Energy cost pass-through and the rise of inflation: Evidence from French manufacturing firms

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Abstract

This paper presents micro evidence on energy price shock transmission to producer prices. We analyze microdata from the French Producer Price Index (PPI) and firms' energy usage. Firms fully pass on positive energy-driven cost shocks to prices but respond more modestly to cost reductions. Despite full pass-through of positive shocks, the recent energy price surge only moderately impacted manufacturing inflation, accounting for approximately 10% of total PPI growth. This limited effect results from the relatively small share of energy in firms' variable costs. The average impact masks significant variations, primarily within industries.

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1 Introduction

After three decades of low inflation, advanced economies are experiencing a surge in inflation, resulting from the combination of various factors, including the reshuffling of demand following the Covid-19 pandemic, disruptions in global supply chains and soaring energy and commodity prices. The role of energy, in particular, has come under intense scrutiny in Europe following the Russian invasion of Ukraine. While direct consequences of surging energy prices on household consumption have been mitigated through fiscal measures, the energy price shock has significant implications for the competitiveness of European businesses. As input costs soar, they ripple through supply chains, contributing to inflationary pressures. This dynamic exposes the ECB to a difficult trade-off, as the supply shock puts pressure on prices while also increasing the output gap. The pass-through of these energy cost shocks is a pivotal factor in determining the adjustment in relative prices (Guerrieri et al., 2023).

This article presents novel empirical evidence on the transmission of energy price shocks to producer prices, using the 2021-2022 crisis as a natural experiment. To carry out our analysis, we use micro-level data underlying the French Producer Price Index (PPI), coupled with information on firms' energy consumption. Information on firms' energy intensity and energy mix is used to measure the heterogeneity in exposure to the energy crisis, which in turn helps identify the energy cost pass-through. We find that firms completely pass energy-driven cost increases to their prices. However, we observe compelling evidence of asymmetric adjustments by firms, with prices reacting more to upward energy shocks than to downward ones. The observed asymmetry is largely driven by an increase in the rate of energy cost pass-through during the energy crisis. Despite full pass-through of positive shocks, the direct impact of soaring energy prices on manufacturing prices remained limited. This can primarily be attributed to the relatively small share of energy expenditure in firms' total costs, on average. Our estimates indicate that the firm response to energy price shocks directly contributed to a 2 percentage point increase in the manufacturing producer price index between January 2021 and December 2022, about a tenth of the cumulative growth in producer prices. However, the average effect hides significant heterogeneity between industries and between firms within the same industry. Some large companies in the chemical and metal industries have raised their price by more than 10 percentage points in response to soaring energy prices.

Our analysis uses two distinct firm-level datasets. First, we exploit microdata from the French PPI, which offers comprehensive information on manufacturing prices at firm and product level, covering the period from January 2018 to December 2022. Second, we use detailed firm-level data on energy consumption, distinguishing between different types of energy sources. The resulting dataset covers a sample of 1,117 manufacturing firms, representing around a tenth of France's total manufacturing output. We explore the relationship between the micro-level price increases and energy-driven cost shocks. We measure these shocks at the firm level, using data on firms' energy consumption and average fluctuations in electricity, gas, and oil prices during the period.[1] In our sample, energy expenses represent on average 2.5% of a firm's variable costs. Heterogeneity around this average and differences in firms' energy mix drive the dispersion in energy cost shocks.

Equipped with a firm-level measure of energy cost shocks, we then estimate their pass-through to producer prices. We explore three specifications: a dynamic specification that allows for a delayed transmission of the shock to prices, a static specification that compares monthly price changes *conditionally* on the price adjusting and the cumulative change in energy costs

[1] These three energy sources account for 99.5% of total energy expenditure by firms in our sample. Our strategy to measure cost shocks uses the observed heterogeneity in firms' energy mix to approximate their exposure to (common) energy price increases. In practice, the specific type of contracts linking firms and their energy suppliers can also affect the timing of their exposure to energy price shocks. We discuss this source of heterogeneity in section 3, using survey data on energy contracts.

since the last update, and a static specification based on quarterly data. In all cases, we control for common shocks affecting all firms within a sector at a given point in time, thus absorbing the potential impact of demand shocks or sectoral wage adjustments. In the context of the energy crisis, the fixed effect component also absorbs the common drift in marginal costs, while identifying the pass-through coefficient from heterogeneity in firms' exposure to energy price variations. Our analysis reveals that energy-driven cost shocks are fully transmitted to domestic prices. Considering the average share of energy expenditure in total costs of manufacturing firms, our findings suggest that a 10% change in energy prices translates into a 0.22% producer price change. The entire adjustment takes place within a quarter. Controlling for two potential confounders, changes in competitors' and input suppliers' prices, slightly reduces the estimated pass-through rate that remains statistically indistinguishable from full pass-through.

Pass-through rates are highly asymmetrical. Specifically, we find that firms fully pass-through cost increases resulting from upward energy price shocks. However, when energy costs fall, firms react more moderately, reducing their prices by a statistically insignificant 21% of the fall in costs. The asymmetry is largely explained by an increase in the response of firms to positive energy price shocks in the last two years of the estimation sample. While the pass-through of positive shocks is estimated equal to 32% in 2018-2020, it jumps to 120% in 2021-2022. We find no evidence that this asymmetry is more prevalent in sectors where the risk of collusion is high, nor when firms are hit by larger shocks. Instead, the asymmetry is more pronounced in periods when inflation is high, and when there is more media attention on energy prices.

In the final section, we examine the aggregate consequences of energy cost shocks on PPI growth. Using our econometric model, we predict the individual price increases driven by the 2021Q1-2022Q4 energy price surge. The heterogeneity in exposure implies a sizable dispersion in predicted adjustment across firms, even within sectors. We then compute the sectoral inflation as predicted by energy shocks. Most sectors are little affected. The two sectors most affected by the 2021-2022 energy crisis are the metal products and chemical industries. In the chemical industry, energy cost shocks may have directly contributed to an additional 5.7 percentage points of inflation. We then aggregate predictions and use an I-O framework to quantify the contribution of the energy crisis to inflation in French manufacturing industries. We find that energy explains around 11% of the increase in the manufacturing PPI over the period.

Related literature. Our article contributes to ongoing efforts to understand the drivers behind the surge in inflation over the 2021-2022 period. di Giovanni et al. (2022) show that in the Eurozone, foreign shocks and supply chain disruptions played a greater role than demand shocks. In their survey of UK firms, Bunn et al. (2022) find that energy prices, labor and material shortages account for a substantial share of the inflationary pressure observed during and after the pandemic. Cavallo et al. (2023) use a New Keynesian model with state dependent price setting to study the impact of a significant cost shock, comparable in scale to the 2021-2022 energy shock. They find that large positive shocks are transmitted to prices at a faster than small positive shocks or large negative shocks. We provide micro-level evidence consistent with such a shift in the pricing behavior of manufacturing firms in the context of the energy crisis.

Our work also contributes to the literature on cost pass-through.[2] Previous studies using micro-price data have examined cost pass-through in specific sectors such as the coffee or beer industries (Nakamura and Zerom, 2010, Goldberg and Hellerstein, 2013). Closer to our research, Ganapati et al. (2020) study the impact of energy cost shocks and estimate a pass-through rate of 70% on manufacturing prices. Our study uses a different methodology, drawing on direct

[2]Our paper is more broadly related to the literature on exchange rate pass-through (see, e.g., Gopinath and Itskhoki, 2010, Burstein and Gopinath, 2014).

information on firms' energy use and energy mix. We further show that the level of pass-through varies over time. Another relevant study by Fontagné et al. (2018) uses electricity prices as a cost shifter to identify the price elasticity of exports. Although they use different data, namely annual export unit values and average electricity costs, their first-stage estimates are consistent with our findings concerning the high degree of price pass-through of energy cost shocks. Dedola et al. (2022) explore the extensive and intensive margins of price adjustments to oil and import price shocks using Danish PPI price data over 1993-2017. They find that selection issues have minimal impact on estimated pass-through. Our analysis in the French context covers a more recent period, enabling us to examine the role of energy cost shocks in the 2021-2022 inflationary surge. It also covers gas and electricity shocks in addition to oil price shocks.

Finally, we contribute to the literature on asymmetric pass-through (Peltzman, 2000, Benzarti et al., 2020). Collusion is often suggested to explain the asymmetry (see, e.g., Fung, 2014), but it can also appear in competitive markets in the presence of imperfect information (Tappata, 2009). We find no evidence for the role of collusion in explaining the observed asymmetry in pass-through. We show asymmetry arises because firms pass on a larger share of positive cost shocks in high-inflation environments and when the sources of inflation are more widely covered by the media. From this point of view, we contribute to the macroeconomic literature that studies the differences in price setting behavior in low- and high-inflation environments (Nakamura et al., 2018, Harding et al., 2023, Taylor, 2000, Cavallo et al., 2023). The results are also suggestive of the role of attention to inflation for corporate price setting (Weber et al., 2023).

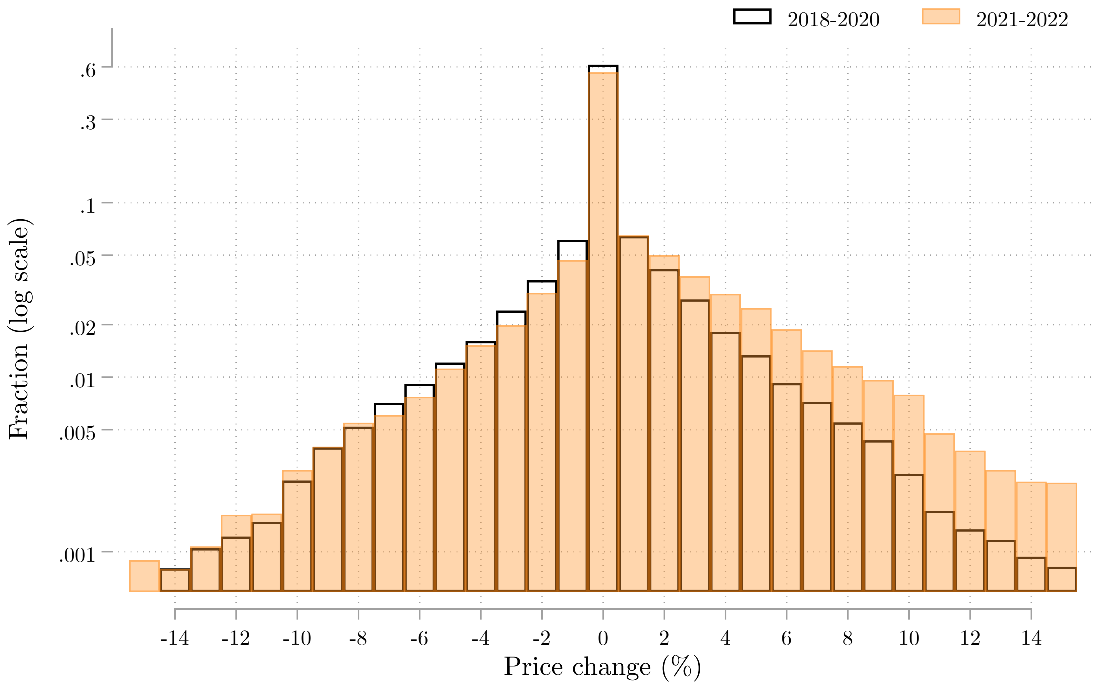
2 Data and Stylized Facts

Individual price data. We use individual price data collected through the OPISE survey (Observation des Prix dans l'Industrie et les Services) conducted by the French Statistical Institute.[3] The data spans from January 2018 to December 2022, and we concentrate on manufactured products.

The OPISE survey covers the largest firms (in terms of their sales) within each 4-digit category. This selection process ensures coverage of at least 40% of each product market, despite covering only 5,000 manufacturing firms in a typical year. Once a firm is selected, it remains surveyed until the next renewal of the sample in the market, which typically happens every five years. Each firm provides a list of its core products that best represent the evolution of its prices. The raw data collected from these products are then used to construct monthly price indices for each firm-product combination. Several adjustments are made to the data to account for factors such as non-response, quality changes, product substitution, and atypical price movements. The survey produced 13,803 domestic price series in 2022, with each series associated with a weight used in the construction of the PPI. From these individual price series, we calculate monthly and quarterly price changes. Any monthly price change below 0.1% in absolute value is set to zero to address potential issues with accuracy, following the approach used in Gautier (2008).

[3]Earlier vintages of this dataset have been used in Gautier (2008), Martin (2011) and Vermeulen et al. (2012).

Figure 1: Distribution of monthly price changes



Notes: This figure shows the distribution of monthly price changes over the 2018-2020 and 2021-2022 periods. The y-axis is in log scale.

In Figure 1, we present the distribution of monthly price changes for two subperiods, 2018-2020 and 2021-2022. The figure shows a clear right-shift in the distribution of price changes in the last two years. We further see that the mass around zero is smaller in 2021-2022, which means that the frequency of price changes has increased during the high-inflation episode. The shift in the distribution of price adjustments is thus the combination of a change in the frequency of (positive) price changes and the size of these changes.[4] The average size of price changes increased from .11% between 2018 and 2020 to .94% during the high-inflation episode.

In Section 3, we explore the potential role of energy as a source of these dynamics. To do this, we first calculate measures of exposure to energy cost shocks at the firm level.

Energy cost shocks. To create a firm-level measure of energy price changes, we use information on each firm's energy consumption by energy type, combined with observed changes in nationwide energy prices. For each firm f, we calculate the change in the price of purchased energy using the following formula:

$$\Delta p_{ft}^E = \sum_e w_{f0}^e \Delta p_t^e \tag{1}$$

Δp_t^e represents the growth in the price of energy type e, calculated at a monthly or quarterly level depending on the specification. The corresponding price series come from INSEE.[5] They correspond to the actual average prices set by energy providers to firms not covered by regulated prices.[6]

Individual energy price series are then aggregated across energy sources within a firm, using information on the firm's energy mix. The shock Δp_{ft}^E is a weighted average of price variations of electricity, natural gas, and petroleum products, with weights w_{f0}^e representing the share of energy e in firm f total energy consumption, measured in tons of oil equivalent. We calculate this weight using data from the INSEE-EACEI survey ("Enquête Annuelle sur les Consommations d'Energie dans l'Industrie"), which provides comprehensive information on consumption at the plant level, classified by energy type. To maximize coverage while using pre-sample data, we calculate w_{f0}^e weights for each firm over the period 2014-2017. This approach allows us to capture the relative importance of each energy type in a firm's overall energy consumption. As a result, Δp_{ft}^E can be seen as a shift-share measure of exposure to energy price shocks by individual firms. This measure varies over time due to common fluctuations in energy prices, and between firms due to disparities in their energy mix.[7]

[4]Inflation dynamics have been a subject of debate in the literature, particularly about the role of the extensive and intensive margins (Gagnon, 2006, Nakamura and Steinsson, 2008, Klenow and Kryvtsov, 2008, Nakamura et al., 2018, Alvarez et al., 2019). We find that both margins are at play during the recent surge in inflation. In 2018-2020, 40% to 45% of price changed every month. The frequency increases by 6 percentage points on average, over 2021-2022. These frequencies are in the high range of the literature, similar to the frequency measured in the US PPI data by Goldberg and Hellerstein (2009), but higher than in EU countries (Vermeulen et al., 2012). The difference might be due to the complexity of collecting producer prices (see Gautier, 2008, for a discussion).

[5]To account for the seasonal nature of electricity prices on European markets and the presence of long-term electricity contracts among French businesses, we remove the seasonal component from the electricity price series. This adjustment allows us to isolate the underlying price changes faced by manufacturing firms. We observe no significant seasonal trend in gas and oil prices, so no further adjustment is required for these series.

[6]The distinction is important because, unlike firms in our sample, households and small enterprises have been insulated from the energy crisis thanks to a price cap on electricity and gas. See details in the Online Appendix.

[7]In the shift-share, exposure to energy prices varies, but the variation in the price of each source of energy is common across firms. In practice, firms have different contracts and pay different prices. In Online Appendix A, we provide statistics on energy contracts for a subset of firms in our estimation sample. We discuss the implications for our estimates in Section 3.1.

We further adjust the energy shock in equation (1) by the share S_{f0}^E of energy in variable costs, averaged over 2014-2017. This adjustment allows us to express the shock as an energy-driven marginal cost shock, simplifying the interpretation of pass-through coefficients. Nominal energy consumption in the numerator is obtained from the EACEI survey. Total variable costs are recovered from firms' balance-sheet data (Insee-FARE dataset) and include the firm's wage bill and intermediate consumption, including expenditure on raw materials, goods, and services.

Merging individual observations from the EACEI survey with price data yields a dataset comprising 1,117 firms. Table 1 gives an overview of firms' exposure to energy price variations. The first three columns show the share of energy in firms' overall costs, by industry. On average, energy represents 2.53% of the total variable costs of the firms in our sample. Among industries, paper products, chemicals, and mineral products have the highest average share of energy costs, representing 4 to 6% of their total variable costs. However, there are significant variations within these sectors, with around 10% of companies in the chemical industry spending more than 15% of their costs on energy purchases. Beyond exposure, the variation in energy costs across firms and sectors can be attributed to their different energy mixes, described in the next three columns of Table 1. Around 71% of energy costs are associated with electricity consumption, while gas and oil respectively account for 23 and 5% of energy consumption, but the mix varies across firms and industries. This heterogeneity in energy mixes participates to the dispersion in the change in energy costs between 2021Q1 and 2022Q4 since the price of electricity rose by 38% while the price of gas and oil prices rose by 163% and 112% respectively (see the last column of Table 1).

Table 1: Energy consumption statistics by industry

	Energy costs (S^E_{f0}, %)			Share of... (%)			$\Delta_{22,21}\bar{p}^E_f$
	P10	P90	Avg.	Elec.	Gas	Oil	(%)
Food	.51	2.76	1.73	70.6	24.8	4.58	44.7
Beverages	.28	3.42	1.51	66.1	30.6	3.28	48.3
Textile	.36	10.2	3.67	62.4	32.5	5.06	50.6
Apparel	.16	3.29	.83	73.9	15.6	10.5	41.1
Leather	.39	1.7	.93	69	23.4	7.55	45.3
Wood products	.42	4.92	2.2	81.8	8.8	9.3	35.6
Paper	.98	11.5	4.29	71.2	25.4	3.27	44.5
Printing	.76	6.73	2.95	79.1	19.3	1.63	39.3
Chemicals	.48	15.6	4.62	66.8	25.9	4.3	44.7
Pharma	.88	12.8	4.61	60.4	38.9	.66	53
Rubber and plastic	.67	4.17	2.17	83	13.6	3.42	36.1
Mineral products	.69	14.4	6.03	60	34	5.66	51.9
Metals	.8	6.73	3.52	70.2	22.5	5.98	43.5
Metal products	.42	4.41	1.91	72.1	21.9	5.59	43.1
Computers, etc.	.12	1.76	.79	84	13.6	2.41	35.6
Electrical products	.28	3.09	1.95	68.6	23.2	6.53	44.2
Machinery	.21	1.76	1	64.6	28.1	7.37	48.5
Automotive indus.	.15	2.38	1.22	71.8	22.2	6.02	43.6
Transport equip.	.16	1.13	.57	69.9	24.2	5.9	45
Furnitures	.39	3.45	1.7	77.6	20.2	2.19	40.3
Other manuf.	.41	2.03	1.21	75.8	22.4	1.72	41.6
All	.38	5.26	2.53	71.5	22.9	5.19	43.6

Notes: "Energy costs" refer to the ratio of the energy bill to total variable costs. Total variable costs include the firm's wage bill and intermediate consumption, which consists of raw materials, merchandises, and services. The energy bill is averaged over the pre-sample years (2014-2017). The values reported as P10, P90, and Avg represent the 10th, 90th percentile, and simple average of the distribution of the energy cost ratios within each 2-digit industry. "Share of..." refers to the proportion of each type of energy (electricity, gas, and oil products) in the total energy bill. To calculate the shares, the annual bill of each energy type is averaged over the pre-sample years, and then divided by the average total energy bill. "$\Delta_{22,21}\bar{p}^E_f$" represents the average change in energy costs within each 2-digit industry between 2021Q1 and 2022Q4. It is computed by first calculating the firm-level change in energy prices, which is a weighted average of the changes in electricity, gas, and oil price indices. The weights used are based on the firm-level shares of energy types. Finally, the average change in energy costs is calculated by averaging the firm-level changes within each 2-digit industry.

3 Estimation of pass-through rates

In this section, we study the pass-through of energy cost shocks on producer prices.

3.1 Baseline

Model and specifications. We estimate a simple equation of pass-through of energy cost shocks into producer prices.

$$\Delta p_{fkt} = \sum_{j=0}^{L} \alpha_j \Delta p^E_{ft-j} \times S^E_{f0} + \beta X_{fkt} + FE_{st} + \epsilon_{fkt} \tag{2}$$

where Δp_{fkt} is the price adjustment in period t for product k of a firm f. Δp^E_{ft} is the corresponding cost shock, measured at the firm level and adjusted for the firm's energy cost ratio. In some specifications, we allow for a delayed transmission of the shock, and therefore introduce L energy cost lags. X_{fpt} is a set of controls, which we discuss later. FE_{st} is a set of 2-digit sector-by-period fixed effects. These fixed effects absorb any sector-specific trend to inflation, demand, labor costs, etc. We thus identify pass-through rates from the cross-section of firms within a sector, exploiting heterogeneity in exposure to the energy cost shock. As shown in Appendix Table A2 and Figure A3, cost shocks are positive on average but have a wide dispersion, which aids in identification.

Estimating pass-through from monthly price data is hampered by the presence of zeros, as firms may not adjust their prices every month, particularly in sectors with higher price rigidity. Burstein and Gopinath (2014) propose a strategy for calculating the pass-through of cumulative changes in costs, *conditional* upon the price being adjusted. One of the limitations of this approach is that energy shocks can also affect the probability of price adjustments (Dedola et al., 2022).[8] Cavallo et al. (2021) propose instead to keep the zeros but include lags in their regression of the pass-through of tariffs to border prices. In Table 2, we pursue both strategies. Column (1) uses a balanced panel of monthly price data, while Column (2) is restricted to non-zero price changes. In the latter case, the shock is cumulated over all periods since the last price adjustment. Finally in Columns (3)-(8), we aggregate the data at the quarterly level.

[8] We estimated an ordered probit model to evaluate the impact of energy cost shocks on the probability that firms adjust prices, following Loupias and Sevestre (2013). The result is a positive but small impact of energy cost shocks on the probability of price adjustment (see Table A3 of the Online Appendix).

Table 2: Pass-through of energy cost shocks

	Monthly		Quarterly					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta p^E_{ft} \times S^E_{f0}$	0.507***		1.158***	0.862***	0.710***	0.603***	1.250***	0.935***
	(0.088)		(0.142)	(0.131)	(0.159)	(0.190)	(0.178)	(0.206)
$- \times$ Large Firm$_f$					0.448**			
					(0.206)			
$- \times$ Large Shock$_f$						0.332		
						(0.213)		
$\Delta p^E_{ft-1} \times S^E_{f0}$	0.231**							
	(0.091)							
$\Delta p^E_{ft-2} \times S^E_{f0}$	0.259***							
	(0.087)							
$\Delta p^E_{ft-3} \times S^E_{f0}$	0.202**							
	(0.087)							
$\Delta p^E_{ft-4} \times S^E_{f0}$	-0.003							
	(0.083)							
$\Delta p^E_{ft-\tau} \times S^E_{f0}$		0.896***						
		(0.101)						
Δp^H_{kt}				0.648***	0.647***	0.649***	0.662***	0.617***
				(0.023)	(0.023)	(0.023)	(0.031)	(0.036)
Δp^V_{ft}				0.583***	0.590***	0.587***	0.777***	0.901***
				(0.123)	(0.123)	(0.123)	(0.212)	(0.228)
Long-run PT	1.195	0.896	1.158	0.862			1.250	0.935
S.E.	0.195	0.101	0.142	0.131			0.178	0.206
Obs.	181,605	104,720	64,721	64,721	64,721	64,721	27,394	22,479

Notes: This table reports the results of the estimation of equation (2). All specifications include 2-digit industry by period fixed effects. In Columns (1)-(2), the period is a month. In Column (1), the left-hand side variable is a first difference in logs, and we keep the zeros when prices do not change from a period to the next. In Column (2), the regression is conditional on output price changes and the explanatory variable is the cumulative change in energy costs since the last price change. In Columns (3)-(8), data is aggregated at the quarterly level. In Column (5), we interact the cost shock with a dummy identifying firms with more than 200 employees. In Column (6), we interact the cost shock with a dummy identifying shocks above their product-level average. In Columns (7)-(8), we run the regression on firms for which we have information on energy contracts. In Column (8), we exclude firms whose contracts is indexed on wholesale prices. Δp^H_{kt} and Δp^V_{kt} respectively denote the "horizontal" and "vertical" shocks. Robust standard errors in parenthesis. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Baseline pass-through estimates. The estimated pass-through of energy shocks on producer prices is 51% on impact (Column (1)). Moreover, the coefficients for the first three lags are statistically significant, indicating a smooth adjustment process. When we consider the cumulative impact of 4 months of energy changes, the pass-through rate reaches 119.5%. In this specification, we cannot reject full pass-through of energy cost shocks into producer prices. For a firm with the average exposure to energy cost shocks in our data (2.53%), this pass-through rate implies that a 10% increase in energy costs leads to a price increase of 0.30%. In Column (2), we exclude zero price changes and estimate the pass-through of energy cost shocks conditional on a price adjustment (Burstein and Gopinath, 2014). The estimated pass-through rate remains high at 89.6% and is not significantly different from full pass-through.

The results in Column (1) indicate that most of the pass-through of energy cost shocks to producer prices occurs within a quarter. For this reason, we now work with quarterly data and reproduce the specification of Column (1) in Column (3). The corresponding pass-through rate is around 116%, which is remarkably similar to the long-term pass-through rate estimated from the monthly data. In unreported results, we verified that introducing a lag in this quarterly specification does not change the results as the entirety of the shock is passed within the next quarter. Based on these results, we will use the static quarterly specification for the remainder of the analysis.

Competition and suppliers. The reduced form evidence consistently indicates that the pass-through of energy-related cost shocks is high and not significantly different from full pass-through. Our estimate of 116% is higher than the pass-through rate estimated in Ganapati et al. (2020), which was 70%. In Column (4), we test whether this high pass-through rate is triggered by commonality factors. Energy cost shocks have a strong commonality component since energy prices are mainly determined on global markets. As a result, firms tend to adjust their prices when their competitors and input suppliers are also likely to do so. To account for this common component, we add two control variables to the reduced-form equation: the change in the PPI at the product level, which represents "horizontal" shocks, and a proxy for changes in input prices, called a "vertical" shock.[9] Both control variables are positively correlated with price adjustments at the firm level. This suggests that firms adjust their prices in response to their competitors' and also pass on a substantial proportion (58%) of price shocks affecting purchases of other inputs. As expected, the estimated pass-through of the firm-specific energy shock is reduced in this specification, to 86%, but the reduction is not statistically significant. In unreported regressions, we find that most of the reduction in pass-through is due to the inclusion of the price index. This means that the fact that all firms in a product market face the same shocks, albeit with different intensities, partly explains the high level of pass-through we estimate.[10]

Strategic interactions. The significant correlation between the firm's price adjustment and its competitors' may reveal the existence of strategic interactions between firms within a product market. In oligopolistic competition models, pass-through varies with firm's market power

[9]The "vertical" shock is computed as follows: $\Delta p^V_{ft} = S^I_{f0} \times \sum_{s'} w^{s'}_{f0} \Delta p_{s't}$, where $w^{s'}_{f0}$ denotes the share of sector s' in firm f intermediate consumption and $\Delta p_{s't}$ represents the change in output prices for sector s'. Since we do not have access to individual data on input-output relationships, we assume that the weights $w^{s'}_{f0}$ are sector-specific and use weights obtained from I-O tables. S^I_{f0} represents the firm's exposure to these shocks, which is calculated as the ratio of domestic intermediate consumption (variable costs minus the wage bill and imported intermediate consumption) over variable costs. The "horizontal" shock represents the average price adjustment in the product market. This variable serves as a proxy for how the firm's competitors adjust their prices.

[10]See Auer and Schoenle (2016), Muehlegger and Sweeney (2022) for a formal discussion of the bias affecting the estimation of own-cost pass-through when firms' adjustment to competitor prices are not controlled for.

(Atkeson and Burstein, 2008, Auer and Schoenle, 2016, Amiti et al., 2019). In Column (5), we introduce an interaction term between the shock and a dummy variable identifying firms with more than 200 employees. The coefficient on the interaction is positive and significant. In our data, large firms tend to pass through a greater proportion of energy-related cost shocks than smaller firms in the same sector. Because our sample focuses on the right-hand side of the firm size distribution, the positive coefficient can capture the increasing part of a relationship that is U-shaped in models of oligopolistic competition à la Atkeson and Burstein (2008).[11] Another implication of oligopolistic models is that the level of pass-through varies with the size of the shock relative to the ones faced by competitors. More specifically, firms adjust their markup to maintain their relative price, which leads them to pass a lower share of relatively large shocks. In Column (6), we augment the baseline specification with an interaction between the shock and a dummy variable identifying firms which marginal cost shock is above the market average. We do not find evidence for differences in pass-through along this dimension. As a consequence, the pass-through estimated on heterogeneous shocks remains a good proxy for the overall energy cost pass-through.

Robustness to the form of contracts. We observe firms' exposure to energy shocks, and the series for oil and gas and electricity prices, but we do not observe the energy bill paid by the firms during the energy crisis, which varies depending on their energy contract. For a small subsample of firms, we got information on energy contracts in 2022. As discussed in Section A of the Online Appendix, a significant proportion of the firms in the manufacturing sector benefit from fixed price contracts while roughly 10% of the respondents are instead exposed to more volatile wholesale prices. Fixed price contracts do not insulate firms from exposure to energy price shocks, although the actual volatility of their costs may be reduced in comparison with what we infer from average prices.

In Columns (7) and (8), we reproduce our baseline estimate exploiting information on 2022 contracts. In this subsample, the pass-through rate is found higher, at 125%, but not statistically different from the 86% estimated on the full sample (Column (7)). In Column (8), we exclude firms whose contracts is indexed on wholesale prices. As expected, excluding these firms that are exposed to more volatile energy prices tends to lower the pass-through. The pass-through remains high however (93.5%). Of course, the energy price series are not perfect in Column (8) because we do not know the exact timing of contract renewals for firms benefiting from fixed price contracts. Such measurement error should however bias our estimated pass-through down. Taken together, the evidence in Table 2 thus suggest an almost full pass-through of energy shocks into producer prices.

[11] This finding contrasts with those of Berman et al. (2012) and Amiti et al. (2019), who found large firms have a lower exchange rate pass-through. Both work with data sets that are representative of the entire distribution of firms. Heterogeneity in pass-through rates is identified by comparing firms with employment rates below and above 100 in Amiti et al. (2019). When we use the same threshold, we estimate a negative coefficient, but one that is not significantly different from zero. This is because most of the firms in our sample (over 75%) have more than 100 employees. When we use a threshold of 200 employees (25% of the firms in our dataset), the coefficient becomes positive and significant. Taken together, these results may be consistent with the existence of a U-shaped relationship between a firm's market share and its optimal pass-through. See Auer and Schoenle (2016) and Garetto (2016) for theoretical arguments and empirical evidence supporting the presence of non-linearities. It should be noted that the relationship between pass-through rates and firm size is unclear in the literature, both empirically or theoretically. Alviarez et al. (2023) thus find that the pass-through rate of Trump's tariff changes to US import prices is greater for exporters with high supply shares. Arkolakis et al. (2019) note that their "Pollak family" model of monopolistic competition and additively separable preferences can generate incomplete pass-through and a pass-through rate that increases or decreases with firm size, depending on parameter values. The relationship between the pass-through rate and the size of the firm is also expected to reverse under super pass-through (Mayer and Head, 2021).

3.2 Asymmetry in pass-through

Asymmetries in pricing behavior following positive and negative cost shocks have been a recurrent topic in the pass-through literature (see, e.g., Peltzman, 2000). In Table 3, we test for the existence of such asymmetries, using as a reference the 86% pass-through rate estimated in Column (4) of Table 2. The results show that there are significant differences in the degree of pass-through of positive and negative shocks (Column (1)). The transmission of positive energy shocks is estimated at 101%. On the other hand, the transmission of negative shocks is estimated at 19.6% and is not significantly different from zero. In Column (2), we show that this asymmetry is almost entirely driven by a change in price setting behaviors in 2021-2022. While the pass-through of positive shocks is only weakly above the pass-through of negative shocks in the pre-crisis period, at 32.4%, it jumps to 119.7% on average in 2021-2022. This asymmetry in the transmission of positive and negative cost shocks is consistent with a recent Eurostat survey which indicates that in 2022-2023 European firms systematically increase their prices when input prices rise, but that very few firms intend to reduce their prices when input prices fall (Schnabel, 2023).

Mechanisms. In Columns (3)-(6), we examine potential mechanisms for asymmetric pass-through starting with collusion. Collusion equilibria are easier to sustain when costs increase, which may explain a larger pass-through of positive shocks. To assess the likelihood of collusive behavior, we constructed a measure based on the frequency of cartel detections in each sector (Connor, 2020).[12] In Column (3), we interact energy shocks with the dummy variable identifying higher collusion risk. The interaction term is positive but not statistically different from zero.

Asymmetry may also be the consequence of supply shocks being transmitted faster when inflation is high (Taylor, 2000, Harding et al., 2023, Cavallo et al., 2023). In Column (4), we interact energy shocks with a dummy variable that takes the value of one when quarterly inflation within a sector is above 1%. The interaction term is positive and significant. Such asymmetry might be a by-product of the form of demand (Harding et al., 2023). The asymmetry may also be the consequence of the pass-through being higher when shocks are large.[13] In Column (5), we investigate whether firms exposed to larger positive shocks, in *absolute* terms, behave differently. The estimated coefficient on the interaction is positive, but not significant.

Westphal (2023) shows that in an environment with market frictions and sequential search, buyers are more willing to accept price hikes if they are *aware* that the cost of inputs has increased. The asymmetry might thus arise from the sources of inflation being more salient (Weber et al., 2023, Korenok et al., 2022, Pfauti, 2023). We investigate this channel in Column (6), using an interaction term between the shock and a measure of the salience of energy price changes. Specifically, we employ Google Trend data to identify quarters when the energy crisis gathered substantial public attention.[14] The interaction term implies a significant correlation between public awareness of energy prices and firms' ability to pass energy cost shocks.

[12] Specifically, we used a dataset compiled by Connor (2020) that lists price-fixing cartels detected in Europe and North America from 1990 to 2017. By counting the number of cartels detected in two-digit NAF industries, we created a dummy variable equal to one for sectors in which more than 50 cartels were detected over the period.

[13] Karadi and Reiff (2019) and Cavallo et al. (2023) provide theoretical arguments and evidence of a stronger transmission of large shocks to inflation, which is driven by adjustments at the extensive margin.

[14] By counting the occurrences of "energy prices" in the French part of Google Trend requests, we constructed a dummy variable equal to one in quarters falling in the last quintile of the distribution, indicating higher public awareness.

Table 3: Asymmetric pass-through of energy cost shocks

	(1)	(2) $\mathbf{1}_{\text{2021-2022}}$	(3) $\mathbf{1}_{\text{Collusion}}$	(4) $\mathbf{1}_{\Delta PPI \geq 1\%}$	(5) $\mathbf{1}_{\text{Large shock}}$	(6) $\mathbf{1}_{\text{Salience}}$
Δ_t^+	1.014***	0.324**	0.863***	0.563***	0.776***	0.713***
	(0.154)	(0.141)	(0.224)	(0.152)	(0.278)	(0.164)
$\Delta_t^+ \times Z$		0.873***	0.258	0.590***	0.310	1.123***
		(0.236)	(0.306)	(0.226)	(0.391)	(0.395)
Δ_t^-	0.196	0.209	0.197	0.211	0.204	0.198
	(0.228)	(0.228)	(0.228)	(0.229)	(0.228)	(0.229)
Δp_{kt}^H	0.649***	0.647***	0.648***	0.645***	0.649***	0.647***
	(0.023)	(0.023)	(0.023)	(0.027)	(0.023)	(0.023)
Δp_{ft}^V	0.594***	0.609***	0.594***	0.604***	0.590***	0.605***
	(0.123)	(0.123)	(0.123)	(0.123)	(0.123)	(0.123)
Avg. Z		.42	.41	.34	.035	.15
Obs.	64,721	64,721	64,721	64,721	64,721	64,721

Notes: This table reports the results of the estimation of equation (2) where the energy-driven cost shock variable is split into positive cost shocks Δ_t^+ and negative cost shocks Δ_t^-. In Columns (2)-(6) we interact the positive cost shock with different dummy variables. $\mathbf{1}_{\text{2021-2022}}$ is equal to one in 2021 and 2022. $\mathbf{1}_{\text{Collusion}}$ is equal to one if the number of international collusion cases of the 2-digit industry is above 50. $\mathbf{1}_{\Delta PPI \geq 1\%}$ is equal to one if quarterly inflation at the product-level is above 1%. $\mathbf{1}_{\text{Large shock}}$ is equal to one if the shock falls in the top 5% of the distribution of all positive cost shocks. $\mathbf{1}_{\text{Salience}}$ is equal to one when the Google index on the expression “prix de l'énergie” is in the upper quintile of its distribution between 2018 and 2022. Robust standard errors in parenthesis.

4 Energy prices and PPI growth: Quantification

To quantify the impact of the 2021-2022 surge in energy costs, we now use the predictions of our empirical model. The predicted change in producer prices $\widehat{\Delta_{22,21} p_{fk}}$ is calculated using the following formula: $\widehat{\Delta_{22,21} p_{fk}} = \hat{\alpha} S^E_{f0} \Delta_{22,21} p^E_f$, where $\hat{\alpha}$ represents the pass-through coefficient (119.7%), and $\Delta_{22,21} p^E_f$ is the cumulated change in energy prices between 2021Q1 and 2022Q4. We extrapolate the results to firms not covered by the energy consumption survey assuming them to display the average energy cost shock of firms in the same 2-digit industry (see Online Appendix B).

Distributional effects. We find substantial heterogeneity in the predicted price changes resulting from the energy crisis. For the median firm in the sample, the 2021-2022 energy shock represents a modest price increase of 1.2 percentage points. However, the impact is substantially larger for firms in the top percentile, reaching 17.6 pp. By regressing actual against predicted prices, we find that energy shocks explain a quarter of the variation in price dynamics between firms.

Figure 2 provides a visual representation of the dispersion of the predicted impact of soaring energy prices in 2021-2022 between sectors and between firms within sectors. In the chemical industry, the cumulative rise in energy prices could have added up to 5.7 pp to sectoral inflation, a number that goes to 7.4 pp in the mineral products industry. By contrast, the energy crisis has virtually no impact on producer prices for transport equipment or computers. However, the most striking result is the substantial heterogeneity observed between firms in the same industry. Overall, 71% of the cross-sectional dispersion is observed within an industry.

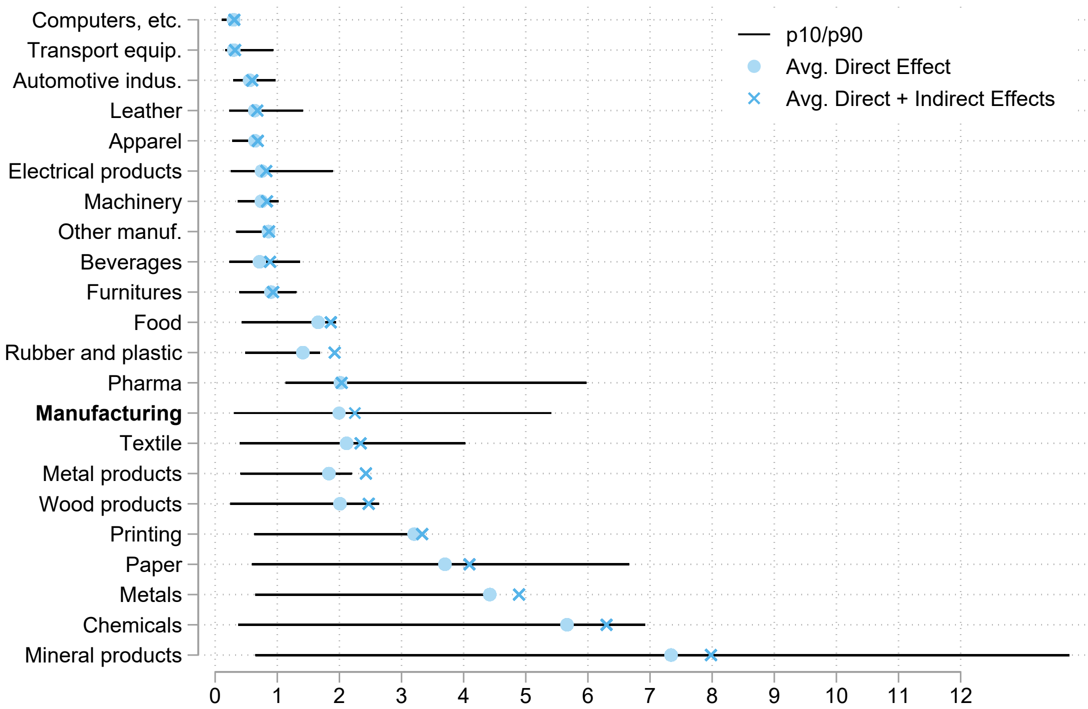
Amplification through I-O linkages. Firms react not only to changes in direct energy prices but also to changes in the prices of other inputs also exposed to the energy crisis (Table 2). To account for these indirect effects, we apply the inverse Leontief matrix to the vector of direct shocks attributed by the model to energy prices:

$$\widehat{\mathbf{\Delta_{22,21} p}}^{D+I}_{st} = (\mathbf{I} - \mathbf{A})^{-1} \widehat{\mathbf{\Delta_{22,21} p}}^{D}_{st}$$

where $\widehat{\mathbf{\Delta_{22,21} p}}^{D+I}_{st}$ and $\widehat{\mathbf{\Delta_{22,21} p}}^{D}_{st}$ respectively denote the vector of overall and direct price adjustments attributed by the model to energy shocks (the blue crosses and circles in Figure 2, respectively). $(\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse, recovered from the French input-output tables, which is adjusted to account for the pass-through of .594 estimated in Column (1) of Table 3.

On average, the transmission of energy-related cost shocks through the production network increases the impact by 13%. In some industries that are not energy-intensive but use energy-intensive inputs, such as rubber or metal products, the indirect transmission of energy price variations leads to a predicted price increase that is more than 30% higher than the direct impact alone.

Figure 2: Predicted price increases in 2-digit industries



Notes: The figure displays the 10th and 90th percentiles of the firm-level predicted price increase distribution within 2-digit industries resulting from the cumulative energy price changes over the period from 2021Q1 to 2022Q4. The blue dots represent the averages at the industry level. The blue crosses incorporate the additional price consequences of the transmission of these shocks along value chains. The changes in prices are presented in percentage points. See Appendix B for details.

Aggregate effects. By aggregation, we can estimate the contribution of soaring energy prices in 2021-2022 to aggregate PPI growth in the French manufacturing industry. Our analysis indicates that the energy shock has led to a 1.7 pp increase in the manufacturing PPI, and 1.9 pp once we incorporate indirect effects. Over the whole period, inflation rose by 21.3%. Around 11% can be explained by the direct impact of the energy crisis on manufacturing prices. In addition, our estimate of asymmetric transmission implies that if energy prices were to return to their January 2021 levels, manufacturing prices would fall by only 0.19%.

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Online Appendix

A Energy contracts

The shift-share variable used to measure energy-cost shocks at the firm-level relies on the implicit assumption that manufacturing firms are all exposed to the same fluctuations in energy prices, conditional on the type of energy. In reality, firms display different energy contracts, that determine the volatility of their energy costs.

In September 2022, INSEE has conducted a survey on firms in the manufacturing and service sectors, to evaluate their exposure to the energy crisis (INSEE, 2022). The survey included questions on the firm's consumption of energy and gas including the value of its energy bill, the nature and expiration date of its contract with the energy provider, the estimated evolution of the unit price paid on energy between 2021 and 2022, the anticipated evolution of the price between 2022 and 2023, and the expected effect of energy prices on the firm's activity in the coming months. The survey covered 1,319 firms, out of which 412 can be matched with our estimation sample.

Table A1: Descriptive statistics on energy contracts

	Electricity	Gas
Number of firms	412	302
Contract type (%)		
Regulated prices	8.5	0
Indexed on regulated prices	6.8	0
Fixed price	47.3	45.4
Indexed on wholesale prices	10.9	14.8
Other	21.4	13.1
No response	5.1	26.7
Contract renewal (Fixed price contract) (%)		
Before end of 2022	53.8	34.8
2023-S1	6.7	8.6
2023-S2	24.1	28.3
2024	8.7	15.0
2025+	6.7	10.7
Estimated price increase 2021-2022 (%)		
Fixed price contract	11.6	44.8
Contract indexed on wholesale prices	81.2	159.8
Estimated price increase 2022-2023 (%)		
Fixed price contract	53.3	28.4
Contract indexed on wholesale prices	48.9	78.1

Notes: The table gives statistics on the subsample of firms in the estimation sample which are surveyed in INSEE (2022). The top panel covers the nature of their contract with their energy provider. It has to be noted that regulated prices are restricted to firms with less than 10 employees. In our data, all firms that declare benefiting from a contract with regulated prices have more than 10 employees. The second panel is the expiration date of the contract, conditional on the firm benefiting from a fixed-price contract. The third panel is the average estimated unit price increase between 2021 and 2022. The fourth panel is the average unit price increase that firms expect to incur between 2022 and 2023. Both estimated unit price increases are computed as weighted averages using nominal energy consumptions as weights.

Table A1 summarizes the main insights from this survey, in the subsample of matched firms. As expected, firms benefit from heterogeneous contracts with their energy providers, from fixed price contracts to contracts indexed on wholesale prices. While our shift-share measure of energy cost shocks may overestimate the volatility of prices for the former, it instead underestimates it for firms which contract is indexed on wholesale prices. Benefiting from a fixed price contract does not imply that you are insulated from the energy crisis though. The reason is that prices are renegotiated when the contract is renewed, which seems to happen at least once a year (see the second panel in Table A1).

The last two panels of Table A1 provide additional insights regarding the price changes faced by firms benefiting from fixed price contracts versus contracts indexed on wholesale prices. As expected, contracts indexed on wholesale prices have been more exposed to the energy crisis in 2021-2023. On average, firms engaged into such contracts declare having suffered a 81% (resp. 160%) increase in the price of their electricity (resp. gas) between 2021 and 2022, which is substantially above the numbers reported by firms benefiting from fixed price contracts, at 12 and 45% respectively. These average price variations can be compared with what is measured in the data and used in our measure of exposure to energy price shocks (Figure A1). Over 2021-2022Q3, the average price increase of electricity (resp. of gas) is equal to 19% (resp. 79%), in the ballpark of numbers reported by firms engaged into fixed term contracts. In Table 2, we test the robustness of our results to negelecting firms engaged into contracts indexed on wholesale prices, for which exposure to energy price shocks is systematically under-estimated. As expected, discarding firms which contract is indexed on wholesale prices reduces our estimated pass-through. But the average pass-through rate remains high and not statistically different from one.

B Quantification exercise

We describe here our procedure to predict producer price changes at the firm- and industry level using pass-through estimates.

Firm-level predicted price changes from energy cost shocks We predict producer price changes using results displayed in Column (2) of Table 3 and set the estimated pass-through rate $\hat{\alpha} = 1.197$. For firms for which we have energy data, we compute the predicted change in output prices from energy cost shocks $\widehat{\Delta_{22,21} p_{fk}}$ as:

$$\widehat{\Delta_{22,21} p_{fk}} = \hat{\alpha} \times S^E_{f0} \times \Delta_{22,21} p^E_f$$

where $\Delta_{22,21} p^E_f$ is the observed firm-level change in energy prices between 2021Q1 and 2022Q4. For firms for which we do not have energy data, we compute:

$$\widehat{\Delta_{22,21} p_{fk}} = \hat{\alpha} \times S^E_{s0} \times \Delta_{22,21} p^E_s$$

where $\Delta_{22,21} p^E_s$ is the 2-digit industry average change in energy prices, computed as: $\Delta_{22,21} p^E_s = w^{elec}_{s0} \times \Delta_{22,21} p^{elec} + w^{gas}_{s0} \times \Delta_{22,21} p^{gas} + w^{oil}_{s0} \times \Delta_{22,21} p^{oil}$, where w^{elec}_{s0}, w^{gas}_{s0} and w^{oil}_{s0} are the shares of the cost of energy e in total energy costs among firms in sector s. Every firm in our sample is given an energy consumption level. S^E_{s0} is the 2-digit industry average share of energy costs in total variable costs. It is computed as the ratio between total energy bill and total variable costs among firms for which we have energy data.

Sectoral predicted price changes Based on the distribution of firm-level predicted price changes, we can compute the corresponding sectoral inflation which the model attributes to energy cost shocks. Namely:

$$\widehat{\Delta_{22,21} p_s} = \sum_{f \in s} w^{ppi}_f \widehat{\Delta_{22,21} p_f}$$

where w^{ppi}_f is the weight of firm f in the OPISE survey, normalized so that weights sum to one within a sector.

C Additional Tables

Table A2: Distributions of shocks and price changes

	5 pctl	Mean	Median	95 pctl	St.dev.
Monthly					
$\Delta p^E_{ft} \times S^E_{f0}$	-.17	.03	.01	.28	.22
Δp_{fkt}	-3.62	.31	0	5.42	4.2
Quarterly					
$\Delta p^E_{ft} \times S^E_{f0}$	-.18	.08	.03	.46	.32
Δp_{fkt}	-4.8	1	0	9.11	5.63

Notes: This table reports statistics on the changes in output prices and cost shocks in our two estimation samples: monthly and quarterly data. $\Delta p^E_{ft} \times S^E_{f0}$ is the firm-level direct change in marginal costs from energy prices. Δp_{fkt} is the output price change. In %. N = 199,742 and 64,721, respectively.

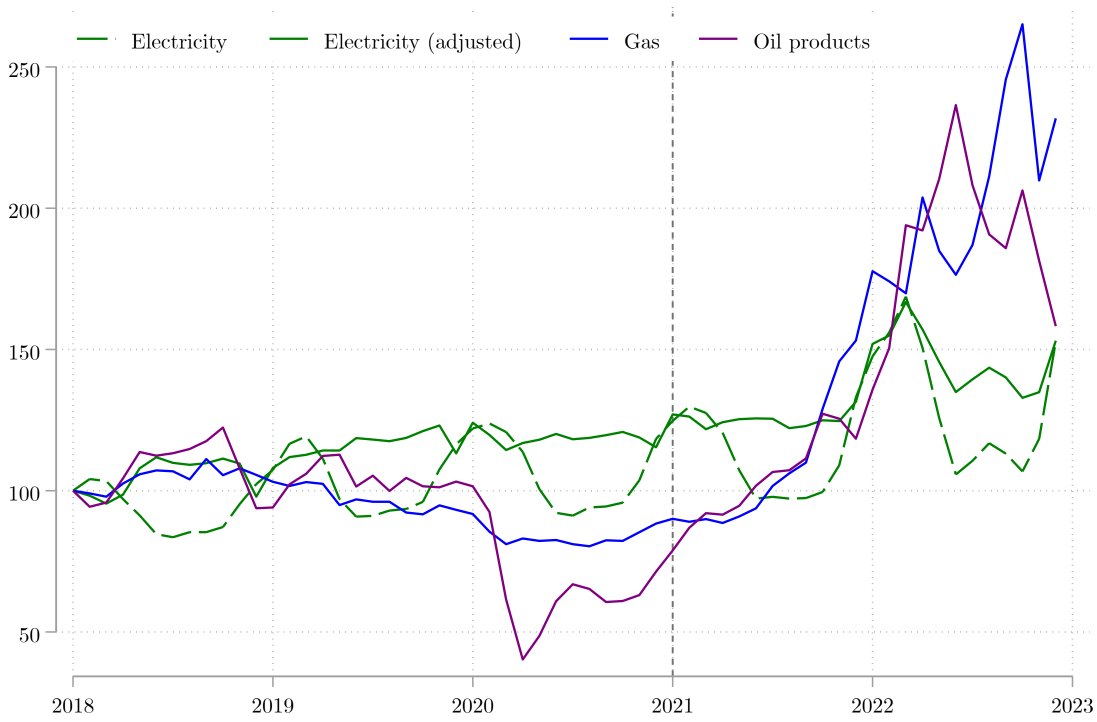
Table A3: Impact of energy cost shocks on price change probabilities

			Marginal effect (pp) on a price	
X	Coefficient	Z-stat	Change	Increase
$\Delta p^E_{ft} \times S^E_{f0}$	5.42	2.89	.29	1.96
Δp^H_{kt}	12.02	40.79	.64	4.34
Δp^V_{ft}	11.06	4.82	.59	3.99

Notes: This table shows results of the estimation of an ordered probit model, following Loupias and Sevestre (2013). The estimated equation is: $\mathbb{1}_{fpt}(\Delta p_{fkt} >=< 0) = \alpha \Delta p^E_{ft-j} \times S^E_{f0} + \beta X_{fkt} + FE_{st} + \epsilon_{fkt}$. The first column reports the estimated coefficient α, the second column shows the associated Z-statistic. The marginal effects give the probability change associated with a 1 percent increase in the corresponding covariate, setting the other covariates at their sample mean. All specifications include 2-digit industry by period fixed effects.

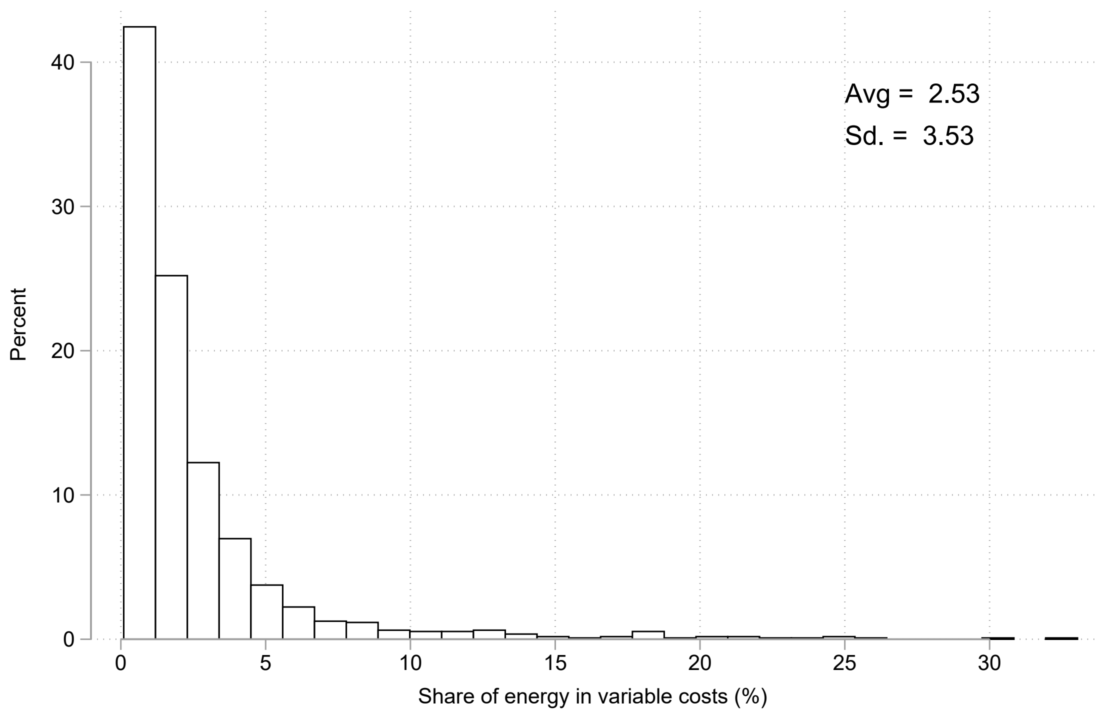
D Additional Figures

Figure A1: Evolution of energy prices



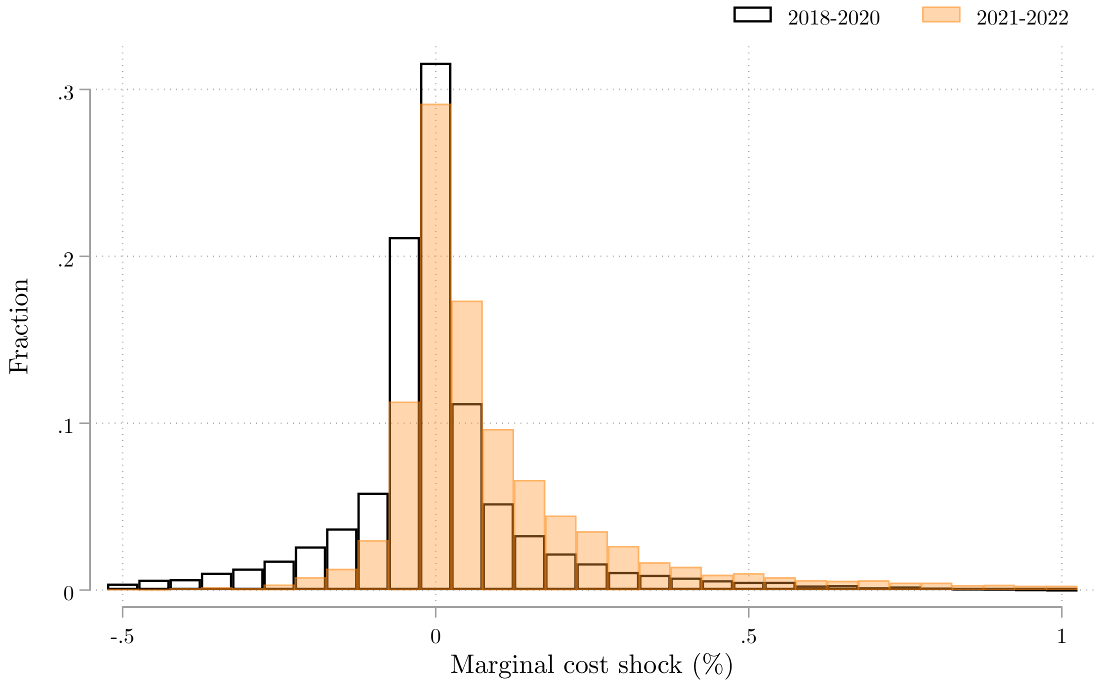
Notes: This figure shows the evolution of the PPI for electricity, gas and oil products, constructed by INSEE. For electricity and gas, the PPI is constructed from prices set by energy providers to firms for direct consumption. For oil products, the PPI is defined for all coking and refining products. For electricity, the raw data in dashed green is corrected for seasonality before being used in the analysis (green solid line). Normalized to 100 in January 2018.

Figure A2: Distribution of energy costs shares S_f^E



Notes: This figure shows the distribution of energy costs share in our sample, the ratio of the energy bill to total variable costs, in percent. Total variable costs are defined as the sum of the firm's wage bill and intermediate consumption (raw materials, merchandises, and services). The ratio is calculated at the firm level by averaging the energy bill to costs ratio over pre-sample years (2014-2017).

Figure A3: Distribution of energy costs shocks $\Delta p^E_{ft} \times S^E_f$



Notes: This figure shows the distribution of energy-driven costs shocks $\Delta p^E_{ft} \times S^E_f$ that we use in the estimation of Equation 2, at the quarterly frequency.