

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 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 into 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 specific to only the most energy intensive firms. We also find that the impact of electricity shocks has weakened over time, suggesting that only firms able to adapt their production process to energy cost shocks have survived. Importantly, when faced with large electricity and gas price increases, firms are less able to reduce their consumption. These results shed light on the mechanisms of resilience of the European manufacturing sector in the context of the present energy crisis.

Keywords: Energy Crisis, Employment, Production, Competitiveness, Electricity, Gas

JEL classification: L6, Q41, Q43

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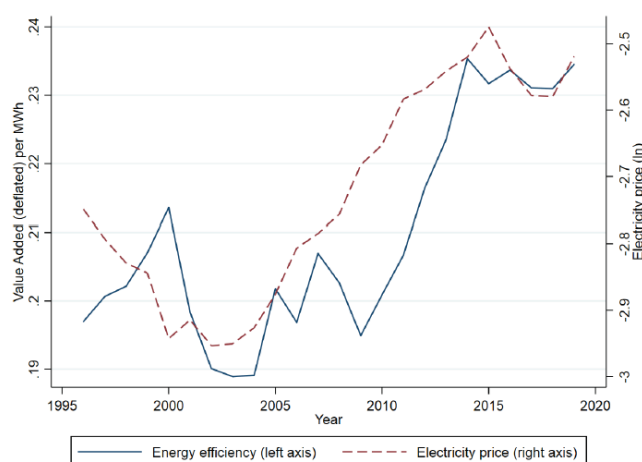
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NON-TECHNICAL SUMMARY

Concerns about the impact of the energy crisis on the European manufacturing sector have been central to the economic policy debate. This was particularly the case in the spring of 2022, when a potential embargo on Russian oil and gas was contemplated and the energy shock materialized in an unprecedented way. In France, however, this massive price shock did not provoke the sudden drop in industrial production that had been feared. At the same time, energy-intensive manufacturing firms significantly reduced their demand for electricity. This suggests that firms have found ways of adjusting not primarily through production scaling back, but through other channels, which can be described as substitutions.

Much can be learned from past episodes of energy price hikes and this paper mobilises plant- and firm-level data over a long period (1996–2019) for French manufacturing firms. Such granular approach sheds a precise light on the many channels of adjustments that manufacturing firms make in the face of energy price hikes. Combining the annual survey on energy consumption conducted at the plant level in France with balance sheets and custom data, this paper estimates the effect of gas and electricity price shocks on firm-level energy demand, efficiency, prices, exports, employment, production, and profits of French firms. This analysis confirms that the impact of energy shocks on energy efficiency is at work at the firm level. Figure 1 illustrates this important mechanism. On the period 1996-2019, energy prices paid by firms and energy efficiency look strongly correlated, i.e. the energy intensity of output declines in periods of raising energy prices.

Figure 1. Energy efficiency and electricity price



Source: EACEI and FICUS/FARE data. The figure plots the average electricity price (dash line) and energy efficiency of French firms (continuous line) in the period 1996-2019. The energy efficiency of firms is calculated as the ratio between the export-price deflated value added of firm and their energy consumption.

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 into 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 specific to only the most energy intensive firms. The price elasticity of energy demand has weakened over time suggesting that the adaptation to price shocks was stronger-and-easier-at the beginning of the period and that only firms able to adapt to energy cost shocks have survived. Importantly, this elasticity is also lower for large price hikes: when faced with large increases in energy prices, firms are less able to reduce their consumption in proportion to price hikes. These results shed light on the mechanisms of resilience of the European manufacturing sector in the context of the present energy crisis.

Les multiples canaux d'ajustement des entreprises aux chocs énergétiques : L'exemple de la France

RÉSUMÉ

Sur la base de données au niveau des entreprises du secteur manufacturier français, nous constatons que les entreprises s'adaptent rapidement, fortement et par de multiples canaux aux chocs énergétiques, même si les factures d'électricité et de gaz ne représentent qu'une petite partie de leurs coûts totaux. Sur la période 1996-2019, face à une augmentation idiosyncratique du prix de l'énergie, les entreprises réduisent leur demande d'énergie, améliorent leur efficacité énergétique, augmentent les importations d'intrants intermédiaires et optimisent l'utilisation de l'énergie de leurs unités de production. Les entreprises sont également en mesure de répercuter entièrement le choc des coûts sur leurs prix à l'exportation. Leur production, leurs exportations et l'emploi diminuent en conséquence. Ces multiples mécanismes d'ajustement font que la baisse des profits est soit non significative, soit faible, soit spécifique aux seules entreprises les plus intensives en énergie. Nous constatons également que l'impact des chocs de prix de l'électricité s'est affaibli au fil du temps, ce qui suggère que l'adaptation au choc était plus facile en début de période et que seules les entreprises capables de s'adapter aux chocs de coût de l'énergie ont survécu. On relève enfin que, confrontées à de fortes augmentations des prix de l'électricité et du gaz, les entreprises sont moins capables de réduire leur consommation à hauteur de la hausse des prix. Ces résultats mettent en lumière les mécanismes de résilience du secteur manufacturier européen dans le contexte de la crise énergétique actuelle.

Mots-clés : crise énergétique, emploi, production, compétitivité, électricité, gaz

Codes JEL : L6, Q41, Q43

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1 Introduction¹

“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 reduced by more than 75% 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 in 2022 electricity and gas prices for manufacturing firms increased by 45% and 107% respectively.

¹We thank Antoine Dechezlepretre, Leonardo Iacovone, Clémence Lenoir, Thierry Mayer, Julien Martin, Isabelle Méjean, Sandra Poncet, Andres Rodriguez-Clare, Michele Ruta, Daniel Xu and economists at the Banque de France, the French Treasury, World Bank and IMF for helpful comments on an early version of this paper. We also thank the participants of the Economic Policy Panel in Stockholm. Lionel Fontagné thanks the support of the EUR grant ANR-17-EURE-0001. The views expressed in this paper are the authors’ and do not necessarily reflect those of the Bank of France or the Eurosystem.

In January 2023, the sentiment around the possible consequences of an energy price crisis has changed, as illustrated by the following quote by the German Minister 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, i.e. “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 Bachmann et al. (2022) for Germany and by Baqaee et al. (2022) for Europe. An ex-post analysis is offered by Moll, Schularick, and Zachmann (2023).

Yet, the crisis impact is not over, the price spikes may still be gradually phased-in, and the manufacturing firms will likely face the consequences of energy price spikes in the coming months. Also, some (mostly small) companies are protected by government subsidies or price caps. However, it is clear that the European manufacturing sector 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. It uses historical data, instead of data on the latest period only, which helps digging into the various adjustment channels of firms to energy price shocks.

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.

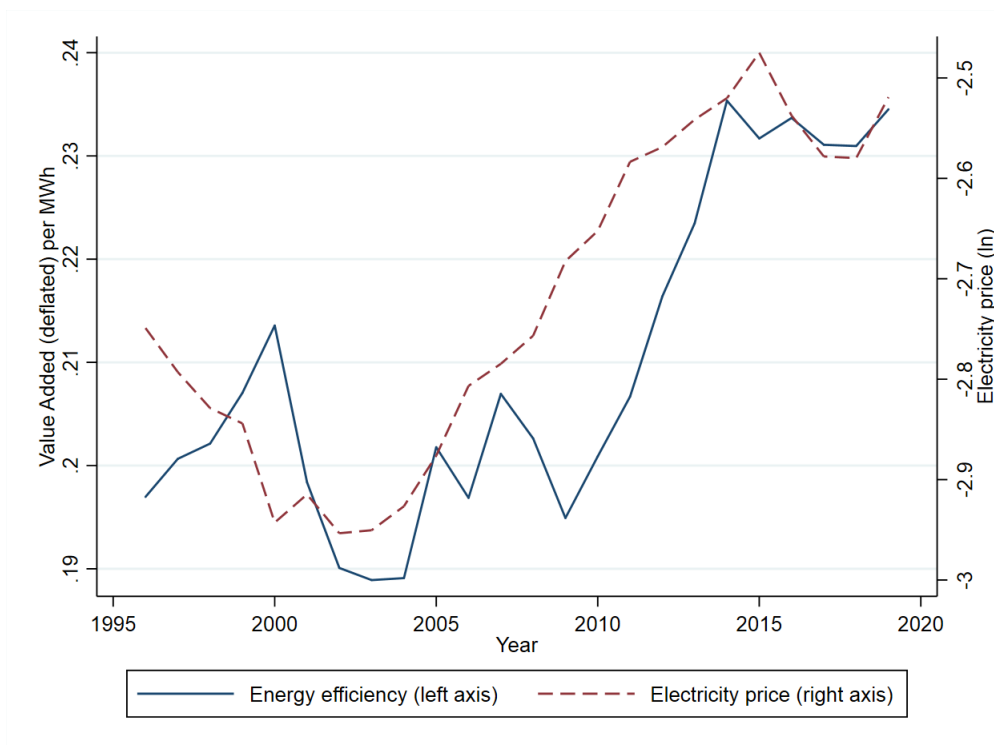
Figure 1 motivates at the aggregate level one important mechanism that we want to document at the firm level. On the period 1996-2019, energy prices paid by firms and energy efficiency look strongly correlated, i.e. the energy intensity of output declines in periods of raising energy prices.² Our main empirical result is that manufacturing firms adjust, strongly, quickly (in the year) and through multiple channels. We provide a very detailed analysis of these channels at the firm and plant level for the period 1996-2019. We are able to estimate the effect of gas and electricity price shocks on firm level energy demand, efficiency, prices, exports, employment, production and profits.

Idiosyncratic firm level shocks experienced by firms before 2022 may differ from the aggregate shock faced by European firms in 2022. For this reason, using our analysis to understand the present crisis must be done with caution. We acknowledge that past channels of adjustment may not be identical, qualitatively and quantitatively, to those of 2022. However, we show that our firm level elasticities (taking into account that these elasticities are lower for larger shocks and also have decreased over time) produce sound estimates of the aggregate impact of energy price shocks observed in 2022. Overall, our message is consistent with the early paper of Bachmann et al. (2022) on the aggregate impact of an embargo on Russian gas: the impact of a large energy price shock is negative (especially on competitiveness) but manufacturing firms do find multiple ways to adapt to large energy price shocks. The mechanisms of adjustment that we identify based on data before the crisis are also consistent with both anecdotal evidence reported in the media and survey data. Based on a recent survey, the French national statistical institute (Insee) documents that, faced with the energy shock, French manufacturing firms have adapted their production methods (38%) and invested to reduce or optimize their consumption (29%). Such changes in

²We do not observe domestic price in the data. So, for this figure we use export unit values as a proxy for prices, and calculate the export-price deflated value added of firms over time – axis on the left. Hence this figure considers only exporting firms.

production and consumption behaviour are more frequent in large plants. Only 4 % of plants reduced their production and 2% stopped it temporarily. Not surprisingly, this was more frequent in more energy dependent sectors, such as in the chemical sector.

Figure 1: Energy efficiency and electricity price.



Source: EACEI and Ficus/Fare data. Note: The figure plots the average electricity price (dash line) and energy efficiency of French firms (continuous line) 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 their energy consumption.

We first find that firms adjust to an energy price shock by reducing energy demand. Based on the period 1996-2019, our preferred (and conservative) estimates of the demand elasticity at the firm level is around -0.4 for electricity and -0.9 for gas – no matter the magnitude of the shock. However, for large price shocks, more similar to those experienced in 2022, elasticities are a bit smaller and equal to -0.2 for electricity and -0.7 for gas. Still, this suggests a significant reaction

of firms to energy price shocks. As for electricity, these elasticities are similar to some existing estimates. Conversely, for gas, our elasticities are larger than those obtained in the previous literature. 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 to energy shocks. 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 (or even more than full) impact of energy costs shocks into their export prices, which then reduces their competitiveness and entails 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 gas intensive firms. All in all, we interpret these results as a suggestive that firms are able to adjust and adapt strongly to the energy shock but that the competitiveness impact is significant.

One contribution of our paper is also to disentangle electricity and gas shocks. We find that electricity shocks affect employment and production in all firms, whereas gas shocks affect only those most intensive in gas, which represent a small share of manufacturing production and employment. This is an important element to understand the dynamics of the present crisis because electricity prices in the manufacturing sector have increased much less than gas prices.

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 has fallen over time. For example, on the period 2012-2019 (the closest to the present period) the impact of energy price shocks on employment and production are close to zero and insignificant contrary to the beginning of the period (1996-2003) when it is negative and significant. 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 estimate 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, Cali et al. 2022, Wolverson, Shadbegian, and Gray 2022, Lafrogne-Joussier, J. Martin, and Méjean 2023, Alpino, Citino, and Frigo 2023), or to exposition to cap-and-trade markets (Colmer et al. 2022) or regulations aiming to curb energy consumption (Chen et al. 2023). In particular, our paper is close to Marin and Vona (2021) who use French firm level data to estimate the wage and employment impact of climate policies captured by large carbon emitting energy prices. While their focus is different (specifically on wages and employment) and do not differentiate energy price shocks by source, some of the results presented in this paper are similar to theirs.

We explain in Section 2 the characteristics and the evolution of the French electricity and gas markets as well as the firm level data adopted in the paper. Section 3 discusses the identification strategy and the instrumental variable adopted to reduce the endogeneity concerns. Section 4 shows results on the elasticity of energy demand and analyzes how this elasticity varies over time

and changes with the size of the price shock. In Sections 5 and 6, 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 7. Estimates of adjustment channels to energy price shocks are discussed in the current context in Section 8. Section 9 discusses some policy implications, both in the short and the long term. The last section concludes.

2 The institutional context and descriptive statistics

2.1 The unstable French energy institutional context

A key 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 important characteristic is that many firms had to renegotiate long-term contracts (not necessarily fixed price) that ended during the period. These long-term contracts can shield firms against sudden price changes, and their expiry means that firms may experience a price rise or fall from one year to the next, depending on the year in which the contract was signed and its duration. These contracts may, on the contrary, include a price revision clause, making them responsive to changes in wholesale energy prices. Importantly for us, many changes in regulations occurred 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%. However, not all firms did it because the convenience to do so hinged on the difference between the firm specific previous contracted price and the (firm specific) TarTAM (transitory regulated tariff). This choice depended also on the date the previous contract was signed. This possibility was then stopped because deemed to be a sectoral subsidy by the European Commission, and therefore implied another change in the energy 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.³

Such a jugged landscape of taxes and tariffs available for firms on energy sources makes energy price dynamics really firm-specific. Also, the plausibly exogenous expiration date of contracts with energy suppliers makes the time variation of prices quasi-random. These two features of the institutional context make France a nice laboratory to test the firm-level consequences of energy price shocks.

2.2 Data and descriptive statistics

This paper relies mainly on *EACEI* database providing information on energy purchase (in k€) 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.⁴ 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 (FICUS/FARE, see below), we aggregate the *EACEI* database at the level of firms by summing electricity bill and consumption across surveyed plants within the same firm.⁵ 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

³The unit values of energy, used in this paper as a proxy for energy prices, are based on the energy bill of firms and hence cover also taxes.

⁴The survey has been conducted on firms with more than 20 employees.

⁵The 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. The *EACEI* data covers surveyed plants of large and small French firms. For large firms all plants are surveyed and *EACEI* data match perfectly other sources. However, it is possible that for small firms only a sub-sample of plants are covered by *EACEI*, and the energy quantities and prices refer only to surveyed plants. The resulting measurement error is reduced here because very few small firms are multi-plant (only 0.78% of firms with less than 50 employees are multi-plants).

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.⁶ 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 1996-2019.⁷ Finally, we use French Customs database providing information on import and export flows of French firms by destination country, product (CN8 classification) and year in the period 1996-2019. The French Customs Database contains all trade flows by firm-product-destination that are above 1000 Euros for extra EU trade and 200 Euros for intra-EU trade, so it can be considered representative of all French exporting firms. We also match the product classification of French Customs data with the BEC classification, and calculate imports of final *vs* intermediates inputs of each French firm in a given year.⁸ 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.⁹ 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.¹⁰

In Table 1 we show the descriptive statistics for our sample. The mean and median dependency of firms on electricity and gas are respectively 2.1 and 0.9 percent (for electricity), and 1.8 and 0.3 (for gas).¹¹ As expected, French firms rely much more on electricity than on gas. The largest share of firms' cost in France is labour, counting on average for the 28% of total costs.

The complex institutional context described above, and the dispersion of electricity price paid

⁶The total cost of firms include the wage bill (including wages and social security contributions), the purchase of intermediate products, raw material and energy. All these variables are from FICUS/FARE data.

⁷FICUS/FARE data are aggregated at the level of the firm and do not provide plant-level information.

⁸Intra-EU firm level imports are not exhaustive. Firms are obliged to declare their intra-EU imports only if above the threshold of 650k€. Below this threshold, firms may decide to declare or not. However, many firms declare intra-EU imports below such a threshold as observed in the Custom data.

⁹We use the average exported quantity of a given product for a given firm-destination combination in the period 1996-2019 as a weight for the weighted firm-destination-year specific export unit value.

¹⁰Real Exchange Rate is calculated using Penn World Table rev. 9.

¹¹The electricity and gas dependency at sector level (average across firms of a given sector) are reported respectively in Appendix Tables A1 and A2.

Table 1: Descriptive statistics.

Variable	Obs.	N. firms	Mean	Median
Electricity price (k€/MWh)	113,893	20487	0.071	0.068
Gas price (k€/MWh)	113,893	20487	0.031	0.029
Employment (unit)	113,893	20487	321	121
Electricity dependency (in % of tot costs)	113,893	20487	2.09	0.86
Gas dependency (in % of tot costs)	113,893	20487	1.77	0.33
Labor dependency (in % of tot costs)	113,893	20487	28.41	26.49
Electricity dependency (in % of var. costs)	113,893	20487	5.09	1.21
Gas dependency (in % of var. costs)	113,893	20487	3.32	0.47

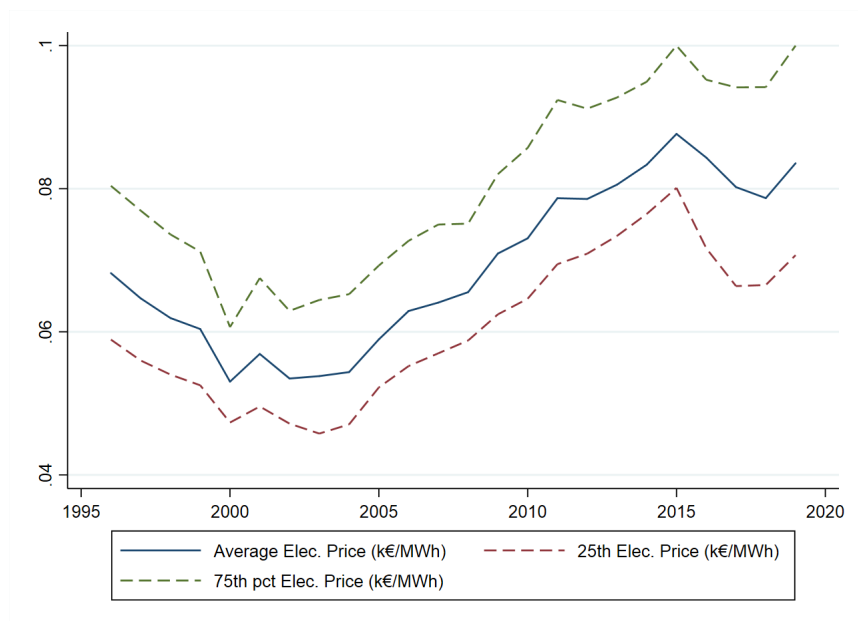
Notes: Descriptive statistics based on the sample of firms used in the econometric estimations. We include all firms consuming electricity and gas. Total costs used to compute factors' dependency of firms in rows 4-6 include the labor cost (social security contributions included), the purchase of raw material and other intermediate inputs (including energy). Variable costs used to compute factors' dependency of firms in rows 7-8 include the purchase of raw materials and other intermediate inputs.

by individual firms in a given year, produce a useful (aggregate) variation of the electricity price over time and a dispersed distribution of electricity prices across firms in a given year. This is illustrated in Figure 2 where we plot the average price in our sample, as well as the price paid at 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.

The description of the electricity market in France reported in the previous section suggests that electricity prices vary at the firm level for reasons that are both endogenous to the firm activity (in particular its *average* electricity intensity) 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 regulated tariffs, local weather). In the empirical part of this paper, we take into account the (endogenous) firm-specific factors in energy price formation by including firm fixed effects.

In the current economic situation, the propagation of electricity and gas price shocks to industrial firms is also affected by the highly heterogeneous nature of their energy contracts. These contracts, most often signed with utilities and other intermediaries, are generally renegotiated

Figure 2: Electricity price over time.



Notes: Electricity price of firms approximated by the ratio between the value of electricity purchase (k€) and quantity (MWh). Source: EACEI data.

after a period of one to three years, at dates that are intrinsically different from one firm to another. Based on a survey conducted in November 2022, INSEE (2022) reports that less than 20% of French manufacturing output is produced by firms whose electricity or gas contract is indexed to spot prices. Besides, 15% of manufacturing output is produced by relatively small producers that are offered a fixed, regulated electricity price, while 40% of manufacturing firms have long-term electricity contracts (resp. 60% long-run gas contracts). In the end, variations in wholesale energy prices, one of the components of energy prices for industrial customers, are not proportionally reflected in the energy price actually paid by industry.

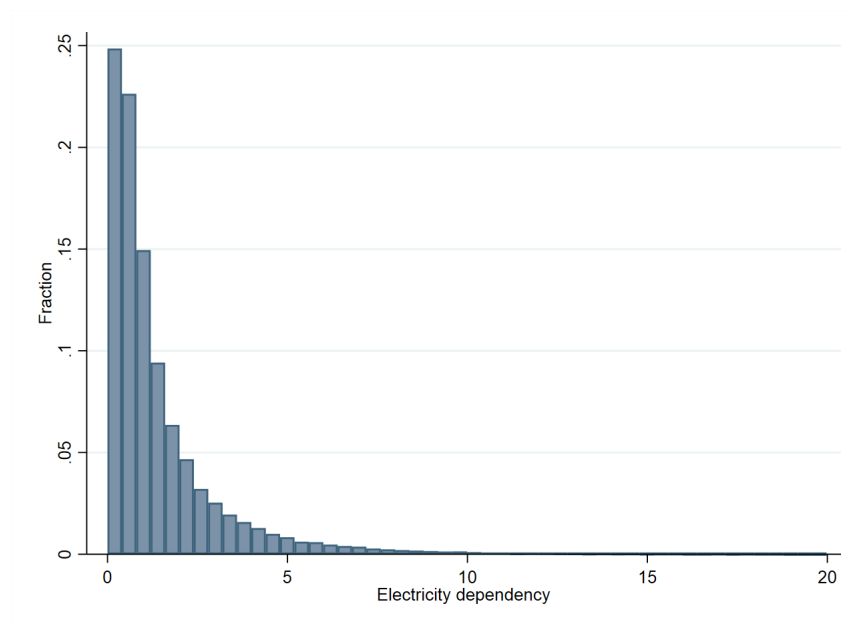
While the current energy shock crisis affects all EU countries, it affects manufacturing firms differently because energy contracts are renegotiated depending on the length of the contract. Based on its 2022 survey of manufacturing firms, INSEE (2022) estimates that more than half of French firms (56%) would be exposed to an electricity price increase in 2023. For gas, the proportion is 2/3. However, due to differences between contracts, expected price increases are very heterogeneous: 25% of firms expect no increase, while 42% expect electricity prices to at least double. Such a strong expected firm-specific effect of the current energy crisis motivates our firm-level analysis, and makes it a sound tool to understand different consequences of a common energy shock on different firms.

The different exposure to electricity and gas shock is a further explanation for the highly heterogeneous reaction of different firms to a common energy price shock. For example, while *all* manufacturing French firms use electricity, a sub-sample of them (around 40% in our sample) do not use gas.¹² We show in Figure 3 the empirical distribution of electricity dependency in our sample: it is defined as the share of the electricity bill in percentage of total costs (excluding the cost of capital). This dependency is below 5% for most of the firms, and around 2% on average as

¹²Since we consider the price of electricity *and* gas (separately in estimations), and because the price of gas is not observed for firms that do not use it, in our estimates we focus on firms that use both electricity and gas. However, we show that the electricity price elasticities do not change when including firms that use only electricity.

shown in Table 1.¹³ This dependency ratio is also a good guide to interpret the price response of firms: in the case of electricity, a 100% increase of price for a firm for which electricity represents 5% of costs (a very high dependency), even if fully passed on to the final consumer, represents a 5% increase in the firm's price.

Figure 3: Empirical distribution of electricity dependency.



Notes: Electricity dependency is defined as the ratio between the cost of electricity and the total costs of the firm (i.e. labor cost, purchase of raw material and other intermediate goods). *Source:* EACEI data.

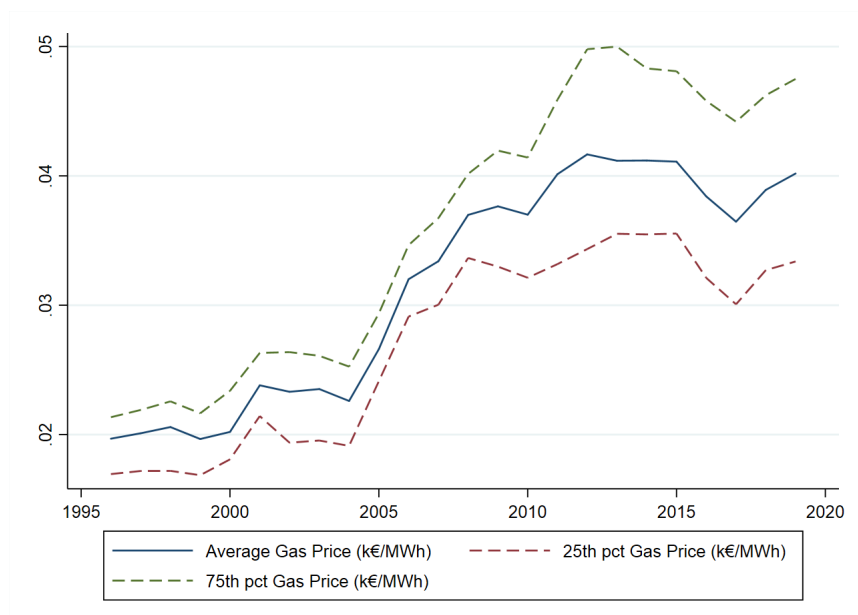
Like electricity prices, gas prices have increased over time (see Figure 4). We already noted that around 40% of manufacturing firms do not use gas. Even among those using gas¹⁴, their gas dependency is more heterogeneous than for electricity, as illustrated by Figure 5. Interestingly, the gas dependency has a highly concentrated distribution: the gas share of total costs for the top 10% most gas dependent firms is around 6-9%, but they represent on average only 6% of

¹³The electricity dependency is also very different across sectors. In Table A1 we show the electricity dependency of the most and less electricity dependent sectors.

¹⁴Manufacturing firms can use gas either as an energy source or as an input in an industrial process (e.g. production of agricultural fertilizers, pesticides).

employment in our sample.¹⁵

Figure 4: Gas price over time.



Notes: Gas price of firms approximated by the ratio between the value of gas purchase (k€) and quantity (MWh).

Source: EACEI data.

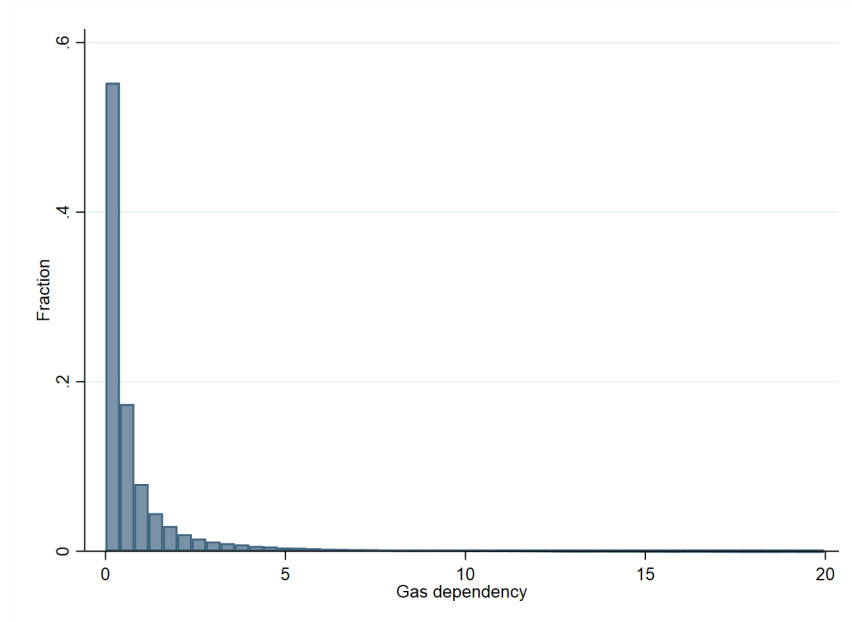
3 Identification strategy and endogeneity issues

3.1 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:

¹⁵Historically, 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 5: Empirical distribution of gas dependency.



Notes: Gas dependency is defined as the ratio between the cost of gas and the total costs of the firm (i.e. labor cost, purchase of raw material and other intermediate goods). *Source:* EACEI data.

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

where $y_{f,s,t}$ is the outcome of firm f in a given sector s and year t .¹⁶ The firm-specific outcomes are (in turn) the purchased quantity of electricity and gas, export prices and export quantities, employment, value added, profits, and energy efficiency. The explanatory variable of interest is the firm-specific price of electricity or gas, calculated as 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 firm, as well as the average workforce composition and capital intensity. When we move to the plant level in Section 7, we include plant fixed effects. 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, 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).¹⁷

For a clear-cut estimation of the demand elasticity, one should compare *treated* with *untreated* firms. While all firms in our sample pay electricity and gas bill, not all of them experience a *change* in the energy price for the institutional reasons detailed above (i.e. some firms do not renegotiate their contract within a given year). Therefore, our approach compares *de facto* treated

¹⁶FICUS/FARE data give information on the main sector (4-digit of the NAF classification) in which the firm operates.

¹⁷Periods are: 1997-1999; 2000-2002; 2003-2005; 2006-2008; 2009-2011; 2012-2014; 2015-2017; 2018-2019.

with untreated firms in the within dimension. Hence, with the disclaimer that the status of a given firm can change over time (i.e. from treated to untreated and vice versa) equation (1) delivers a standard estimate of the demand elasticity.

In order to inform on the aggregate response of energy demand and other economic outcomes to the price shock, we weight all regressions by the employment of the firm in the initial year. However, the inclusion of sector-time fixed effects makes our elasticity identified on differences with respect to the sector-average price shock (i.e. on deviations of firm's price from the average price of the sector) and precludes an interpretation in terms of macroeconomic demand elasticity to the price shock because the average effect is absorbed into the sector (and time) fixed effects.¹⁸ In Tables A5 and A6 we show OLS and 2SLS results by omitting sector-year fixed effects.

The investigation can be disciplined within a simple framework. We start with the profit function of firm f . Firm, sector and year subscripts are omitted for simplicity. The profit of firm f is the difference between its value added, VA and its wage bill wL , where w is the mean wage of the firm (which we assume to be fixed in the short term) and L its employment.¹⁹

$$\Pi = VA - wL. \quad (2)$$

Equation 2 establishes the accounting relation between ε_p^{VA} , namely the elasticity of value added to energy price p , the elasticity of employment to energy price ε_p^L , and the elasticity of profits to energy price ε_p^Π , shown by Equation 3:

$$\varepsilon_p^\Pi = \varepsilon_p^{VA} \times \frac{VA}{\Pi} - \varepsilon_p^L \times \frac{wL}{\Pi} \quad (3)$$

Part of the adjustment of firm f to the energy price shock goes through increased energy effi-

¹⁸Such a cross-section identification flavor echoes the macroeconomics literature that relies on cross-sectional individual data to identify macroeconomic mechanisms (Nakamura and Steinsson 2018).

¹⁹We are grateful to our discussant Julien Martin for suggesting this approach.

ciency, which we define as value added over energy demand $\frac{VA}{E}$. The elasticity of energy demand to the price shock is ε_p^E . Equation 3 thus implies:

$$\varepsilon_p^\Pi = \left(\varepsilon_p^{\frac{VA}{E}} + \varepsilon_p^E \right) \times \frac{VA}{\Pi} - \varepsilon_p^L \times \frac{wL}{\Pi} \quad (4)$$

How energy demand responds to energy price might differ for electricity and gas. Hence, we estimate ε_p^E separately for the two sources of energy in the empirical part of the paper.

3.2 Endogeneity

Firms choose their energy provider, the energy contract that best fits their activity and anticipation of future prices, and they negotiate the energy price provided they have some market power. For these reasons, the *level* of the price paid by a firm is likely endogenous to its characteristics. However, as discussed in Section 2, the institutional context suggests that the *changes* in the energy price of firms can fairly be considered exogenous to the firm: the evolution of electricity and gas prices of a firm with long-term contract partly depends on its expiration date, which is arguably exogenous to firm-specific characteristics and/or economic shocks. Also, firms on regulated prices or facing spot markets are also price-takers. For these reasons, in equation 1 we introduce firm fixed effects, exploit the within variation, and estimate the energy price elasticities using the arguably exogenous *changes* in the energy price of firms over time. Also, sector-year fixed effects further reduce any 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. For example, an expected positive demand shock could help the firm to negotiate a lower energy price, or a contract whose price varies according to the consumption volume. We adopt an Instrumental Variable (IV) strategy to address this endogeneity concern and check the robustness of our baseline OLS estimations. We follow a standard Bartik (shift-share) approach and instrument the energy price

$p_{f,s,t}^{IV}$ as follows:

$$p_{f,s,t}^{IV} = \left[\frac{p_{f,s,t_0}}{\bar{p}_{s,t_0}} \right] \times \bar{p}_{s,t} \quad (5)$$

where p_{f,s,t_0} 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 reduce endogeneity, in calculating the average sectoral price $\bar{p}_{s,t}$ we exclude the firm f 's price (leave-one-out approach):

$$\bar{p}_{s,t} = \frac{1}{N-1} \sum_{i \neq f \in N} p_{i,s,t_0} \quad (6)$$

where N is the total number of firms in each sector s .²⁰ The term in bracket in equation (5) 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 economic rationale for our instrument is that the exposition of firms at a given point in time to the overall evolution of energy prices is mediated by their permanent (dis)advantage compared to competitors in the same sector: any time-varying sector specific change in the price of energy translates into firm-specific price changes through a time-invariant firm-specific factor which we interpret as bargaining power. We accordingly assume that price difference between firm f and its sector has a permanent component.

The exclusion restriction of our instrument is based on two assumptions. First, variations in the sector-specific average energy price do not depend on firm-specific characteristics. This assumption is likely satisfied because we explicitly omit firm f from the calculation of the average sector price, because the terms and the types of contracts are uncorrelated across firms in a sector,

²⁰We replace sector-year with year fixed effects in the 2SLS estimations to have sufficient power for identification which rests upon sector-year variation.

and because the expiration date of energy contracts of other firms in the sector $i \neq f$ (determining $\bar{p}_{s,t}$ in equation 6) is likely uncorrelated with the price setting of firm f . The second exclusion restriction assumption bases on the orthogonality between the initial firm's ability to bargain (term in brackets in eq. 5) and the *contemporaneous* variation in the economic outcomes of the firm.²¹ This assumption likely holds because firm fixed effects capture any firm-specific factor that may have affected both 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 for weak-IV test and the p-value of Anderson-Rubin Wald test on the weak-instrument-robust inference. These statistics confirm : (i) the relevance of the IV (i.e. significant correlation between the IV and observed energy price of the firm), (ii) the absence of weak-IV bias problem, and (iii) the possibility of making inference even in case of weak IV. While this type of instrument has been extensively used in the literature, one concern is its robustness to heterogenous treatment effects across sectors or over time (de Chaisemartin and Lei 2021). We therefore report most of our results using a simple lagged structure, which addresses endogeneity without resorting to complex assumptions. The IV identification strategy is mostly used to check the robustness of our OLS estimates with lagged variables.

4 Energy demand in response to energy price shocks

The first specification in Table 2 suggests a high (almost unitary) elasticity of demand for electricity. However, this first specification suffers an important reverse causality problem: 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 (see columns 2-3). We obtain

²¹Any direct effect of sector-specific energy price on firm outcomes is captured by time-sector fixed effects.

a lower electricity demand elasticity, around -0.5, when using lagged electricity price in columns (2) and (3). Interestingly, the elasticity is not much affected when controlling for value added of the firm in column (3). This suggests that the reduction of electricity demand takes place mostly through other channels than a reduction of production. This is important in the present context, in which a policy concern is that the reduction in energy demand could only be achieved by a drastic reduction in industrial production. A second way of reducing the endogeneity concern is controlling for firm-time fixed effects. In regression (4) we include firm-by-period fixed effects (where periods are 3-year windows) to control for any firm-specific characteristics that varies over time. The elasticity is close to the lagged specification. To fully address the endogeneity concern from both reverse causality (the possible relation between firm level energy prices and demand) and measurement error (energy prices computed here as unit values), in column (5) we show 2SLS estimation results. Reassuringly, both the lagged regressions and the instrumental variable estimation generate electricity demand elasticities that are similar to those obtained by Marin and Vona (2021). Our preferred estimate is therefore around -0.4 to -0.5 for electricity demand. One possible concern is also 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 same structure of Table 2 is used to show results on the elasticity of demand for gas in Table 3. Overall, the point estimates are larger with a lower bound of around -0.9 which we will take as our preferred estimate. This elasticity is higher than that obtained in the existing literature. For example, Andersen, Nilsen, and Tveteras (2011) find an elasticity for the French manufacturing sector around -0.14.

In appendix Table A3, we analyse the persistence of the impact of price shocks and show

Table 2: Electricity demand price elasticity

Dep Var:	<i>Firm electricity demand (ln)</i>				
	(1)	(2)	(3)	(4)	(5)
Electricity price (ln)	-1.089*** (0.212)			-0.628*** (0.091)	-0.372* (0.192)
Elec. Price (ln) lag		-0.536*** (0.197)	-0.467** (0.199)		
Value Added (ln)			0.353*** (0.030)		
Estimator		OLS			2SLS
Firm FE	yes	yes	yes	no	yes
Year FE	no	no	no	no	yes
Sec-Year FE	yes	yes	yes	yes	no
Firm-Per FE	no	no	no	yes	no
First stage IV coeff.					0.262***
K-P Wald F-stat					549
A-R Wald test (p-val)					0.039
Observations	108,344	90,384	89,720	87,389	108,342

Notes: The dependent variable is the total quantity of electricity purchased by firm in a given year. Electricity price approximated by value over quantity purchased in the year. Standard error are cluster by firm in columns (1)-(4). 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 in column (5). *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

the estimates of the elasticity of demand for gas and electricity with lags up to year $t - 2$. For electricity, the lag at $t - 2$ is not significant and its inclusion does not change the main impact at $t - 1$. For gas, the lag at $t - 2$ is significant and negative. The cumulative impact remains similar with a total elasticity of around -0.9 and the main effect coming a year after the shock. We can therefore conclude that the impact on demand is rapid and does not reverse after the shock.

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 change with the magnitude of the price shocks. To do so, in Table 4 we show the electricity and gas demand elasticity for respec-

Table 3: Gas demand price elasticity

Dep Var:	<i>Firm gas demand (ln)</i>				
	(1)	(2)	(3)	(4)	(5)
Gas price (ln)	-1.762*** (0.270)			-0.944*** (0.147)	-1.236*** (0.130)
Gas. Price (ln) lag		-0.922*** (0.209)	-0.899*** (0.217)		
Value Added (ln)			0.288*** (0.032)		
Estimator		OLS			2SLS
Firm FE	yes	yes	yes	no	yes
Year FE	no	no	no	no	yes
Sec-Year FE	yes	yes	yes	yes	no
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	87,389	108,342

Notes: The dependent variable is the total quantity of gas purchased by firm in a given year. Gas price approximated by value over quantity purchased in the year. Standard error are cluster by firm in columns (1)-(4). 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 in column (5). *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

tively negative and positive price changes (see columns 1-2), for positive price shocks below 25th percentile (column 3) and price changes comprised between 25th and 75th percentile (column 4). Results using large energy price shocks, above 75th percentile, are reported in column (5) of Table 4. The electricity demand elasticity is reduced but not zero: -0.23 for the largest price increases of our sample (that correspond to a 36% price increase on average). This is also true for gas (where large price increases correspond to 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.

Table 4: Non-linear energy price demand elasticity

<i>Panel a: Electricity demand (ln)</i>					
	(1)	(2)	(3)	(4)	(5)
Elec. Price (ln) lag	-0.755*** (0.241)	-0.295*** (0.065)	-0.068 (0.126)	-0.342*** (0.103)	-0.228*** (0.071)
Observations	34,504	38,015	7,284	17,592	6,416
<i>Panel b: Gas demand (ln)</i>					
	(1)	(2)	(3)	(4)	(5)
Gas. Price (ln) lag	-0.507*** (0.101)	-1.123*** (0.156)	-1.232*** (0.322)	-1.061*** (0.204)	-0.712*** (0.121)
Observations	27,676	44,415	8,566	20,486	7,585
Price shock	Negative	Positive		Positive	
			<i>Small</i>	<i>Medium</i>	<i>Large</i>
Avg $\Delta \ln(p^{Elec})$	-8.7%	13.1%	1.3%	7.5%	36.2%
Avg $\Delta \ln(p^{Gas})$	-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. Cluster firm robust standard errors in parenthesis. *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

We also analyse 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 Table 5, 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 stronger-and-easier at the beginning of the period and 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

4), during a more recent period (2012-2019), the price elasticity of electricity demand is -0.16. This is the most conservative estimate that can be used to think of the policy implications of the 2021-2022 energy price shock.

Table 5: Time-varying energy demand elasticity

Dep Var:	Electricity	Gas
	Demand	Demand
	(1)	(2)
$p_{i,t-1}^{Elec} \times \text{Period 96-03}$	-0.622** (0.286)	-0.196 (0.228)
$p_{i,t-1}^{Elec} \times \text{Period 04-11}$	-0.506*** (0.136)	-0.322** (0.151)
$p_{i,t-1}^{Elec} \times \text{Period 12-19}$	-0.326** (0.146)	-0.240 (0.158)
$p_{i,t-1}^{Gas} \times \text{Period 96-03}$	-0.292*** (0.083)	-1.408*** (0.204)
$p_{i,t-1}^{Gas} \times \text{Period 04-11}$	-0.077 (0.065)	-0.506*** (0.125)
$p_{i,t-1}^{Gas} \times \text{Period 12-19}$	-0.271 (0.186)	-0.755*** (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. Cluster firm robust standard errors in parenthesis. *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

5 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. The pass-through to production prices impacts negatively the competitiveness of the firm and the demand for its products. Employment is affected because of the fall in production.

Hence, we first analyse 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 current shock is aggregate and it affects French firms (although heterogeneously) and European firms too.

Hence, we now analyse how energy price shocks impact manufacturing firms' export prices and performance. For this estimation, we use firm level and destination specific data coming from customs data. Table 6 first shows that firms are able to pass through the energy price shock into their export prices. A 10% increase in electricity and gas prices lead manufacturing exporters to increase their prices by around 0.4% and 0.13% respectively. Given that electricity and gas account respectively for an average of 2.1% and 1.8% of the costs for which we have information (labour and intermediate goods), this suggests that the pass through into export prices is at least 100%. One interpretation is that manufacturing firms view energy costs (as well as intermediate goods) as marginal costs. Labour costs (that make around one third of their total costs) may, at least in the short run, be viewed as a fixed cost and may therefore not be taken into account in short term price changes. This evidence on export prices is consistent with the study of Lafrogne-Joussier, J. Martin, and Méjean (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.

Not surprisingly, the increase in export prices generates a fall in export quantities. The im-

fact 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 was not sufficient to fully compensate the international competitiveness effect induced by the energy price shock.

Table 6: Export related outcomes

Dep Var:	Export price (ln)		Export quantity	
	(1)	(2)	(3)	(4)
Elec. Price (ln) lag	0.040*** (0.007)	0.040*** (0.006)	-0.255*** (0.056)	-0.153*** (0.049)
Gas. Price (ln) lag	0.015*** (0.005)	0.012** (0.005)	-0.142** (0.064)	-0.089 (0.054)
Real Exchange Rate (ln)	0.049*** (0.008)		0.336*** (0.075)	
Firm-Dest. FE	yes	yes	yes	yes
Sec.-year FE	yes	yes	yes	yes
Dest.-Year FE	no	yes	no	yes
Observations	1,686,631	1,914,109	1,686,558	1,914,109

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

6 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. This logical sequence brings us back to the decomposition of the elasticity of profit to the energy price outlined above. We can now provide an order of magnitude for each of the terms in the decomposition provided by Equation 4. Table 7 shows the results on production, employment, energy efficiency and profit elasticity to energy prices (both electricity and gas). We saw above that lag-price strategy produces more conservative estimation of the energy demand elasticity. So, in Table 7 we present the estimates using lagged energy prices.

The effect of an electricity price shock is to reduce employment and production (see columns 1 and 3 in Table 7). 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% (see Table 6 columns 1-2). In Table 6, the quantity exported decreased by 2.2%, consistent with a price elasticity around 5. The decrease of export values is around 1.8%, which is similar to the 1.6% fall of total production showed in Table 7 column (3). In specifications (2) and (4) of Table 7 we interact the electricity price with the electricity and gas dependence of the sector in which the firm f operates.²² Interestingly, we find little evidence that firms in electricity intensive sectors react differently than firms in less electricity intensive sectors. For gas, the message is a bit different. We find a negative impact of a price shock only for firms in sectors having non-null gas dependency (i.e. only interaction term

²²The sector electricity and gas dependency are calculated follows. First, we calculate the firm-specific energy dependency as the share between energy bill and the total costs of the firm. Second, we average firm-dependencies at sector-year level (weighting by firms' employment). Finally, we take the average sector dependency over the entire period 1996-2019.

statistically different from zero).

As for the other outcomes in columns (5)-(8). The energy efficiency (measured by the ratio of value added to MWh) increases significantly in case of a positive gas price shock, but not in case of electricity price shock. Profits fall moderately, but only for positive changes in the electricity price (-1.6%) and for positive changes in gas price only in gas dependent sectors. 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.

These results can be rationalized using the decomposition of Equation (3) for electricity: using estimates in Table 7, $\varepsilon_p^{VA} = -0.16$ in column (3) and $\varepsilon_p^L = -0.15$ in column 1. The share of labour ($\frac{wL}{VA}$) is around 55% in our sample, and therefore $(\frac{VA}{\Pi}) = 2.2$. These values imply that the elasticity of profit to the price of electricity is 0.17, the point estimates reported in column 7 of Table 7.²³

Similarly, equation (4) shows that ε_p^{VA} , which is -0.16 in column 3 of Table 7, can be decomposed in $\varepsilon_p^{\frac{VA}{E}}$ equal (acknowledgedly noisy) to 0.21 in column 5 of Table 7 and ε_p^E . This implies a price elasticity of electricity demand ε_p^E equal to -0.37, close to the point estimate reported in column 3 of Table 2.²⁴

²³This calculation cannot be done for gas, given the imprecision of estimates.

²⁴The estimated price elasticity of electricity demand is -0.47 in column 3 of Table 2. Using the IV, the point estimate is -0.37 in column 5 of Table 2.

Table 7: Firm-level outcomes: OLS results

Dep Var:	Empl. (ln)		Value Add. (ln)		Erg Eff. (ln)		Profit (ln)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Elec. Price (ln) lag	-0.150*** (0.042)	-0.161** (0.079)	-0.159*** (0.042)	-0.060 (0.077)	0.214 (0.160)	0.578* (0.319)	-0.162* (0.085)	-0.021 (0.159)
Elec. Price (ln) lag x Ele dep.		0.008 (0.042)		-0.086* (0.045)		-0.312** (0.143)		-0.124 (0.085)
Gas. Price (ln) lag	-0.017 (0.035)	0.048 (0.043)	-0.013 (0.042)	0.067 (0.052)	0.379*** (0.128)	0.423*** (0.156)	-0.010 (0.068)	0.052 (0.085)
Gas. Price (ln) lag x Gas dep.		-0.071** (0.036)		-0.088*** (0.026)		-0.050 (0.046)		-0.071** (0.032)
Firm FE	yes	yes	yes	yes	yes	yes	yes	yes
Sec-Year FE	yes	yes	yes	yes	yes	yes	yes	yes
Observations	90,384	90,384	89,720	89,720	89,720	89,720	72,499	72,499
R-squared	0.961	0.961	0.960	0.960	0.879	0.880	0.883	0.883

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. Cluster firm robust standard errors in parenthesis. *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

In appendix (see Table A4), we analyze the persistence of the impact of price shocks and present estimates of the elasticity of demand for gas and electricity with lags up to year $t - 2$. We find no effect beyond one year and the inclusion of $t - 2$ prices does not change much the main coefficients. The only instance of persistence is for energy efficiency increasing 2 years after a positive gas price shock. There is no sign of reversal either which means that the negative impact on production and employment seem permanent.

In Table 8, we analyze whether the impact of energy price shocks has changed during the period 1996-2019 by interacting the (lagged) price shocks with three period dummies. Consistent with results of Table 5 which suggested a falling energy demand elasticity, the impact of energy price shocks on employment (column 1), value added (column 2), energy efficiency (columns 3) and profits (column 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 absorb these shocks or have disappeared if they were not able to adjust. This suggests that French manufacturing firms entered the present energy crisis after a period of adjustment to energy shock and/or selection (i.e. exit). Remember also that figure 1 provided evidence of an increased energy efficiency starting in 2010.

A battery of robustness checks are reported in the appendix section. Table A5 shows a robustness check excluding sector-year fixed effects and our results hold. We also show in Table A6 a set of results for energy demand and other outcomes using IV strategy excluding year fixed effects.²⁵ The estimated coefficients are similar to the OLS estimations. Table A7 shows our baseline results using the full sample of firms (i.e. including firms that do not use gas in production), and the elasticities to electricity price remain qualitatively the same. Finally, in Appendix Table A8 we interact electricity and gas price with the energy dependency of firms and show that, in general, elasticities do not depend on the energy dependency of firms.

²⁵The exclusion of year fixed effects improves the power of the IV as it exploits the time variation of energy prices.

Table 8: Time-varying elasticity on other outcomes

Dep Var:	Employment	Value added	Energy efficiency	Profit
	(1)	(2)	(3)	(4)
$p_{i,t-1}^{Elec} \times \text{Period 96-03}$	-0.242*** (0.078)	-0.280*** (0.075)	0.153 (0.236)	-0.491*** (0.137)
$p_{i,t-1}^{Elec} \times \text{Period 04-11}$	-0.192*** (0.045)	-0.159*** (0.049)	0.250* (0.138)	-0.121 (0.134)
$p_{i,t-1}^{Elec} \times \text{Period 12-19}$	-0.057 (0.050)	-0.066 (0.061)	0.213 (0.150)	0.074 (0.132)
$p_{i,t-1}^{Gas} \times \text{Period 96-03}$	-0.110 (0.085)	-0.067 (0.074)	0.558*** (0.105)	0.021 (0.139)
$p_{i,t-1}^{Gas} \times \text{Period 04-11}$	-0.018 (0.052)	0.010 (0.069)	0.190** (0.089)	0.038 (0.106)
$p_{i,t-1}^{Gas} \times \text{Period 12-19}$	0.042 (0.040)	0.005 (0.046)	0.382* (0.205)	-0.077 (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. Cluster firm robust standard errors in parenthesis. *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

7 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 multi-plant firms. Another related channel is to increase imports of intermediate inputs, presumably in substitution of the most energy intensive ones.

In Table 9, 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 (with 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 (or, in other words, the energy price of other plants of the same firms increases the energy demand of the specific plant). 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 in columns (2) and (4), the effect is somewhat reduced.

Table 9: 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*** (0.029)	-0.115*** (0.027)	-0.036 (0.037)	-0.008 (0.038)
Elec. Price (ln) lag firm	0.079*** (0.026)	0.057** (0.024)	0.059* (0.035)	0.048 (0.036)
Gas. Price (ln) lag plant	-0.069*** (0.019)	-0.051*** (0.018)	-0.420*** (0.043)	-0.404*** (0.044)
Gas. Price (ln) lag firm	0.014 (0.013)	0.011 (0.013)	0.107*** (0.026)	0.105*** (0.028)
VA (ln)		0.281*** (0.012)		0.237*** (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. Cluster plant robust standard errors in parenthesis. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.

Finally, in Table 10, 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. Column (1) in Table 10 does not show a statistically significant

increase in *total* imports following energy price shocks. Column (2) in Table 10 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 10: Imports and energy price shocks

Dep Var:	Tot Imports	Interm. Imp.
	(1)	(2)
Elec. Price (ln) lag	0.330 (0.230)	0.565** (0.286)
Gas. Price (ln) lag	-0.111 (0.109)	-0.195 (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. Cluster firm robust standard errors in parenthesis. *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

8 The 2022 energy crisis in the lens of our estimates

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 react and adapt to changes in the price of energy. This may explain the resilience of European manufacturing firms during the 2022 energy price crisis. But, to what extent the channels we identified during the period 1996-2019 were at work during the recent crisis? There are several important differences between the current crisis and the period 1996-2019. First, the 2022 crisis was characterized by an aggregate shock that impacted all firms in (almost) all sectors, while our identification of the impact of energy shocks is based on changes of firm-specific energy prices. During the period

we use in this paper (1996-2019), the aggregate energy prices increased (especially for gas, whose price almost doubled). However, given the inclusion of sector-year fixed effects, our regressions do not use variations in the aggregate dynamics of energy prices to estimate the various elasticities. Tables A5 and A6 in appendix show our results (OLS and IV) where sector-year fixed effects have been removed so that the identification (also) uses aggregate yearly price movements. The estimated elasticities are similar to our baseline estimations. This suggests that the adjustment mechanism of firms is similar in presence of a firm-specific or sector-aggregate energy price shock. The exception is for aggregate gas shocks that have larger negative effects on employment, production and profits. The aggregate - European wide - feature of the 2022 shock also means that the competitiveness effect may have been smaller, as it affected more or less similarly all European firms. Note however that because of the length of contracts and because some contracts were renegotiated during the 2022 crisis and some were not, firms experienced shocks of different size. Hence, part of the shock was also very idiosyncratic – as captured by our identification.

A second difference between the 2022 energy price shock and the firm level price shocks we exploit in the 1996-2019 period concern the magnitude of the shock. According to INSEE data, in nominal terms electricity (gas) prices for manufacturing firms increased by 90% (38%) between March 2022 and March 2023. However, if one computes the shock as the difference between the average of a “normal” (non COVID) year (2019) and the average from March 2022 and March 2023, it is smaller for electricity (+52%) and larger for gas (+121%). The inclusion of sector-year fixed effects in our regressions controls for yearly sectorial manufacturing prices; and our estimates 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 products (excluding energy) during the same period (average of March 2022-March 2023 and average of 2019): it was about 22% in France. Hence, the real electricity price increase was around 30% and around 100% for gas. Remember that when we restrict our estimates on large shocks, these are 36.2% for electricity

and 53.1% for gas. Hence, for electricity the larger shocks of the 1996-2019 period are similar to the 2022 crisis. For gas, the 2022 price increase is around twice the size of the largest shocks we observe during the 1996-2019 period. This calls therefore for prudence in using our results for the 2022 gas crisis.

Our demand elasticity estimates suggest that large and more recent shocks generate smaller elasticities. We retain therefore an elasticity of around 0.16 for electricity and 0.7 for gas. According to McWilliams and Georg Zachmann (2023) in March 2023, gas consumption by the industrial sector in France was reduced by 17% relative to the 2019-2021 average. Clearly, our estimated gas demand elasticity is too large. This can be explained by the size of the shock: a larger shock reduces the demand elasticity. As for electricity, our estimate suggests an average 4.8% fall of demand in the manufacturing sector due to the shock.²⁶

Our last piece of evidence is that average manufacturing production in France was on average 3.3% lower in the period March 2022-March 2023 compared to the average of 2019. If we take our full period elasticity (-0.15) of electricity prices on production and the real electricity price shock (+30%) during the same period, this would predict a similar, slightly larger, fall of 4.5%. Note, however, that during the latest period (2012-2019) the elasticity is around -0.07 (although not significant). In this case, the predicted production fall is -2.1%. As for gas, the real price shock is much larger (+100%) but applies only to the 58% of manufacturing firms that use gas. Also, the production elasticity of the gas price is negative only for the most gas intensive firms. Out of the 58% of manufacturing firms that use gas, the great majority have a very small gas intensity and therefore only slightly affected by a change in the price of gas. Hence, our results suggest that a gas price shock does not have a large aggregate direct impact on manufacturing and employment. This was also the conclusion of Bachmann et al. (2022) with a state-of-the-art multi-sector macro

²⁶This figure must be interpreted with some caution, as we do not have data on trends in electricity demand in the French manufacturing sector over the period considered above. The data reported by INSEE (for a different period, December 2021 to December 2022) is for energy intensive manufacturing firms only. It is therefore larger than our estimates (demand for electricity fell by 22%).

model with production networks based on Baqaee and Farhi (2021) for Germany. For France, Baqaee et al. 2022 suggest that the aggregate impact of gas price change, based on a similar analysis, was likely modest.

Although our quantitative estimates cannot be readily used in the present crisis (especially for gas), we can conclude from these simple back of the envelope exercises that our elasticities are broadly consistent with what was observed during the current crisis, in particular if one considers that a larger shock entails a smaller demand elasticity and that the impact of energy shocks on the manufacturing sector have decreased over time. This suggests that the very detailed mechanisms that we have identified and quantified at the firm and plant level on past data are useful to analyze the adjustment of firms in the present crisis.

9 Policy options discussion: short and long term

Different European countries have adopted different short term policy responses to the energy crisis, partially shielding mostly households and small firms from the price shock. Some policies (e.g France) amounted to a price cap with a maximum increase in prices lower than what the market would have produced. This was targeted on very small firms. In other countries, taxes and duties on energy were lowered, again mostly targeted to small firms. The ministry of economy in Germany has contemplated plans for a subsidized price of 0.06€/per kWh that would only be available to certain industries, and would be capped at 80% cent of a business's consumption in a bid to push energy saving.²⁷

In this section we discuss and compare two stylized types of subsidies. In the first option, a government absorbs part of the market energy price hike $\Delta p^e/p^e$ between periods 1 and 2 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 market price increase and s is the absorption rate. The fiscal cost of this policy is therefore :

²⁷See Financial Times May 5, 2023.

$$\bar{C} = s(p_2^e - p_1^e)Q_2^e \quad (7)$$

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 in percentage terms would be:

$$\frac{\Delta Q^e}{Q^e} = -\beta(1 - s)\frac{\Delta p^e}{p^e} \quad (8)$$

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

$$\bar{C} = s\frac{\Delta p^e}{p^e}Q_1^e[p_1^e - \beta(1 - s)(p_2^e - p_1^e)] \quad (9)$$

A second policy option is for the government 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 driven, at the margin, by the market price :

$$\frac{\Delta Q^e}{Q^e} = -\beta\frac{\Delta p^e}{p^e} \quad (10)$$

The fiscal cost of this second option is:

$$\tilde{C} = \alpha Q_1^e(p_2^e - p_1^e) \quad (11)$$

We constrain the fiscal cost of the two options to be equal, and compare the associated price increase.²⁸ Remember that the price increase of the first option is simply $(1 - s)\Delta p^e/p^e$. In the second option, the constraint of equal fiscal cost pins down the share of energy demand for which

²⁸Of course, fixing the price increase and comparing the fiscal costs leads the same conclusion.

the price hike is fully absorbed:

$$\alpha = s \left[1 - \beta(1 - s) \frac{\Delta p^e}{p^e} \right] \quad (12)$$

The market price increase ($\Delta p^e/p^e$) affects firms only for a share of their electricity demand in the second period: $Q_2^e - \alpha Q_1^e$ with $Q_2^e = Q_1^e(1 - \beta \Delta p^e/p^e)$ which is lower than Q_1^e because electricity demand is affected at the margin by the market price increase. Hence, the average effective price increase for firms is (for $\alpha < 1$):

$$\frac{\tilde{\Delta p^e}}{p^e} = \frac{\Delta p^e}{p^e} \frac{Q_2^e - \alpha Q_1^e}{Q_2^e} = \frac{\Delta p^e}{p^e} \frac{1 - \alpha - \beta \frac{\Delta p^e}{p^e}}{1 - \beta \frac{\Delta p^e}{p^e}} \quad (13)$$

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 (second option). 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. 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 more efficient and 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 4) 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.²⁹

These distortionary policy responses to reduce the energy price shock for manufacturing firms can be very costly. McWilliams and Georg Zachmann (2023) report 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 of euro. These include measures both for households and firms. We do not have a breakdown that distinguishes the fiscal cost of price measures for firms. The estimated cost of the German plan to subsidize electricity for energy intensive manufacturing firms is 25-30 billion of euros per year.

Our results of the previous sections suggest 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 1996-2019 as energy prices and energy efficiency are strongly correlated. Given this observed ability of firms 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. This is particularly important for sectors and firms that are highly dependent on gas. In France and in Europe, there are few sectors and firms for which the cost of gas represents more than 10% of total costs. Policy instruments should be targeted towards these sectors and firms. The EU should also support decarbonized production processes built on large-scale deployment of domestic renewables. This has the additional advantage of improving competitiveness by reducing energy costs.

Moreover, if another policy objective is to reduce energy dependence and increase the re-

²⁹The 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 $\beta^L < \beta^M$. With our estimates of β^L and β^M for electricity (around 0.2 and 0.34) this suggests that the non linear subsidy is superior only for $s > 0.32$.

Table 11: Heterogeneous electricity price elasticity and the energy efficiency of firms.

Dep Var:	Employment	Value added
	(1)	(2)
Elec. Price (ln) lag	-0.130*** (0.038)	-0.148*** (0.046)
Elec. Price (ln) lag × Energy Eff (ln)	0.034 (0.032)	-0.002 (0.033)
Gas. Price (ln) lag	-0.062* (0.034)	-0.144*** (0.042)
Gas. Price (ln) lag × Energy Eff (ln)	0.094** (0.037)	0.094*** (0.034)
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. Cluster firm robust standard errors in parenthesis. *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

silience of manufacturing to energy shocks, increasing energy efficiency may help. This is suggested - at least for gas - by the results of Table 11 where we interact energy prices with energy efficiency (the average of the past three years). In Table 11 we 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 subsidize 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.

10 Conclusion

The energy crisis is not over, prices spikes will be gradually phased in, while manufacturing firms will thereafter to cope with the consequences of the energy transition on energy prices. It is therefore of utmost importance to scrutinize the reasons why the manufacturing sector has been more resilient than expected. This paper tentatively uncovered the underlying adjustment mechanisms using historical firm level data for the French manufacturing sector. It shows that, when faced with an idiosyncratic energy price increase, firms adapted quickly, strongly and through multiple channels to energy shocks. They reduce their demand, improve their efficiency, increase their imports of energy intensive intermediate inputs and optimize the activity level of their different plants. There is indeed eventually a toll on competitiveness: firms pass-through the cost shock into their export prices, and see their demand, production and employment fall. Importantly firms have become more resilient to electricity price shocks over time, which can be interpreted as the combined outcome of energy efficiency gains within firms, and firm or plant selection. The mere presence of these numerous adjustment channels must be borne in mind when designing transitional support to industry during periods of soaring energy prices. If, as we have shown here, there is no panacea when it comes to designing an effective mechanism to respond to price rises in the short term, support for energy efficiency investments should be more promising in the medium term.

The findings of this paper may also be related to one dimension of the current policy debates on the reforms of the European electricity markets. The European Commission as well as economists (see Ambec et al. [2023](#)) proposed that the main objective of reforms should be encouraging 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 last 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 proposed reform.

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Appendix tables

Table A1: Electricity dependency by sector.

Sector	Unweighted Mean	Weighted Mean	Median
Top-3 Sector			
Wastewater collection and treatment	9.05	3.17	1.09
Capture, treatment and distribution of water	5.15	3.71	2.69
Food industry	3.89	0.93	0.72
Bottom-3 Sector			
Edition	0.50	0.34	0.32
Manufacturing of tobacco products	0.47	0.31	0.34
Pollution abatement and other waste management services	0.34	0.16	0.09

Notes: Unweighted statistics in columns 1 and 3. Employment-weighted statistics reported in column 2. Top 0.01 percentile firms in electricity (gas) dependency dropped as outliers.

Table A2: Gas dependency by sector.

Sector	Unweighted Mean	Weighted Mean	Median
Top-3 Sector			
Coke and refining	3.57	3.22	1.29
Manufacture of other non-metallic mineral products	3.12	3.00	1.05
Textile	2.64	1.60	0.85
Bottom-3 Sector			
Capture, treatment and distribution of water	0.12	0.05	0.03
Film, video, television and music production	0.09	0.09	0.08
Pollution abatement and other waste management services	0.02	0.2	0.02

Notes: Unweighted statistics in columns 1 and 3. Employment-weighted statistics reported in column 2. Top 0.01 percentile firms in electricity (gas) dependency dropped as outliers.

Table A3: Persistence in energy demand price elasticity.

Dep Var:	<i>Firm electricity demand (ln)</i>			<i>Firm gas demand (ln)</i>		
	(1)	(2)	(3)	(4)	(5)	(6)
Elec. Price (ln) lag	-0.536*** (0.197)	-0.476*** (0.166)	-0.391*** (0.145)			
Elec. Price (ln) 2-lag		-0.169 (0.132)	-0.165* (0.087)			
Elec. Price (ln) 3-lag			-0.213 (0.149)			
Gas. Price (ln) lag				-0.922*** (0.209)	-0.665*** (0.098)	-0.554*** (0.087)
Gas. Price (ln) 2-lag					-0.294** (0.118)	-0.118** (0.053)
Gas. Price (ln) 3-lag						-0.376* (0.200)
Estimator	OLS			OLS		
Firm FE	yes	yes	yes	yes	yes	yes
Sec-Year FE	yes	yes	yes	yes	yes	yes
Observations	90,384	76,410	64,921	90,384	76,410	64,921
R-squared	0.944	0.943	0.946	0.921	0.928	0.932

Notes: The dependent variable is the total quantity of electricity and gas purchased by firm in a given year. Electricity and gas price approximated by value over quantity purchased in the year. Auto-correlation issue in lagged electricity and gas price reduced by the inclusion of firm fixed effects (i.e. within identification). Cluster firm robust standard errors in parenthesis. *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

Table A4: The persistent effect of energy prices on employment, value added, energy efficiency and profits.

Dep Var:	<i>Emplo. (ln)</i>	<i>Value added (ln)</i>	<i>Erg. Eff. (ln)</i>	<i>Profit (ln)</i>
	(1)	(2)	(3)	(4)
Elec. Price (ln) lag	-0.112*** (0.034)	-0.143*** (0.038)	0.116 (0.118)	-0.172** (0.077)
Elec. Price (ln) 2-lag	-0.021 (0.027)	0.013 (0.033)	0.119 (0.075)	0.038 (0.070)
Elec. Price (ln) 3-lag	-0.053* (0.030)	-0.041 (0.033)	0.080 (0.088)	-0.181** (0.071)
Gas. Price (ln) lag	0.020 (0.033)	-0.020 (0.036)	0.175*** (0.052)	-0.098** (0.047)
Gas. Price (ln) 2-lag	-0.009 (0.035)	-0.021 (0.035)	0.031 (0.055)	0.011 (0.055)
Gas. Price (ln) 3-lag	0.018 (0.033)	0.038 (0.027)	0.362** (0.182)	-0.074 (0.061)
Firm FE	yes	yes	yes	yes
Sec-Year FE	yes	yes	yes	yes
Observations	64,921	64,475	64,475	51,742
R-squared	0.965	0.959	0.888	0.880

Notes: The dependent variable is in turn total employment in the firm, the value added, the energy efficiency and the total profit of the firm. Electricity and gas price approximated by value over quantity purchased in the year. Cluster firm robust standard errors in parenthesis. *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

Table A5: Estimations excluding sector-year fixed effects. OLS estimations

Dep Var:	Elec. demand	Gas demand	Empl.	Value added	Energy efficiency	Profit
	(1)	(2)	(3)	(4)	(5)	(6)
Panel a: Electricity price estimation						
Elec. Price (ln) lag	-0.526*** (0.163)		-0.159*** (0.040)	-0.088** (0.042)	0.499*** (0.187)	-0.217** (0.088)
Per capita GDP (ln)	-0.108 (0.420)		-0.773*** (0.078)	0.066 (0.081)	0.258 (0.475)	0.008 (0.143)
Observations	90,392		90,392	89,728	89,728	72,507
Panel b: Gas price estimation						
Gas Price (ln) lag		-0.830*** (0.272)	-0.080*** (0.029)	-0.110*** (0.041)	0.382* (0.216)	-0.231*** (0.072)
Per capita GDP (ln)		0.748 (0.878)	-0.756*** (0.083)	0.204* (0.119)	-0.048 (0.722)	0.272 (0.198)
Observations		90,392	90,392	89,728	89,728	72,507
Firm FE	yes	yes	yes	yes	yes	yes
Sec-Year FE	no	no	no	no	no	no

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

Table A6: Estimations excluding sector-year fixed effects. 2SLS estimations

Dep Var:	Elec. demand	Gas demand	Emplo.	Value added	Energy efficiency	Profit
	(1)	(2)	(3)	(4)	(5)	(6)
Panel a: Electricity price estimation						
Electricity price (ln)	-0.562*** (0.017)		-0.157*** (0.012)	-0.025* (0.014)	0.722*** (0.019)	-0.521*** (0.030)
Per capita GDP (ln)	0.056*** (0.020)		-0.693*** (0.014)	0.071*** (0.016)	-0.022 (0.022)	0.333*** (0.035)
First stage IV coeff.	0.896***		0.896***	0.896***	0.896***	0.893***
K-P Wald F-stat	6.3e+4		6.3e+4	6.3e+4	6.3e+4	5.4e+4
Observations	108,342	108,342	108,342	107,464	107,464	86,921
Panel b: Gas price estimation						
Gas price (ln)		-0.950*** (0.025)	-0.143*** (0.013)	-0.290*** (0.015)	0.423*** (0.020)	-0.885*** (0.033)
Per capita GDP (ln)		1.130*** (0.049)	-0.563*** (0.026)	0.593*** (0.030)	-0.181*** (0.040)	1.547*** (0.067)
First stage IV coeff.		0.942***	0.942***	0.941***	0.941***	0.905***
K-P Wald F-stat		3.8e+4	3.8e+4	3.8e+4	3.8e+4	2.8e+4
Observations	108,342	108,342	108,342	107,464	107,464	86,921
Firm FE	yes	yes	yes	yes	yes	yes
Sec-Year FE	no	no	no	no	no	no

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

Table A7: Electricity demand and other outcomes elasticity to electricity price. Full sample

Dep Var:	elec. demand	Emplo.	Value added	Energy efficiency	Profit
	(1)	(2)	(3)	(4)	(5)
Electricity price (ln)	-0.378*** (0.108)	-0.124*** (0.026)	-0.125*** (0.027)	0.240*** (0.094)	-0.127*** (0.049)
Estimator	OLS				
Firm FE	yes	yes	yes	yes	yes
Sec-Year FE	yes	yes	yes	yes	yes
Observations	157,724	159,909	158,630	156,497	129,117

Notes: The dependent variable are: (i) the quantity of electricity purchased by firm in a given year, (ii) employment, (iii) value added, (iv) energy efficiency and (v) profit. Electricity price approximated by value over quantity purchased in the year. Cluster firm robust standard errors in parenthesis. *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.

Table A8: The role of firm's energy dependency

Dep Var:	<i>Elec. qty (ln)</i>	<i>Gas qty (ln)</i>	<i>Empl. (ln)</i>	<i>Value Add. (ln)</i>	<i>Erg Eff. (ln)</i>	<i>Profit (ln)</i>
	(1)	(2)	(3)	(4)	(5)	(6)
Elec. Price (ln) lag	-0.480*** (0.178)	-0.266* (0.159)	-0.144*** (0.042)	-0.148*** (0.043)	0.231 (0.163)	-0.151* (0.086)
Elec. Price (ln) lag x Firm Ele dep.	0.002 (0.002)	0.005 (0.003)	-0.005 (0.004)	-0.010* (0.006)	-0.015* (0.009)	-0.010 (0.007)
Gas. Price (ln) lag	-0.217** (0.086)	-0.878*** (0.188)	-0.017 (0.035)	-0.013 (0.042)	0.379*** (0.128)	-0.009 (0.068)
Gas. Price (ln) lag x Firm Gas dep.	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.001 (0.001)	-0.001 (0.001)	-0.001* (0.001)
Firm FE	yes	yes	yes	yes	yes	yes
Sec-Year FE	yes	yes	yes	yes	yes	yes
Observations	90,384	90,384	90,384	89,720	89,720	72,499
R-squared	0.944	0.921	0.961	0.960	0.880	0.883

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. Cluster firm robust standard errors in parenthesis. *** $p < 0, 01$; ** $p < 0, 05$; * $p < 0, 1$.