidies or price caps. It remains that European manufacturing has been more resilient than some expected. This paper attempts to analyze some of the firm-level mechanisms behind this resilience of the manufacturing sector when faced with a large energy shock.

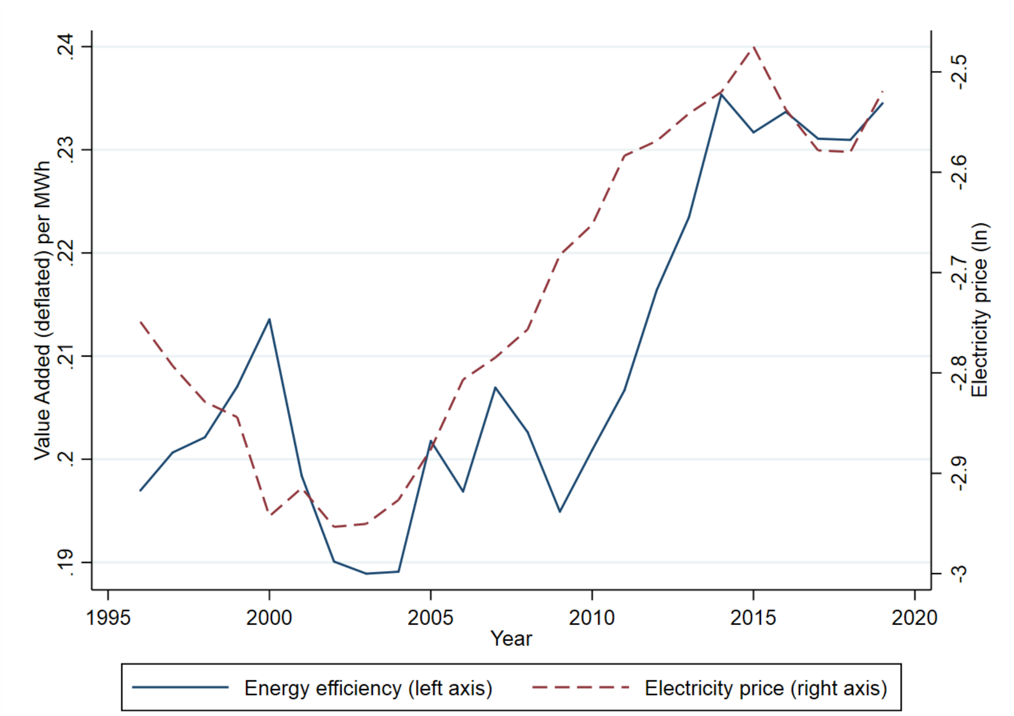
Whether and how European manufacturing firms can withstand energy shocks is important both in the short term and the long term. Sanctions against Russia and more generally geopolitical tensions may in the future generate more price hikes. The economic costs of these sanctions for the European economy not only matter *per se* but also because they will condition their political acceptability. The energy transition will also require higher CO2 intensive energy prices so that what we learn from this energy crisis may also have consequences for the climate crisis.

Figure 1 is suggestive at the aggregate level of one important mechanism that we want to document at the firm level. On the period 1995-2019, energy prices paid by firms and energy efficiency look strongly correlated[1].

Our main empirical result is that manufacturing firms adjust, strongly, quickly (in the year) and through multiple channels. Firms adjust to an energy price shock by reducing energy demand. Our preferred (and conservative) estimates of the demand elasticity at the firm level is around - 0.4

[1]For this figure, we use the sum of export-price deflated value added of firms. Since our sample only has exporter firms, we do not observe producer prices.

Figure 1: Energy efficiency and electricity price.



Source: EACEI and Ficus/Fare data. *Note*: The figure plots the average electricity price and energy efficiency of French firms in the period 1996-2019. The energy efficiency of firms is calculated as the ratio between the export-price deflated value added of firm (i.e. $VA_{i,t}/p_{i,t}^{exp}$) and the energy consumption.

for electricity and -0.9 for gas. For electricity, the elasticity is similar to some existing estimates. For gas, our estimated elasticity is high compared to some existing estimates. We also find that only a small share of the fall in energy demand comes from a fall in production. This may therefore explain the resilience of the manufacturing sector. Importantly, we find that the price elasticity of energy demand has fallen over time and that it is also lower for large price hikes. This suggests that in the present crisis, we should be more conservative and use smaller (in absolute value) but still non-zero energy price elasticities.

Manufacturing firms pass-through the full impact of energy costs shocks into their prices, which then reduces their competitiveness and generates a fall in demand for their products. The energy price shock indeed generates a sizable fall in production and employment, which is consistent with the size of the price increase. For example, a 10% electricity price increase translates at the firm level into a 1.6% and 1.5% fall in production and employment. Energy efficiency increases at the firm level. Profits fall but modestly or only for the most energy intensive firms. We interpret this result through our finding that firms are able to adjust and adapt strongly to the energy shock.

Another channel that we uncover (and that was discussed anecdotally in the press in the present crisis) is that on top of the channels already mentioned, multi-plant firms relocate energy demand (and presumably production) towards those with lower prices and increase imports of intermediate inputs (presumably those more intensive in energy).

A last and interesting finding is that manufacturing firms have grown more resilient to energy price shocks over time: the impact of these shocks on employment, production and profits have fallen over time. One interpretation is that firms have adapted their technology and production processes to higher energy prices and that a selection process has eliminated those not able to adjust.

Our paper is related to the large empirical literature estimating the elasticity of demand for energy (see Labandeira, Labeaga, and López-Otero 2017 for a survey). The subset of papers that estimates the elasticity of demand for electricity and gas by manufacturing firms is much smaller, but the estimates are not very different for households and industry: their average value is between 0.2 (short term) and 0.5 (long term) but with large differences across articles.

Our paper also speaks to the literature addressing the response of individual firms to energy or other (imported) inputs price shocks (Dussaux 2020, Ganapati, Shapiro, and Walker 2020, Csereklyei 2020, Marin and Vona 2021, Dedola, Kristoffersen, and Zullig 2021, Wolverton, Shadbegian, and Gray 2022, Joussier, J. Martin, and Mejean 2023, Alpino, Citino, and Frigo 2023). The closest paper to ours is Marin and Vona 2021 who use the same French firm level data to estimate the wage and employment impact of climate policies which they capture by large carbon emitting energy prices. Their focus is the impact on wages and employment but clearly, some of results are similar to theirs.

We explain in section 2 the characteristics and evolution of the French electricity and gas markets which are important for the validity of our identification strategy. Section 3 describes the firm level data and section 4 the identification strategy including fixed effects and the instrumental variables we use for energy prices. Section 5 estimates the elasticity of energy demand and analyzes how this elasticity depends on time and the size of the price shock. In sections 6 and 7, we estimate the pass-through of energy price shocks and their effects on competitiveness, production, energy efficiency and profits. Other channels of adjustment are analyzed in section 8. The estimates of the channels of adjustment to price shocks are discussed in the context of the present context in section 9. Finally, section 10 discusses some policy options both in the short and the long term.

2 The institutional context: past and present

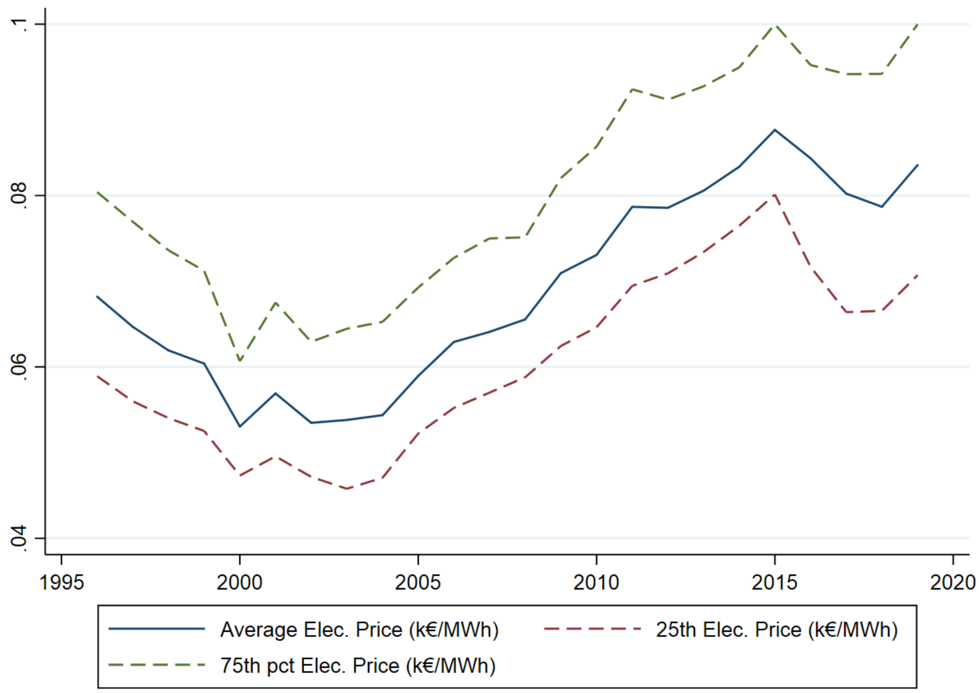
A characteristic of the French electricity market is that many contracts co-exist with both regulated and market driven prices. During the period we analyze, several regulatory changes have interacted with market movements. Regulated prices are offered only by EDF (the main historical operator) and unregulated prices are offered by all operators to all firms (Alterna, Direct Energie, EDF, Enercoop, GDF Suez, Poweo, and others). Firms can also have several contracts with several producers (for example multi-plant firms can have several contracts), and some firms may also produce their own electricity.

Another characteristic is that many firms had to renegotiate long-term contracts that ended during the period. These long term contracts allowed firms to have lower prices and their expiration means that firms may experience an increase or a decrease in price in different years depending on the year the contract was initially signed and its length. Importantly for us, there has also been many changes in regulations during the period 2001-2010. Under the pressure of the European Commission the market has been partially deregulated and opened with an increasing role of both imports and exports. Large firms were the first to be able to opt out from regulated prices in 2000 and this possibility was open progressively to all firms in the 2000s. However, in the same period many different electricity tariffs co-existed and were affected by several changes. For example, in 2006 there was a large increase in electricity prices for firms that had opted (in the preceding years) for contracts with deregulated market prices. The government decided in 2007 to allow those firms to go back to a transitory regulated tariff (TarTAM tariff) calculated on the basis of the regulated tariff plus a surcharge depending on the firm of 10%, 20% or 23%. Not all firms chose to do so as it depended on the difference between the firm specific previous contracted price and the (firm specific) TarTAM (transitory regulated tariff). This choice depended itself on the date the previous contract was signed. This possibility was then stopped in particular because it was deemed to be a sectoral subsidy by the European Commission,n and this meant another change in price for some but not all firms. There are also different regulated tariffs for firms. The Blue tariff (small electricity users) allowed a fixed price (for a year) with possibility to have lower prices during the night. Yellow and Green tariffs (intermediate and large electricity users) may also benefit from a fixed price with lower average prices during the year if they accept to pay higher prices possibly on a maximum 22 days in the year (very cold days in winter when household demand is high). Depending on the location of the firm in France these price increases may differ. In addition, some firms benefit from low prices because they are close to hydroelectric facilities. Finally, the electricity price also depends on several taxes especially the so-called TURPE (to pay for distribution and transport in particular) since 2000 which was created after the European Commission obliged France to separate the production and the distribution of electricity. The tax is itself quite complex, firm specific (in particular it is reduced if the firm has experienced a power outage of more than 6 hours in the year) and changes every year. It can constitute up to 40% of the final electricity cost. Another tax (CSPE to finance renewable costs) also varies every year. Finally, there are additional taxes at the city and department level that can vary both across locations and years.

Because of this complex institutional context, the dispersion of prices paid for electricity by the individual firms is a systematic empirical pattern at each date. This is illustrated in figure 2 where we plot the average price in our sample, as well as the price paid in the 25th and 75th percentiles of the distribution respectively.For instance in 2015 we observe a 20 percent difference in the price paid on average by these two subgroups of firms.

This description of the electricity market in France suggests that electricity prices vary at the firm level for reasons that are both endogenous to the firm activity (in particular its *average* electricity use, which is then captured by firm fixed effects in our empirical strategy) and more importantly exogenous to the firm activity (regulation changes, year and length of beginning of contract, tax changes both at the national and local levels, location, changes in both market and

Figure 2: Electricity price over time.



Source: EACEI data.

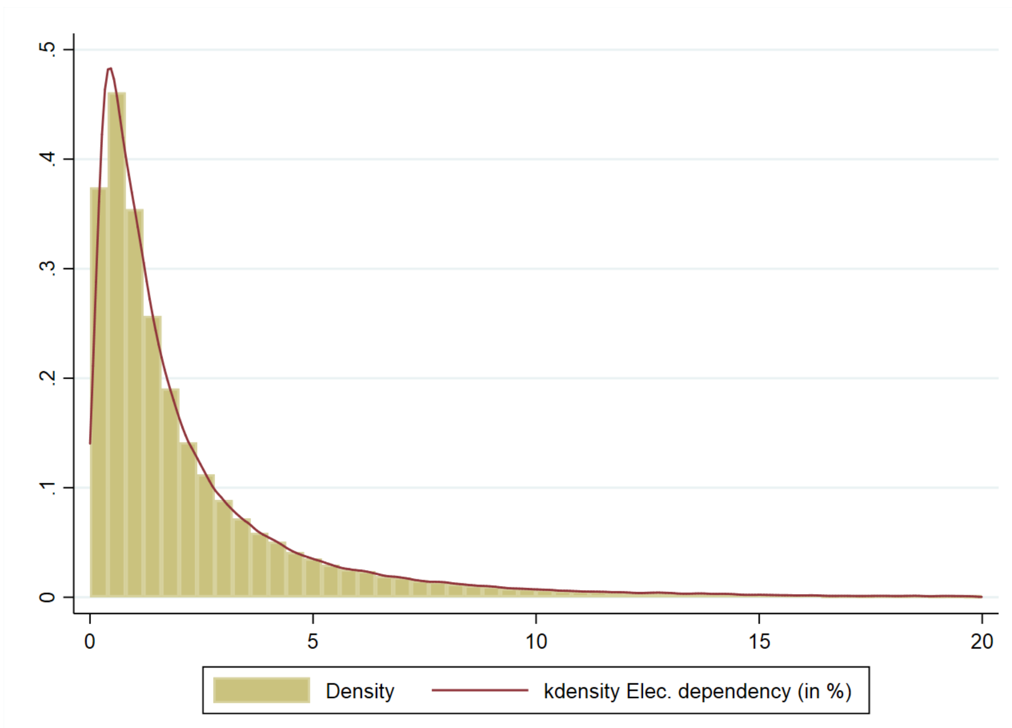
regulated tariffs, local weather). We take into account some of the impact of firm characteristics on electricity prices by including a firm fixed effect.

In the present context that serves as the main motivation of our paper, the diffusion of electricity and gas price shocks to firms is also affected by the prevalence of long-term, fixed-price contracts. INSEE 2022 reports that less than 20% of French manufacturing output is produced by firms whose electricity or gas contract is indexed on spot prices. Besides, 15of manufacturing output is produced by relatively small producers that are offered a fixed regulated electricity price. In between these extremes, 40% of manufacturing firms benefit from long-term electricity contracts and 60% from long-run gas contracts. Among these firms, 48%(resp. 36%) will have their electricity contract (resp. gas contract) renegotiated before the Wholesale prices for energy are one component of energy prices for industrial customers and only those who directly transact in wholesale markets and only for their unhedged energy purchases are immediately impacted. Most industrial facilities (in France and in the rest of Europe) contract with utilities and other intermediaries. As a result, they become affected by wholesale price developments only when their contracts that include price guarantees are renegotiated. These contracts are typically between one and three years.

The energy shock affects all countries in the EU but they affect different firms in the manufacturing sector very differently. This is because firms energy contracts are renegotiated depending on the length of the contract. INSEE 2022 for example based on a survey of industrial firms estimates that more than half (56%) would be exposed to an electricity price increase. For gas, the share is 2/3. Due to the differences in contracts, price increases are very heterogeneous. Based on the Insee survey on 2023 on electricity prices among industrial firms, whereas 25% anticipate no increase, 42 % anticipate at least a doubling of prices. This means that our firm or plant level analysis is legitimate to understand a shock that is very different from one firm to another.

This is also because firms are differently exposed to an energy price shock. We show in figure 3 the empirical distribution of electricity dependency in our sample, in percentage of total costs (excluding the cost of capital), computed as an average over the whole period. This dependency is below 5 percent for most of the firms, and rather 2.5 percent percent on average as shown in table 3. It should be noted that the most electricity-dependent sector are not necessarily the most exposed to international competition, which leaves room for pass through to the end consumers, as opposed to sectors dependent on gas (see table 2). This dependency ratio is also a good guide to interpret the price response of firms: in the case of electricity, a 20 percent increase of 5 percent in costs, even if fully passed on to the client represents a 1 percent increase in the firm's price.

Figure 3: Empirical distribution of electricity dependency.



Source: EACEI data.

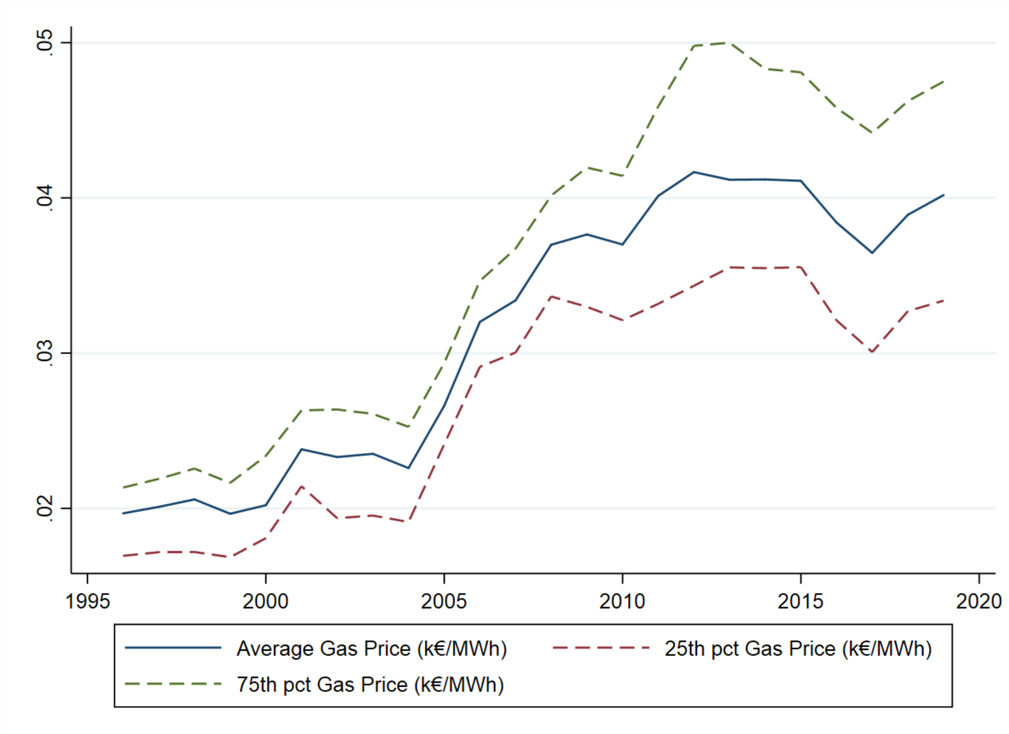
Considering gas, we observe a similar pattern in terms of the price paid by individual firms (fig. 4) and in terms of the distribution their gas dependency (fig. 5). Industry can use gas either as

Table 1: Electricity dependency by sector.

Sector	Mean	Median
	Top-3 Sector	
Capture, treatment and distribution of water	20.85	18.17
Wastewater collection and treatment	5.23	3.01
Non-metallic mineral product manufacturing	4.13	0.87
	Bottom-3 Sector	
Edition	0.74	0.69
Leather and footwear industry	0.52	0.61
Manufacturing of tobacco products	0.46	0.45

an energy source or as an input in an industrial process (e.g. production of agricultural fertilizers, pesticides, ...). Of the industrial customers who use gas, on average 27% are bound by a contract indexed to the wholesale market price (39% in the chemical industry) while 57% report that they have a fixed price over a contractual period (INSEE 2022). The renewal of contracts appears to be less frequent than for electricity: in the INSEE survey, 36% of industrial firms declared they a gas supply contract expiring by the end of 2022, against 48% for electricity. Historically, the gas industry has developed on the basis of long-term contracts with industrial buyers that include an indexation clause on the price of competing energies (generally the price of oil for the previous six months). Gas was distributed by a monopoly (Gaz De France – GDF, in the French case), and there was no exchange between countries or possibility of arbitrage. The European market was liberalized in the mid-1990s under pressure from the European Commission to introduce competition. The most important date from this point of view was 1998, when the gas market was largely liberalized, with the total liberalization of the market being announced in a 2003 directive imposing the separation of gas transport-storage and distribution activities.

Figure 4: Gas price over time.

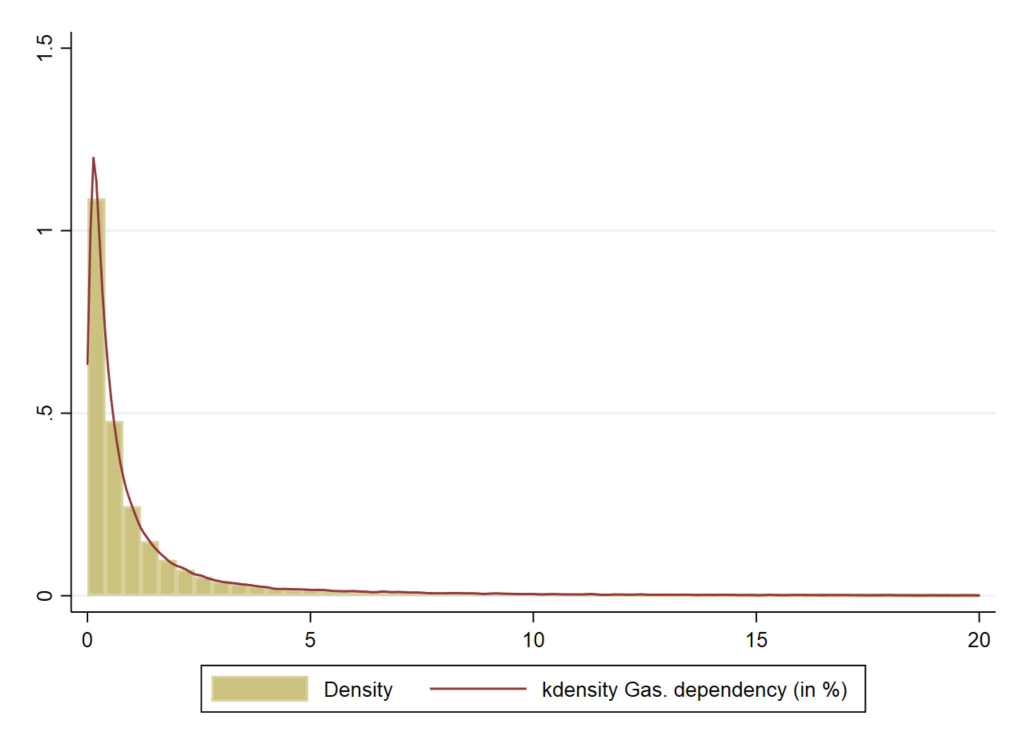


Source: EACEI data.

Table 2: Gas dependency by sector.

Sector	Mean	Median
	Top-3 Sector	
Manufacture of other non-metallic mineral products	4.84	1.69
Coke and refining	4.37	1.83
Waste collection, treatment and disposal	2.45	1.30
	Bottom-3 Sector	
Manufacture of computer, electronic and optical products	0.20	0.19
Film, video, television and music production	0.16	0.15
Pollution abatement and other waste management services	0.06	0.07

Figure 5: Empirical distribution of gas dependency.



Source: EACEI data.

3 Data

This paper relies mainly on $EACEI$ database providing information on energy purchase (in thousands of €) and consumption (MWh) by French firms in the period 1996-2019. For each combination of plant-year, we have information about the usage and purchase of different types of energy such as electricity, carbon, coke and gas. $EACEI$ is a survey based dataset collecting information on about 5,000 firms per year.[2] In the first part of our analysis, when we test the energy price demand elasticity, for the sake of coherence with the French balance sheet data, we aggregate the $EACEI$ database at the level of firms by summing electricity bill and consumption across plants within the same firm.[3] In the second part of the paper, when we analyse the cross-plant re-allocation of energy demand, we use $EACEI$ plant-level specific data and energy price. Using respectively firm- and plant-level $EACEI$ data we calculate the *average* energy price of firms and plants by dividing the purchased value and quantity of energy (we therefore obtain unit value of energy purchase, i.e. k€per MWh). We do so for electricity and gas respectively. We also calculate the electricity and gas dependency of firms as the cost share of respectively electricity and gas on total costs.[4]

The second important source of data is the FICUS/FARE balance sheet data providing information on value added, gross operating surplus, employment, wage bill, purchase of raw materials and intermediate products of French firms in the period 1996-2019.[5] Finally, we use $Douanes$ database providing information import and export flows of French firms by destination country, product (CN8 classification) and year in the period 1996-2019. The $Douanes$ Database contains all trade flows by firm-product-destination that are above 1000 Euros for extra EU trade and 200

[2]The survey has been conducted on firms with more than 20 employees.

[3]The French firm identifier $siren$ is used to aggregate at the level of firm, and then merge $EACEI$ data with balance sheet and export Custom database.

[4]The total cost of firms include the wage bill, the purchase of intermediate products and raw material (from FICUS/FARE data) and all the energy bills (from EACEI data).

[5]FICUS/FARE data are aggregated at the level of the firm and do not provide plant-level information.

Euros for intra-EU trade, so it can be considered an exhaustive sample of all French exporting firms. We also match the product classification of $Douanes$ data with the BEC classification, and calculate imports of final vs intermediates inputs of each French firm in a given year. As for exports, we calculate unit values (here used as a proxy for price) and aggregate the information at the level of firm-destination-year. We keep the destination market information to compare the price (and export) elasticity to energy price shock to a more standard Real Exchange Rate shock.[6]

In table 3 we show the descriptive statistics for our sample. The mean and median dependency of firms on electricity and gas are respectively 2.5 and 1.3 percent (for electricity), and 1.7 and 0.5 (for gas). As expected French firms rely much more on electricity than on gas. The largest share of firms' cost in France is labor, counting on average for the 33% of total costs.

Table 3: Descriptive statistics.

Variable	Obs.	Mean	Median
Electricity price (k€/MWh)	113,893	0.071	0.068
Gas price (k€/MWh)	113,893	0.031	0.029
Electricity dependency (in %)	113,893	2.52	1.30
Gas dependency (in %)	113,893	1.67	0.51
Employment (unit)	113,893	321	121
Labor dependency (in %)	113,893	32.80	28.55

4 Identification strategy

We adopt a standard within-firm identification strategy to test the many channels of adjustment to energy shocks. Thus, our baseline empirical specification is as follows:

$$y_{f,s,t} = \beta p_{f,s,t} + \theta_f + \theta_{st} + \epsilon_{f,s,t} \tag{1}$$

[6]Real Exchange Rate is calculated using Penn World Table rev. 9.

where $y_{f,s,t}$ is the outcome of firm f in a given sector s and year t.[7] We start by estimating the energy demand elasticity, so the firm-specific outcomes are (in turn) the purchased quantity of electricity and gas. Then, in the second part of the empirical exercise, we focus on other firm-specific outcomes: (i) employment, (ii) value added, (iii) gross operating surplus, and (iv) energy efficiency. In the last part we focus on trade-related outcomes and test the effect of changes in energy prices on import, exports and export prices. The explanatory variable of interest, observed at the plant level and which can be aggregated to the firm level, is the firm-specific price of electricity and gas, calculated as the year's electricity (gas) bill divided by the quantity consumed. We are not specifically interested in cross-price demand elasticity, so in estimating the elasticity of demand for electricity and gas we respectively use electricity and gas price only. We include both electricity and gas price when we consider other firm-level outcomes.

In all estimations we include firm fixed effects θ_f controlling for any firm-specific time-invariant factor affecting the outcome of firms, such as the average size and productivity of the firms, as well as the average workforce composition and capital intensity. We also include 2-digit NAF sector-year fixed effects θ_{st} controlling for business-cycle and any technological (or productivity) shock affecting all firms of a given sector. We therefore identify our coefficient of interest, β, on the pure within-firm variation in energy price and outcomes conditional on any sector-specific shock. In robustness check specifications reported in column (4) of Tables 4 and 5 we also include firm-by-period fixed effects (where periods are 3-year windows). The inclusion of firm-by-period fixed effects controls for any firm-specific characteristics that varies over time (i.e. by 3-year window).[8]

As discussed in section 2, the institutional context suggests that *changes* in the energy price of firms can largely be considered exogenous to the firm. Indeed, the evolution of electricity and gas prices of a given firm depends on the expiration date of the previous contract, which

[7] FICUS/FARE data give information on the main sector (4-digit of the NAF classification) in which the firm operates.
[8] Periods are: 1997-1999; 2000-2002; 2003-2005; 2006-2008; 2009-2011; 2012-2014; 2015-2017; 2018-2019.

is arguably exogenous to firm-specific characteristics and/or economic shocks, and on the price at the aggregate level at the time of expiration which itself depends on regulation changes and macroeconomic determinants. Also, the large set of fixed effects included in equation 1 strongly reduces the omitted variable concern. However, if unobserved firm-specific shocks affect the negotiation of the energy price when the new contract is signed, then endogeneity may bias the OLS estimations. One concern is that a positive expected demand shock on the firm could help the firm negotiate a lower energy price. To address this endogeneity concern, we adopt an Instrumental Variable (IV) strategy to check the robustness of our baseline OLS estimations. We adopt a Bartik approach and instrument the energy price as follows:

$$p^{IV}_{f,s,t} = \left[\frac{p_{f,s,t_0}}{\bar{p}_{s,t_0}}\right] \times \bar{p}_{s,t} \tag{2}$$

where $p_{f,s,t0}$ is the price of a given firm f in the initial year (i.e. when the firm is observed in the sample for the first time), and $\bar{p}_{s,t}$ and $\bar{p}_{s,t_0}$ stand respectively for the average sector price of energy in year t and in the initial year t_0. To further reduce endogeneity concern, we exclude the specific firm f from the calculation of the average sector price:

$$\bar{p}_{s,t} = \frac{1}{N-1} \sum_{i \neq f \in N} p_{i,s,t_0} \tag{3}$$

where N is the total number of firms in each sector s. The term in bracket in eq. (2) represents the price gap of a given firm f with respect to the (average) energy price in sector s in the initial year. It represents whether and how much a specific firm f is able to obtain energy price below/above the sector average. Such a price gap is interacted by the time-varying energy price of the sector. The underlying idea is that any time-varying sector specific change in the price of energy translates into firm-specific price through a time-invariant firm-specific ability to bargain its price (term in bracket). The exclusion restriction assumption is based on the idea that: (i) variations in sector-specific average energy price do not depend on firm-specific characteristics, and (ii) that the firm's ability to bargain in the initial year is uncorrelated with the contemporaneous variation in the economic outcomes of the firm.[9] The assumption (i) is satisfied because we explicitly omit firm f from the calculation of the average sector price, and because the timing of expiration of energy contracts of other firms in the sector $i \neq f$ (determining $\bar{p}_{s,t}$ in eq. 3) is likely uncorrelated with the price setting for firm f. The assumption (ii) likely holds because firm fixed effects capture any firm-specific factors that may have affected the firm's ability to bargain in the initial year and its current economic outcomes. In the bottom part of tables of results for 2SLS estimations we always report the first-stage coefficient, the Kleibergen-Paap Wald F-statistics and the p-value of Anderson-Rubin Wald test on the weak-instrument-robust inference. These statistics show the relevance of our IV, the absence of weak-IV bias problem and the robustness of our baseline elasticity to any potential weak IV problem.

5 Energy demand in response to energy price shocks

Estimating the demand elasticity for energy is a difficult task as price and quantity are general equilibrium objects determined simultaneously. However, as explained above and in Fontagné, P. Martin, and Orefice 2018 and also Auray, Caponi, and Ravel 2019, prices of electricity in the French market have, at the plant and firm level, a high degree of exogeneity that derives from the French institutional and contractual specificities. Most price shocks across firms derive from contract renegotiations that take place during a period with non firm specific events (aggregate price shocks, regulatory changes).

We control for several factors that could generate a concern of reverse causality from demand to prices. Including firm (or plant) level fixed effects in particular means we take into account all (time-invariant) characteristics of the energy demand of the firm, such as its size and efficiency,

[9]Note that any direct effect of sector-specific energy price on firm-specific outcomes is captured by fixed effects.

that could affect the price it pays. In particular, a legitimate concern is that firms with higher energy demand can negotiate contracts with lower prices per KWh. The time-invariant component of this potential avenue for reverse causality is taken care by the firm fixed effect. We also include year fixed effects to take into account cyclical factors affecting both demand and prices.

Table 4: Electricity demand price elasticity

Dep Var:	*Firm electricity demand (ln)*				
	(1)	(2)	(3)	(4)	(5)
Electricity price (ln)	-1.089***			-0.628***	-0.376**
	(0.183)			(0.091)	(0.192)
Elec. Price (ln) lag		-0.536***	-0.466**		
		(0.197)	(0.199)		
Value Added (ln)			0.352***		
			(0.030)		
Estimator	OLS				2SLS
Firm FE	yes	yes	yes	no	yes
Sec-Year FE	yes	yes	yes	yes	yes
Firm-Per FE	no	no	no	yes	no
First stage IV coeff.					0.262***
K-P Wald F-stat					550
A-R Wald test (p-val)					0.037
Observations	108,344	90,384	89,720	87,388	108,342

Notes: The dependent variable is the total quantity of electricity purchased by firm in a given year. Electricity and gas price approximated by value over quantity purchased in the year. In the bottom part of the tables we show: (i) the first-stage coefficient, (ii) the Kleibergen-Paap Wald F-statistics and (iii) the p-value of Anderson-Rubin Wald test on the weak-instrument-robust inference. Robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

The first regression in table 4 suggests a high (almost unitary) elasticity of demand for electricity. However, the time varying component of the reverse causality problem is not fully taken care through firm fixed effects: a firm that expands and increases its demand for energy could negotiate a lower price per Kwh. To alleviate this concern, we then show two sets of results. First, we show our results where the demand for energy in year t is regressed on the price of energy lagged one year. Regressions (2), (3) and (4) suggest a lower elasticity of demand around -0.5. Note importantly that this elasticity is not much reduced when controlling for production (regression 4). This suggests that the reduction of electricity demand takes place mostly through other means than a reduction of production. This is important in the present context, in which a concern is that the reduction in energy demand could only be achieved by a drastic reduction in industrial production.

One possible concern is that the estimated price elasticity of electricity demand comprises the effect of gas prices on electricity prices themselves. Indeed, gas turbines are often the marginal electricity producer. However, this concern is alleviated by the use of year fixed effects that absorb any aggregate change in gas prices. Also, we have checked that when controlling for the firm level gas price, the electricity price elasticity estimates are unaffected.

The concern for reverse causality and endogeneity of the relation between firm level energy prices and demand leads us to show an identification strategy based on an instrumental variable. A second reason to use instrumental variables is that energy prices (which we compute as unit values) may suffer from measurement error. The instruments we choose for electricity and gas prices are a variant of a Bartik shift-share instrument, as previously discussed in relation with Eq. 2.

Interestingly, both the lagged regressions and the instrumental variable estimation we present generate electricity demand elasticities that are similar to those obtained by Marin and Vona 2021 who use a different instrumental variable strategy.

Our preferred estimate is therefore around -0.4 to -0.5 for electricity demand.

We present similar results for the elasticity of demand for gas in table 5. The estimate is higher with a lower bound of around -0.9 which we will take as our preferred estimate. This elasticity is high and higher than in the existing literature. For example, Andersen, Nilsen, and Tveteras 2011 find an elasticity for the French manufacturing sector around -0.14.

Table 5: Gas demand price elasticity

Dep Var:	Firm gas demand (ln)				
	(1)	(2)	(3)	(4)	(5)
Gas price (ln)	-1.762***			-0.944***	-1.236***
	(0.270)			(0.147)	(0.130)
Gas. Price (ln) lag		-0.922***	-0.899***		
		(0.209)	(0.217)		
Value Added (ln)			0.287***		
			(0.032)		
Estimator		OLS			2SLS
Firm FE	yes	yes	yes	no	yes
Sec-Year FE	yes	yes	yes	yes	yes
Firm-Per FE	no	no	no	yes	no
First stage IV coeff.					0.472***
K-P Wald F-stat					1426
A-R Wald test (p-val)					0.000
Observations	108,344	90,384	89,720	87,388	108,342

Notes: The dependent variable is the total quantity of gas purchased by firm in a given year. Electricity and gas price approximated by value over quantity purchased in the year. In the bottom part of the tables we show: (i) the first-stage coefficient, (ii) the Kleibergen-Paap Wald F-statistics and (iii) the p-value of Anderson-Rubin Wald test on the weak-instrument-robust inference. Robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

With the present crisis in mind, and the fact that current price increases are larger than those in the 1996-2019 period, we analyze whether price elasticities are different for the largest price increases in our sample. For electricity the elasticity is reduced but not zero for the largest price increases of our sample (that correspond to a 36% price increase on average). This is also true for gas (resp. 53%). Hence, there is evidence that a large energy price shock makes it more difficult to reduce energy demand, although the adjustment in demand remains quantitatively significant.

We also analyze whether the reaction of French manufacturing firms to price changes has evolved over time during the period 1996-2019. We therefore interact the energy prices (electricity and gas) with three period dummies: 1996-2003, 2004-2011 and 2012-2019. As shown in the table

Table 6: Non-linear energy price demand elasticity

	Panel a: Electricity demand (ln)				
	(1)	(2)	(3)	(4)	(5)
Elec. Price (ln) lag	-0.755***	-0.295***	-0.068	-0.342***	-0.209***
	(0.241)	(0.065)	(0.125)	(0.103)	(0.071)
Observations	34,504	38,015	7,284	17,592	6,416
	Panel b: Gas demand (ln)				
	(1)	(2)	(3)	(4)	(5)
Gas. Price (ln) lag	-0.507***	-1.123***	-1.232***	-1.061***	-0.711***
	(0.101)	(0.156)	(0.322)	(0.204)	(0.121)
Observations	27,676	44,415	8,566	20,486	7,585
Price shock	Negative	Positive		Positive	
			Small	*Medium*	*Large*
Avg Δ ln(p^{Elec})	-8.7%	13.1%	1.3%	7.5%	36.2%
Avg Δ ln(p^{Gas})	-11.1%	20.4%	2.1%	13.2%	53.1%
Firm FE	yes	yes	yes	yes	yes
Sec-Year FE	yes	yes	yes	yes	yes

Notes: The dependent variable is in turn the electricity and gas demand. Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

7, the price elasticity of electricity demand decreased during the period covered by our analysis. This is less clear for gas. One interpretation of this result is that the adaptation to price shocks (on average energy prices have increased during this period) was most potent at the beginning of the period and was more difficult at the end. It still remains, however, that even at the end of the period, firms adjust their electricity and gas demand significantly when the price of energy increases.

If we restrict our estimation to the largest positive shocks (those of column (5) in table 6), during the latest period (2012-2019), the price elasticity of electricity demand is -0.15. This is the most conservative estimate that can be used to think of the policy implications of the 2021-2022 energy price shock.

Table 7: Time-varying energy demand elasticity

Dep Var:	Electricity Demand	Gas Demand
	(1)	(2)
$p^{Elec}_{i,t-1}$ × Period 96-03	-0.622**	-0.196
	(0.286)	(0.228)
$p^{Elec}_{i,t-1}$ × Period 04-11	-0.506***	-0.322**
	(0.136)	(0.151)
$p^{Elec}_{i,t-1}$ × Period 12-19	-0.327**	-0.240
	(0.146)	(0.158)
$p^{Gas}_{i,t-1}$ × Period 96-03	-0.292***	-1.408***
	(0.083)	(0.204)
$p^{Gas}_{i,t-1}$ × Period 04-11	-0.077	-0.506***
	(0.065)	(0.125)
$p^{Gas}_{i,t-1}$ × Period 12-19	-0.271	-0.755***
	(0.186)	(0.245)
Firm FE	yes	yes
Sec-Year FE	yes	yes
Observations	90,384	90,384

Notes: Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

6 Price pass-through and competitiveness

The framework we have in mind to analyze how an energy price shock affects production and employment works mostly through the impact it has on marginal costs of production which pass-through to production prices and impact negatively the competitiveness of the firm and the demand for its products. Employment is affected because of the fall in production.

Hence, we first analyze how the cost shock translates into prices. We do not observe domestic production prices, so we will take export prices as a proxy for the latter. We will interpret the impact of energy price shocks on prices in terms of the firm competitiveness relative to other firms either in France or elsewhere. In the present debate on the impact of the energy shock on European industry, the issue of competitiveness vis-à-vis the rest of the world looms large. An important difference between our analysis and the present situation is that the shock is an aggregate one and affects French firms (although heterogeneously) and European firms too.

Hence, we now analyze how energy price shocks impact industrial firms' export prices and performance. For this estimation, we use firm level and destination specific data coming from customs data. Table 8 first shows that firms are able to pass through the energy price shock into their export prices. Given that electricity and gas account respectively for 2.5% and 1.7% of the costs for which we have information (labor and intermediate goods), this suggests that the pass through into export prices is full. This evidence on export prices is consistent with the study of Joussier, J. Martin, and Mejean 2023 who show, in the context of the 2022 crisis, that French industrial firms were able to pass through the whole energy cost shock on their producer prices. These findings on the full pass-through of energy costs into manufacturing prices may be one reason for the firms' resilience in the present crisis. However, it also suggests that the diffusion of energy cost shocks along supply chains will mean that inflation will be prolonged even after the end of the initial shock.

Non surprisingly, the increase in export prices generates a fall in export quantities. The impact is consistent with an international price elasticity around 5, which we had already reported in previous work (Fontagné, P. Martin, and Orefice 2018). When one controls for the bilateral (France to destination country) real exchange rate, the impact of changes in the price of energy is large: a 10 % increase in electricity (gas) prices reduces exports quantities by around 2 % (1%). The coefficient on the bilateral real exchange rate in the same regression suggests that to compensate the competitiveness loss due to the electricity (gas) price shock, almost 7% (3%) bilateral depreciation of the euro would be necessary. Hence, our interpretation of the impact on competitiveness is that (in part due to the full pass-through into prices) the energy cost hike is a sizable competitiveness shock. In the present crisis, although the euro has depreciated in real effective terms (around 3% according to the ECB in 2022 relative to the 2019-2021 period), this has clearly not compensated the energy price shock (see below).

Table 8: Export related outcomes

Dep Var:	Export price (ln)		Export quantity	
	(1)	(2)	(3)	(4)
Elec. Price (ln) lag	0.041***	0.040***	-0.223***	-0.136***
	(0.007)	(0.006)	(0.054)	(0.048)
Gas. Price (ln) lag	0.013**	0.010*	-0.112**	-0.074
	(0.005)	(0.005)	(0.054)	(0.051)
Real Exchange Rate (ln)	0.049***		0.334***	
	(0.008)		(0.075)	
Firm-Dest. FE	yes	yes	yes	yes
Sec.-year FE	yes	yes	yes	yes
Dest.-Year FE	yes	yes	yes	yes
Observations	1,686,605	1,914,105	1,686,605	1,914,105

Notes: Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

7 Production, employment, energy efficiency and profits

We interpret the measured impact on export prices and quantities as a proxy of the impact of the energy cost shock on production prices and the competitiveness of the firm. The energy shock, which we saw is passed-through into higher prices, then reduces through this mechanism both production and employment. We saw above that even after controlling for production, an increase in energy prices was still generating a fall in energy demand. Again, we can use contemporary and lagged prices to have a range of estimates. In this case, though, the range of estimates is much smaller, so we only present the estimates with lagged prices in table 9.

The effect of an electricity price shock is to reduce employment and production (regressions 1 and 3). The effect is quantitatively important for the whole period: a 10% increase in electricity prices reduces employment and production by 1.5% and 1.6% respectively. One way to interpret this result is that following an electricity price increase of 10%, with full pass-through, firms increase their production prices by around 0.4% (the estimate on export prices). In table 8, the quantity exported decreased by 2.2%, consistent with a price elasticity around 5. The decrease of export values is around 1.8%, similar to the fall 1.6%. of total production in table 9. In regressions (2) and (4) we interact the electricity price with the firm measured dependence to energy (the share of energy costs in total measured costs). Interestingly, we find little evidence that firms more dependent on electricity react differently from less dependent firms. For gas, the message is a bit different, as we only find a negative impact of a price shock for firms which are more dependent on gas. The likely reason is that the use of gas in manufacturing production only applies to some firms and some sectors, whereas all manufacturing firms use electricity.

The energy efficiency (measured by the ratio of value added to MWh) increases significatively for gas, but not for electricity.

Profits fall moderately, but only for electricity (-1.6%) and for gas only for the most dependent firms. For electricity, the impact on profits (although sizable) is a bit less than the direct cost increase and the combined effect of prices and production. This is consistent with increased energy efficiency (at least for some) as well as additional channels of adjustment that we describe below.

Table 9: Firm-level outcomes: OLS results

Dep Var:	*Emplo. (ln)*		*Value Add. (ln)*		*Erg Eff. (ln)*		*Profit (ln)*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Elec. Price (ln) lag	-0.151***	-0.175*	-0.160***	-0.091	0.212	0.607*	-0.165*	-0.051
	(0.042)	(0.090)	(0.042)	(0.086)	(0.160)	(0.348)	(0.085)	(0.173)
Elec. Price (ln) lag x Ele dep.		0.012		-0.042		-0.230**		-0.070
		(0.035)		(0.035)		(0.113)		(0.067)
Gas. Price (ln) lag	-0.016	0.123*	-0.012	0.147**	0.380***	0.486***	-0.008	0.143
	(0.035)	(0.064)	(0.042)	(0.067)	(0.128)	(0.180)	(0.068)	(0.105)
Gas. Price (ln) lag x Gas dep.		-0.206**		-0.237***		-0.157		-0.229***
		(0.085)		(0.064)		(0.107)		(0.083)
Firm FE	yes	yes	yes	yes	yes	yes	yes	yes
Sec-Year FE	yes	yes	yes	yes	yes	yes	yes	yes
Observations	90,384	89,952	89,720	89,297	89,720	89,297	73,098	72,742

Notes: The dependent variable is turn total employment in the firm, its value added and the energy efficiency (i.e. value added per MWh). Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

In table 10, we show the main regressions of 9, but with instrumented energy prices rather than lagged prices. The messages are robust to the use of an instrumental variable. The coefficients are in general more significant. They are larger in absolute size for the impact of the gas price shock on employment and production. For energy efficiency, the effect of both electricity and gas price shocks is also larger and more significant. The impact on profits is not significant.

Table 10: Firm-level outcomes. 2SLS results

Dep Var:	*Emplo. (ln)*	*Value Add. (ln)*	*Erg Eff. (ln)*	*Profit (ln)*
	(1)	(2)	(3)	(4)
Electricity price (ln)	-0.159***	-0.150***	0.662***	-0.028
	(0.017)	(0.020)	(0.026)	(0.044)
Gas price (ln)	-0.060***	-0.060***	0.592***	0.031
	(0.014)	(0.016)	(0.021)	(0.033)
Firm FE	yes	yes	yes	yes
Sec-Year FE	yes	yes	yes	yes
Observations	108,340	107,462	107,462	86,921

Notes: The dependent variable is turn total employment in the firm, its value added and the energy efficiency (i.e. value added per MWh). Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

In table 11, we analyze whether the impact of energy price shocks has varied during the period 1996-2019 by interacting the (lagged) price shocks with three period dummies. Consistent with results of table 7 which suggested a falling energy demand elasticity, the impact of energy price shocks on employment (regression 1), value added (regression 2), energy efficiency (regression 3) and profits (regression 4) seems to have fallen in the most recent period. One interpretation is that during a period of rising energy prices and more global competition in the manufacturing sector, firms have adjusted their production process to better weather these shocks or have disappeared if they were not able to adjust. This suggests that the period before the present energy crisis, through a selection effect or adjustment, French manufacturing firms entered the present energy crisis. Remember also that figure 1 provided evidence of an increased energy efficiency starting in 2010.

Table 11: Time-varying elasticity on other outcomes

Dep Var:	Employment	Value added	Energy efficiency	Profit
	(1)	(2)	(3)	(4)
$p^{Elec}_{i,t-1}$ × Period 96-03	-0.242***	-0.280***	0.153	-0.491***
	(0.078)	(0.075)	(0.236)	(0.137)
$p^{Elec}_{i,t-1}$ × Period 04-11	-0.192***	-0.160***	0.249*	-0.123
	(0.045)	(0.049)	(0.138)	(0.134)
$p^{Elec}_{i,t-1}$ × Period 12-19	-0.059	-0.070	0.209	0.069
	(0.050)	(0.062)	(0.151)	(0.132)
$p^{Gas}_{i,t-1}$ × Period 96-03	-0.110	-0.067	0.558***	0.021
	(0.085)	(0.074)	(0.105)	(0.139)
$p^{Gas}_{i,t-1}$ × Period 04-11	-0.018	0.011	0.190**	0.040
	(0.052)	(0.069)	(0.089)	(0.106)
$p^{Gas}_{i,t-1}$ × Period 12-19	0.043	0.007	0.384*	-0.074
	(0.040)	(0.046)	(0.205)	(0.089)
Firm FE	yes	yes	yes	yes
Sec-Year FE	yes	yes	yes	yes
Observations	90,384	89,720	89,720	72,499

Notes: Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

8 Other channels of adjustment: relocation and intermediate inputs imports

Energy consumption and efficiency, prices, production, employment and profits are the standard channels through which we expect manufacturing firms to adjust to an energy price shock. We now investigate two other channels, which have been discussed anecdotally in the press in the present crisis, through which firms can also adjust to energy shocks. One channel is to relocate part of their production. We do not have direct data on relocation outside of France but we have data on relocation inside France for multiplant firms. Another related channel is to increase imports of intermediate inputs, presumably in substitution of the most energy intensive ones.

In table 12, we show how electricity and gas demands at the plant level depend not only on the energy prices at the plant level but also at the firm level where the firm level price excludes the plant itself. The sample is much reduced given that the estimation is restricted to firms with multiple plants in France. Interestingly, we see that a higher electricity (gas) price in a plant tends to increase electricity (gas) demand in other plants in the same firm. This suggests that firms adapt their production process across plants to increase energy demand and production in plants with lower prices. Note that when we control for production at the plant level, the effect is somewhat reduced.

Table 12: Plant level evidence: the within-firm substitution effect

Dep Var:	Elec. demand (ln)		Gas demand (ln)	
	(1)	(2)	(3)	(4)
Elec. Price (ln) lag plant	-0.147***	-0.115***	-0.036	-0.008
	(0.029)	(0.027)	(0.037)	(0.038)
Elec. Price (ln) lag firm	0.079***	0.057**	0.059*	0.048
	(0.026)	(0.024)	(0.035)	(0.036)
Gas. Price (ln) lag plant	-0.069***	-0.051***	-0.420***	-0.404***
	(0.019)	(0.018)	(0.043)	(0.044)
Gas. Price (ln) lag firm	0.014	0.011	0.107***	0.105***
	(0.013)	(0.013)	(0.026)	(0.028)
VA (ln)		0.281***		0.237***
		(0.012)		(0.017)
Plant-Dest. FE	yes	yes	yes	yes
Sec.-year FE	yes	yes	yes	yes
Observations	29,196	27,342	29,196	27,342

Notes: Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

In table 13, we analyze another channel of adjustment to an energy price shock. Firms can alter their production process to substitute imported inputs (presumably those most intensive in energy) to local produced inputs. Regression (1) does not show a statistically significant increase in total imports following energy price shocks. Regression (2) suggests however that for electricity price shocks, firms do increase the imports of intermediate inputs which may be a better measure of the substitution towards lower energy price sources of production. This is not the case for gas though.

Table 13: Imports and energy price shocks

Dep Var:	Tot Imports	Interm. Imp.
	(1)	(2)
Elec. Price (ln) lag	0.330	0.565**
	(0.230)	(0.286)
Gas. Price (ln) lag	-0.111	-0.195
	(0.109)	(0.155)
Firm-Dest. FE	yes	yes
Sec.-year FE	yes	yes
Observations	81,679	81,438

Notes: Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

9 The present crisis in the lens of our estimates (to be completed)

Our results based on the 1996-2019 period point to significant and multiple adjustments of manufacturing firms to energy shocks. Even in the short term, firms are able to substitute and adapt.

According to Bruegel, in January 2023, gas consumption by the industrial sector in France was reduced by 25% relative to the 2019-2021 average. This was also the average reduction observed at the EU level. During the same period, prices in euro of gas for the industry increased by 140% according to INSEE. For electricity, INSEE reports a 104% price increase on the same period for the industrial sector. It is to be noted that our empirical estimates of the impact of energy price shocks should be interpreted as a real price shock. Hence, to place our estimates in the present context, we must take into account the increase in the price of manufacturing (hence excluding energy) which, during that same period, was about 22% in France. Hence, the real gas price increase was about 118% and for electricity about 82%. Our last piece of evidence is that average manufacturing production in France was about 5% lower in 2022 compared to 2019.

Are these aggregate numbers in the present crisis broadly consistent with our firm-level estimates? We already noted that our estimates should be taken with caution to interpret the current crisis for two main reasons: the end of the period (2012-2019) estimates of the impact of energy shocks are lower than for the whole period; large price shocks have a lower impact on energy demand than more modest ones. Given the size of the present energy shock, this non-linearity is important. Table 14 suggests indeed that the elasticities of demand for largest (highest quartile) price shocks (about 36% for electricity and 53% for gas) are lower (0.2 and 0.7) but still significant. With these elasticities and the observed energy price shocks, the demand for electricity and gas by manufacturing firms should have fallen by around 16% and 82% respectively. We do not have precise data for electricity consumption of in the French industry, but the predicted fall (even though large) does seem reasonable. For gas, however, the predicted fall is much too large. This can be explained by the fact that the observed price shock in the present context is around double than our largest observed price shocks in the period for which we have data. A lower demand elasticity in the present crisis can also be rationalized by the result that it was lower at the end of the period (just before the crisis).

A different – and even more tentative – approach can be contemplated to better target the current situation. We already noticed that the demand elasticity of electricity is about -0.15 in the last sub-period (2012-19) for the largest (highest quartile) energy price shocks. The price of manufacturing in December 2022 was 21.5% above the average 2019-21, and the price of electricity 47.6%, hence a real electricity price increase by about 26%. The expected drop in electricity demand should be about -4% and thus the electricity bill up by about 21% (using average elasticities of table 10, columns 1 and 2). Employment and value added should have decreased by about 4%. Such magnitude is in line with the observation that French manufacturing production was down by -5% in 2022 compared to 2019.

Table 14: Large energy price shocks

Dep Var:	Elec. demand	Gas demand	Emplo.	Value added	Energy efficiency	Profit
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel a: Electricity price shock (average = 36.2%)					
Elec. Price (ln) lag	-0.209***		-0.171***	-0.228***	-0.019	-0.349*
	(0.071)		(0.048)	(0.067)	(0.081)	(0.180)
Observations	6,416		6,416	6,350	6,350	4,504
	Panel b: Gas price shock = (average = 53.1%)					
Gas Price (ln) lag		-0.711***	-0.096**	-0.147**	0.197**	-0.004
		(0.121)	(0.043)	(0.058)	(0.086)	(0.123)
Observations		7,585	7,585	7,490	7,490	5,540
Firm FE	yes	yes	yes	yes	yes	yes
Sec-Year FE	yes	yes	yes	yes	yes	yes

Notes: Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

10 Policy options discussion: short and long term (to be completed)

Different European countries have adopted different short term policy responses to the energy crisis partially shielding both households and firms from the price shock (see Bruegel for an analysis). Some policies (e.g France) amounted to a price cap with a maximum increase in prices lower than what the market would have produced. In other countries, taxes and duties on energy were lowered. Some subsidize energy to absorb part of the price hike although it was mostly applied to SMEs. Another policy (e.g Netherlands and Germany) amounted to a non linear subsidy in the sense that a subsidized price was applied to a share of the past energy consumption and the rest was priced at the market price. A no subsidy policy (applied in Sweden for example) was a third option.

We now discuss and compare the two first subsidy policy options. In the first option, the government absorbs part of the market energy price hike $\Delta p^e/p^e$ between periods 1 and 2 (say between 2019 and 2022) so that the price increase effectively paid by firms is $(1-s)\Delta p^e/p^e$ where $\Delta p^e = p_2^e - p_1^e$ is the energy price increase and s is absorption rate. The fiscal cost of this policy is therefore :

$$\bar{C} = s(p_2^e - p_1^e)Q_2^e \tag{4}$$

where Q_2^e is the quantity of energy demand by firms at the higher (partly subsidized) price (1-s). Given an estimate of the price elasticity of demand for energy, β and the partial public absorption, the change of energy demand is:

$$\frac{\Delta Q^e}{Q^e} = -\beta(1-s)\frac{\Delta p^e}{p^e} \tag{5}$$

Hence, taking into account the change in demand, the fiscal cost of the policy is:

$$\bar{C} = s\frac{\Delta p^e}{p^e}Q_1^e\left[p_1^e - \beta(1-s)(p_2^e - p_1^e)\right] \tag{6}$$

A second policy option is to fully absorb the energy price hike, but for a fixed portion α of the initial energy consumption Q_1^e. Any additional energy consumption of the firm is paid at the market price p_2^e. The decrease of energy consumption (assuming the fall in consumption is limited so that it does not fall below the level αQ_1^e) is therefore marginally driven by the market price :

$$\frac{\Delta Q^e}{Q^e} = -\beta \frac{\Delta p^e}{p^e} \tag{7}$$

The fiscal cost of this second option is:

$$\tilde{C} = \alpha Q_1^e (p_2^e - p_1^e) \tag{8}$$

To make the two options comparable, we constrain the fiscal cost to be equal which pins down the share of energy demand for which the price hike is fully absorbed in the second option:

$$\alpha = s \left[1 - \beta(1-s) \frac{\Delta p^e}{p^e} \right] \tag{9}$$

The average price increase of the firm is (for $\alpha < 1$):

$$\frac{\tilde{\Delta p^e}}{p^e} = \frac{\Delta p^e}{p^e} \frac{1 - \alpha - \beta \frac{\Delta p^e}{p^e}}{1 - \beta \frac{\Delta p^e}{p^e}} \tag{10}$$

It is easy to check, that for the same fiscal cost, the average price increase of the firm is lower with the non-linear subsidy. Or to put it another way, this option can generate the same firm-level average price increase at a lower fiscal cost. The reason is that the signal that generates a fall in the energy consumption (which reduces the base of the subsidy) applies on the marginal units at a higher price with the non-linear subsidy. Hence, it allows (for the same fiscal cost) a lower average price increase while at the same time a larger reduction of energy consumption. From this point of view, the non-linear subsidy appears superior to the linear subsidy. If the negative impact on employment depends on the effective average price shock, not the marginal price, the non-linear subsidy also produces a better employment outcome.

However, this result assumes that the price elasticity of demand (β) is equal whether the price hike effectively (i.e inclusive of public subsidies) experienced by firms is large or moderate. Our estimates (see table 3) suggest that the price elasticity is lower (in absolute value) for large price hikes (in our sample on average 36.2% for electricity and 53.1% for gas) than for moderate ones (on average 7.5% for electricity and 13.2% for gas). The comparison of the two policy options becomes ambiguous with lower price elasticities (in absolute terms) for large price increases, as firms would be less affected on their marginal demand (i.e. the unsubsidized part) than for moderate increases. [10].

These short-term distortionary policy responses to reduce the energy price shock for firms are very costly: Bruegel (2023) reports the fiscal costs of the absorption of the energy crisis in particular non-targeted and distortionary price measures. The total costs (from September 2021 to January 2023) in the EU of non-targeted price measures amounted to € 218 billion. These include measures both for households and firms. We do not have a breakdown that distinguishes the cost of price distortionary for firms but it is clear that the fiscal cost of these short term measures were very large.

Our results of the previous sections suggest indeed that energy efficiency at the firm level (especially for gas) increases following energy price hikes. Figure 1 in the introduction was suggestive of this mechanism at the aggregate level on the period 1995-2019 as energy prices and energy efficiency look strongly correlated. Given this observed ability of firms here to adapt to energy price shocks through energy efficiency, our main policy recommendation is to limit short-term price absorption by the public budget and use public money to help transition to cleaner energy and technologies that are less dependent on imports from foreign countries. This has the additional advantage of improving competitiveness by reducing energy costs. In this case, the policy objective should be to increase energy efficiency defined as the value added per unit of energy in MWh.

[10]The non-linear pricing policy remains superior if $\beta^L - \beta^M(1-s) > 0$ where β^L (β^M) is the price elasticity for large (moderate) price increases and $\beta^L < \beta^M$.

Table 15: Heterogeneous electricity price elasticity and the energy efficiency of firms.

Dep Var:	Employment	Value added
	(1)	(2)
Elec. Price (ln) lag	-0.133***	-0.152***
	(0.038)	(0.046)
Elec. Price (ln) lag $\times$ Energy Eff (ln)	0.035	-0.000
	(0.032)	(0.033)
Gas. Price (ln) lag	-0.062*	-0.143***
	(0.034)	(0.042)
Gas. Price (ln) lag $\times$ Energy Eff (ln)	0.093**	0.093***
	(0.037)	(0.035)
Observations	64,205	63,937
R-squared	0.968	0.964
Firm FE	yes	yes
Sec-Year FE	yes	yes

Notes: Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

Moreover, if another policy objective is to reduce energy dependence and increase the resilience of manufacturing to energy shocks, increasing energy efficiency may help. This is suggested - at least for gas - by the results of table 15 where we interact energy prices with energy efficiency (the average of the past three years). We want to test if employment and production are more resilient to price shocks in more energy efficient firms. This is the case for gas (but not for electricity) as the interaction between gas prices and energy efficiency is positive and significant for both employment and value added. A clear policy implication is therefore that a better use of public money is to subsidize innovation and energy efficiency in the manufacturing sector, rather than subsidies to energy consumption. Our results of a strong and fast adaptation of manufacturing firms to energy shocks suggests that a large part of the public support to manufacturing taking the form of price subsidies was due to efficient lobbying rather than informed economics.

We can also relate our findings to one dimension of the current policy debates on the reforms of the European electricity markets. The European Commission proposed reform's main objective is to encourage more long-term contracts. The rationale is to increase the incentives for investment in relation to the technologies needed to decarbonize the power system and also to reduce firms exposition to price shocks. On this latter point, our results both on the negative impact of price shocks on manufacturing and employment and on the positive impact of these price shocks on energy efficiency suggest that price volatility should be reduced but that the price signal remains a powerful instrument for the energy transition. From this point of view, our results are consistent with the broad aims of the reform.

References

Alpino, Matteo, Luca Citino, and Annalisa Frigo (2023). *The effects of the 2021 energy crisis on medium and large industrial frms: evidence from Italy*. Tech. rep. Bank of Italy.

Andersen, Trude Berg, Odd Bjarte Nilsen, and Ragnar Tveteras (2011). "How is demand for natural gas determined across European industrial sectors?" In: *Energy Policy* 39.9, pp. 5499–5508.

Auray, Stéphane, Vincenzo Caponi, and Benoit Ravel (2019). "Price elasticity of electricity demand in france". In: *Economie et Statistique* 513.1, pp. 91–103.

Csereklyei, Zsuzsanna (2020). "Price and income elasticities of residential and industrial electricity demand in the European Union". In: *Energy Policy* 137, p. 111079.

Dedola, Luca, Mark Strøm Kristoffersen, and G Zullig (2021). "The extensive and intensive margin of price adjustment to cost shocks: Evidence from Danish multiproduct firms". In: *Manuscript, April*.

Dussaux, Damien (2020). *The joint effects of energy prices and carbon taxes on environmental and economic performance: Evidence from the French manufacturing sector*. Tech. rep. OECD environnment working paper 154, Paris.

Fontagné, Lionel, Philippe Martin, and Gianluca Orefice (2018). "The international elasticity puzzle is worse than you think". In: *Journal of International Economics* 115, pp. 115–129.

Ganapati, Sharat, Joseph S Shapiro, and Reed Walker (2020). "Energy cost pass-through in US manufacturing: Estimates and implications for carbon taxes". In: *American Economic Journal: Applied Economics* 12.2, pp. 303–42.

INSEE (2022). "Les entreprises face à la hausse des prix de l'énergie : des situations et des réactions contrastées". In: *Note de conjoncture – 15 December*.

Joussier, Raphael Lafrogne, Julien Martin, and Isabelle Mejean (2023). "Cost pass-through and the rise of inflation". In: *mimeo Sciences Po*.

Labandeira, Xavier, José M Labeaga, and Xiral López-Otero (2017). "A meta-analysis on the price elasticity of energy demand". In: *Energy policy* 102, pp. 549–568.

Marin, Giovanni and Francesco Vona (2021). "The impact of energy prices on socioeconomic and environmental performance: Evidence from French manufacturing establishments, 1997–2015". In: *European Economic Review* 135, p. 103739.

McWilliams, Ben et al. (2023). "How would the European Union fare without Russian energy?" In: *Energy Policy* 174, p. 113413.

Wolverton, Ann, Ronald Shadbegian, and Wayne B Gray (2022). *The US Manufacturing Sector's Response to Higher Electricity Prices: Evidence from State-Level Renewable Portfolio Standards.* Tech. rep. National Bureau of Economic Research.