The Many Channels of Firm's Adjustment to Energy Shocks: Evidence from France[1]

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[1]This paper is not meant to represent the position or opinion of the Banque de France or the Eurosystrem.

Motivation 1/3

- Impact of the 2022 energy crisis on the European manufacturing sector.

- Potential embargo on Russian gas and oil:
    - German chancellor, March 2022: '*'Hundreds of thousands of jobs would be at risk... Entire branches of industry are on the brink*."

    - German Ministry of Finance: Jan. 2023 "*The German industry and society are once again proving much more resilient and adaptable than certain people feared*."

- Between the end of 2020 and November 2022 gas (electricity) prices for manufacturing French firms almost tripled (doubled).
    - 5% reduction in French manufacturing production.

- How did firms adjust to such a shock? Answer based on French plant/firm level data.

Motivation 2/3

Channels of adjustment to an energy shock:

- Energy demand.
- Energy efficiency (VA/MWH).
- Prices (pass through).
- Output and employment.
- Production relocation between plants and imports of energy intensive intermediate inputs.

Motivation 3/3

"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)

What do we do

- We employ standard diff-in-diff firm level approach to test the multiple channels of firm's adjustment to electricity and gas price shocks.

- **Main result**: firms adjust quickly through various channels:
  - Substantial reduction in energy demand (smaller elasticity for large price shocks).
  - Increase in energy efficiency (value added per MWh).
  - Full pass through into (export) prices $\Rightarrow$ exports fall.
  - Reduction in firms' output and employment.
  - Cross-plant production reallocation.
  - Mild negative effect on profits.

Related literature

- Price elasticity of energy demand:
  - Labandeira, Labeaga & Lopez-Otero (2017): Survey on price elasticity.
  - Alpina, Citino & Frigo (2023): Infra-annual elasticity for 2021.

- Cost pass-through:
  - Ganapati, Shapiro & Walker (2020): 70% of energy price changes passed through consumers.
  - Lafrogne-Joussier, Martin & Méjean: EACI + OPISE data.

- Wage and employment impact of energy price shocks:
  - Marin & Vona (2021): 0.5 short-term elasticity of energy consumption.

- Price signal and green investment driven TFP gains:
  - Cali,Cantore, Iacovone et al. (2022): 0.15 elasticity of TFP to fuel price.

Context

- Several contracts co-exist with both regulated and market driven prices:
  - Regulated prices: EDF.
  - Market prices: Alterna, Direct Energie, Enercoop, GDF Suez, Poweo.

- Many changes in regulations during the period 2001-2010.

- Electricity price can vary within a year for a given contract.

- Contracts are renegotiated ($\simeq$ 2 years) or comprise provisions for price adjustment.

- Firms can be (un)lucky depending on the timing of the contract renegotiation.

Identification strategy 1/3

- Price of electricity at the plant and firm level:
  - Firm level evidence: elasticity, employment and efficiency effect.
  - Plant level evidence: cross-plant substitutability.

- Within identification (firm fixed effects) + Sector-year fixed effects.

- French institutional and contractual setting $\rightarrow$ Limited endogeneity concern:
  - Within firm *changes* in energy price driven by the (random) timing of contracts.
  - The timing of price shocks at firm level depends on the timing of contract renegotiation.

Identification strategy 2/3

Baseline equation

$$y_{f,s,t} = \beta p_{f,s,t}^{elec\backslash gas} + \theta_f + \theta_{st} + \epsilon_{f,s,t}$$

- y_{ft} is in turn: (i) electricity demand (ii) employment, (iii) value added, (iv) operational profits, (v) energy efficiency, (vi) import, (vii) export prices and (viii) exports

- p_{ft}^{elec} is the electricity price in keuros/MWh (i.e. electricity bill over quantity).

- p_{ft}^{gas} is the gas price in keuros/MWh (i.e. gas bill over quantity).

- θ_f firm fixed effects $\rightarrow$ identification: within-firm variation in energy price and outcomes

- θ_{st} sector-year fixed effects.

Identification 3/3

- Scaling-up firms increase their energy demand and negotiate lower price (endogeneity).

- Unobserved firm-specific shocks affecting the energy price and firm's outcomes.

- Three strategies:
    1. Price of energy lagged one year.
    2. Firm-period fixed effects (period= three-year window).
    3. IV (shift-share approach).

- Shift share IV: Sector-specific *changes* in energy price (leave-one-out) affect firm-specific price *changes* proportionally to the initial firm-sector gap in energy price setting:

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

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

Data

EACEI:

- Electricity and gas bill (in k€), purchased quantity (MWh), in the period **1995-2019** at plant and firm level.
- Survey based data (repeated cross section with firm ID info).

FICUS/FARE:

- Number of workers (units), value added, operational profits for the universe of French firms in the period 1995-2019, firm level.

French Custom Data:

- Export value and quantity of French firms in the period 1995-2019.
- Unit Values as proxy for export price (weighted average across products and destinations).

Descriptive Statistics
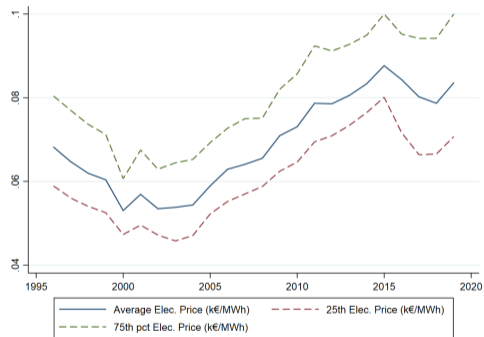
Table 1 – Descriptive statistics.

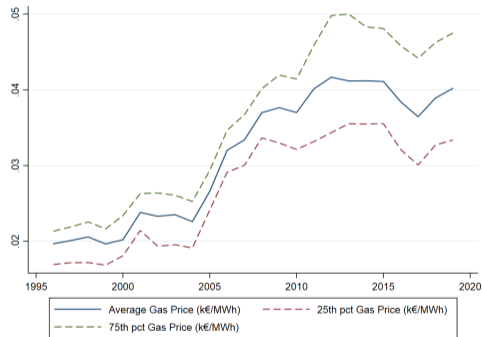| Variable	Obs.	Mean	Median
Electricity price (keuros/MWh)	113,893	0.071	0.068
Gas price (keuros/MWh)	113,893	0.031	0.029
Electricity dependency (in %)	113,893	2.52	1.30
Gas dependency (in %)	113,893	1.67	0.51
Employment (unit)	113,893	321	121
Labor dependency (in %)	113,893	32.80	28.55

▶ Sector Elec. ▶ Sector Gas.

Descriptive Statistics

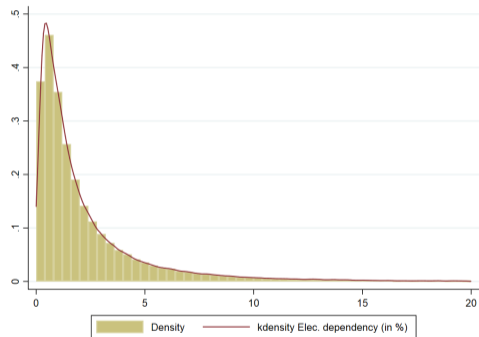Figure 1 – Energy price over time.

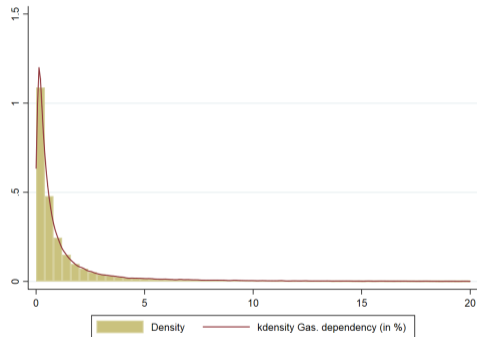(a) Electricity price.

(b) Gas price.

Source: Authors' calculations on EACEI data.

Descriptive Statistics

Figure 3 – Empirical distribution energy dependency of French firms.

(a) Electricity dependency.

(b) Gas dependency.

Source: Authors' calculations on EACEI data.

Results: Energy demand 1/4

Table 2 – Electricity demand price elasticity

Dep Var:	Firm electricity demand (ln)				
	(1)	(2)	(3)	(4)	(5)
Electricity price (ln)	-1.089*** (0.183)			-0.628*** (0.091)	-0.376** (0.192)
Electricity price (ln) lag		-0.536*** (0.197)	-0.466** (0.199)		
Value Added (ln)			0.352*** (0.030)		
Estimator	OLS				2SLS
Firm FE	yes	yes	yes	no	yes
Sec-Year FE	yes	yes	yes	yes	yes
Firm-Period FE	no	no	no	yes	no
IV^{Elec}					0.262***
K-P Wald F-stat					550
Observations	108,344	90,384	89,720	87,388	108,342

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

Results: Energy demand 2/4

Table 3 – Gas demand price elasticity

Dep Var:	Firm gas demand (ln)				
	(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)			0.287*** (0.032)		
Estimator	OLS				2SLS
Firm FE	yes	yes	yes	no	yes
Sec-Year FE	yes	yes	yes	yes	yes
Firm-Per FE	no	no	no	yes	no
IV^{Gas}					0.472***
K-P Wald F-stat					1426
Observations	108,344	90,384	89,720	87,388	108,342

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

Results: Energy demand 3/4

Table 4 – Non-linear energy price demand elasticity

	(1)	(2)	(3)	(4)	(5)
Panel a: Electricity demand (ln)					
Elec. Price (ln) lag	-0.755***	-0.295***	-0.068	-0.342***	-0.209***
	(0.241)	(0.065)	(0.125)	(0.103)	(0.071)
Observations	34,504	38,015	7,284	17,592	6,416
Panel b: Gas demand (ln)					
	(1)	(2)	(3)	(4)	(5)
Gas. Price (ln) lag	-0.507***	-1.123***	-1.232***	-1.061***	-0.711***
	(0.101)	(0.156)	(0.322)	(0.204)	(0.121)
Observations	27,676	44,415	8,566	20,486	7,585
Price shock	Negative	Positive		Positive	
			Small	*Medium*	*Large*
Avg $\Delta \ln(p^{Elec})$	-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%

Notes: Firm FE and Sec-Year FE in all specifications. The dependent variable is in turn the electricity and gas demand. Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Results: Energy demand 4/4

Table 5 – Time-varying energy demand elasticity

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

Notes: Firm FE and Sec-Year FE in all specifications. Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Results: Competitiveness

Table 6 – Export related outcomes

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

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

Results: Production, employment, energy efficiency and profits

Table 7 – Impact on employment, production, efficiency and profits. OLS results

Dep Var:	Emplo. (ln)	Value Add. (ln)	Erg Eff. (ln)	Profit (ln)
	(1)	(2)	(3)	(4)
Electricity Price (ln) lag	-0.151***	-0.160***	0.212	-0.165*
	(0.042)	(0.042)	(0.160)	(0.085)
Gas Price (ln) lag	-0.016	-0.012	0.380***	-0.008
	(0.035)	(0.042)	(0.128)	(0.068)
Observations	90,384	89,720	89,720	73,098

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

- Firm-level 2SLS results: ▸ IV results
- Firm-level results by energy dependency: ▸ By dependency
- Firm-level results by sub-period: ▸ By sub-period
- Firm-level results for high shocks: ▸ Large shocks
- Firm-level results by energy efficiency: ▸ Energy efficiency

Results: cross-plant production relocation

Table 8 – Plant level evidence: the within-firm substitution effect

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

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

Also substitution of imported energy-intensive intermediate inputs to own production ▸ Imports

The current energy shock in the lens of our estimates

- Preferred demand elasticities: Electricity -0.4 $\sim$ -0.5; Gas -0.9.

- Non-linear price elasticities: lower for higher price shocks and in more recent time.

- Back of the envelope calculation:
    - Price of manufactures Dec 22 / average 2019-21 = + 21.5%.
    - Price of electricity Dec 22 / average 2019-21 = + 47.6%.
    - Real electricity price: +26%.
    - Elasticity for large shocks end of the period: 0.15.
    - Expected electricity demand: -4% (i.e. +26% $\times$ 0.15).
    - Electricity bill: +21% (higher price but lower demand).
    - Employment, VA, profits $\simeq$ -4%
    - Actual outcome: French manuf. prod. down by -5% in 2022 compared to 2019

Policy discussions

- Short term policies: energy price caps and subsidies responded to concerns on production and employment
- Discuss two costly (total for EU = 220 billion euros) short term policy options :
  - 1) Partial absorption of price increase for total firm consumption (France)
  - 2) Partial price absorption only for a portion of past consumption : allows price signal to work for extra consumption (Netherlands)
  - Is 2) superior to 1) (lower fiscal cost for same firm level price) ? only if price elasticity of demand does not decrease much with large price increases
- Long term policy options
  - Objective should be to increase energy efficiency : price signal works
  - Use public money for increasing innovation and energy efficiency to help transition towards clean energy (cost reduction and competitiveness)
  - Reform of the European electricity market: to reduce volatility and firms exposure to shocks, develop long term contracts to smooth shocks at firm level (maybe with minimum prices)

Figure 5 – Energy efficiency and electricity price.
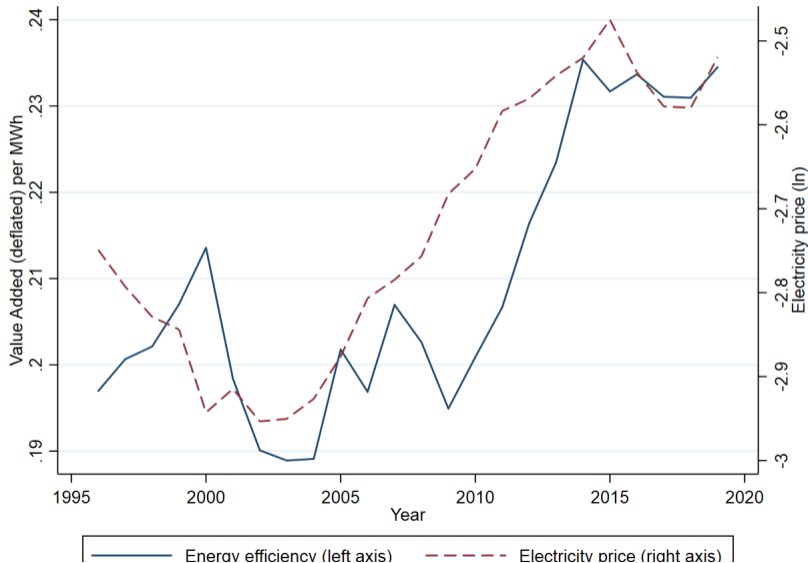
THANKS FOR YOUR ATTENTION

Descriptive Statistics

Table 9 – Electricity dependency by sector.

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

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Descriptive Statistics

Table 10 – Gas dependency by sector.

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

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Results: heterogeneous elasticity by energy dependency

Table 11 – Firm-level outcomes: heterogeneous elasticity by energy dependency

Dep Var:	Emplo. (ln)	Value Add. (ln)	Erg Eff. (ln)	Profit (ln)
	(1)	(2)	(3)	(4)
Elec. Price (ln) lag	-0.175*	-0.091	0.607*	-0.051
	(0.090)	(0.086)	(0.348)	(0.173)
Elec. Price (ln) lag × Ele dep.	0.012	-0.042	-0.230**	-0.070
	(0.035)	(0.035)	(0.113)	(0.067)
Gas. Price (ln) lag	0.123*	0.147**	0.486***	0.143
	(0.064)	(0.067)	(0.180)	(0.105)
Gas. Price (ln) lag × Gas dep.	-0.206**	-0.237***	-0.157	-0.229***
	(0.085)	(0.064)	(0.107)	(0.083)
Observations	89,952	89,297	89,297	72,742

Notes: The dependent variable is turn total employment in the firm, its value added and the energy efficiency (i.e. value added per MWh). Electricity and gas price approximated by value over quantity purchased in the year. Robust standard errors in parenthesis. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

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Results: heterogeneous elasticity by period

Table 12 – Time-varying elasticity on other outcomes

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

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

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Results: elasticity to large shocks

Table 13 – Large energy price shocks

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

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

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Results: elasticity by firm's energy efficiency

Table 14 – Energy price elasticity and the energy efficiency of firms.

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

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

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Imports and energy price shocks

Table 15 – Imports and energy price shocks

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

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

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Results: Production, employment, energy efficiency and profits

Table 16 – Impact on employment, production, efficiency and profits. 2SLS results

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

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

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