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 positions or opinions of the Banque de France or the Eurosystem.**

Motivation 1/2

- Concerns on the impact on the European manufacturing sector of the energy crisis in 2022
- Two statements on a 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). Manufacturing production increased by 2.6%
- How did firms adjust to such a shock? Look at rich French plant/firm level data (1995-2019)

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  - German Ministry of Finance: Jan. 2023 "The German industry and society are once again proving much more resilient and adaptable than certain people feared"
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- How did firms adjust to such a shock? Look at rich French plant/firm level data (1995-2019)

Motivation 2/2

Channels of adjustment to an energy shock:

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

Main results

Multiple channels: firms adjust quickly and strongly

- Substantial reduction in energy demand but less so for large shocks and less so at the end of the period
- Energy efficiency (VA/MWH) increases
- Pass through into prices is 100% $\Rightarrow$ exports fall
- Output and employment fall
- Production relocation between plants
- Imports of energy intensive intermediate inputs
- Small hit on profits and mostly on energy intensive firms

Related literature

- Price elasticity of energy demand:
  - Survey in Labandeira, Labeaga & Lopez-Otero, (En. Policy, 2017)
  - Alpina, Citino & Frigo, Infra-annual elasticity for 2021 (Banca d'Italia, 2023)
- Cost pass-through:
  - Ganapati, Shapiro & Walker, US Census Bureau Data (AEJ Applied, 2020)
  - Lafrogne-Joussier, Martin & Méjean, same data as ours + OPISE (mimeo, 2023)
- Wage and employment impact of climate policies:
  - Marin & Vona, same data as ours (EER, 2021)

Context

- French electricity market:
  - Several changes in regulations during the period 2001-2010
  - Several contracts co-exist with both regulated and market driven prices.
  - 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

- Standard diff-in-diff firm level approach to test the multiple channels of firm's adjustment to electricity and gas price shocks
- Price of electricity (gas) 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

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

- 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 negotiate lower price (endogeneity):
  - Firms sales ↑, demand for energy ↑, negotiated Mwh price ↓
- 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:

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

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

Data

EACEI:

- Electricity and gas bill (in keuros), 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, EBE 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: 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

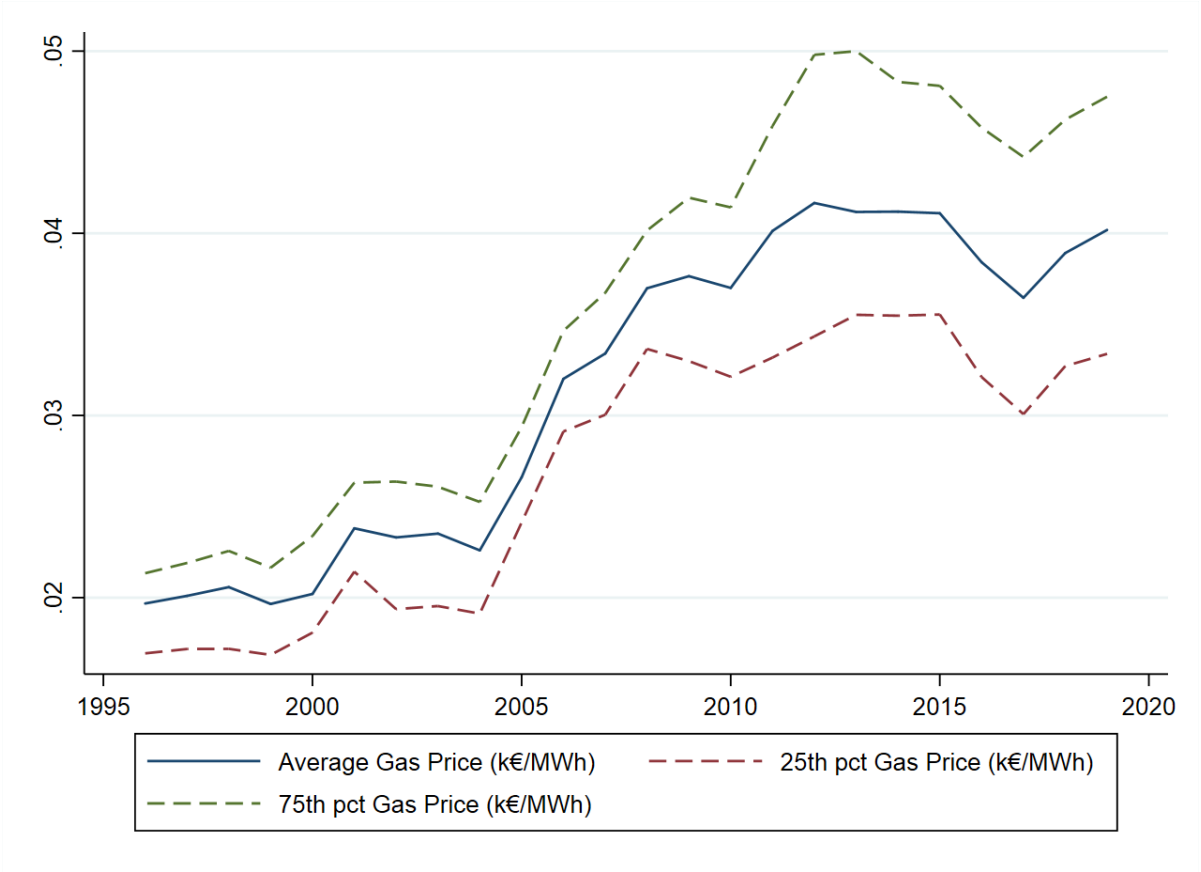
Descriptive Statistics

Figure: Electricity price over time.

Source: Authors' calculations on EACEI data.

Descriptive Statistics

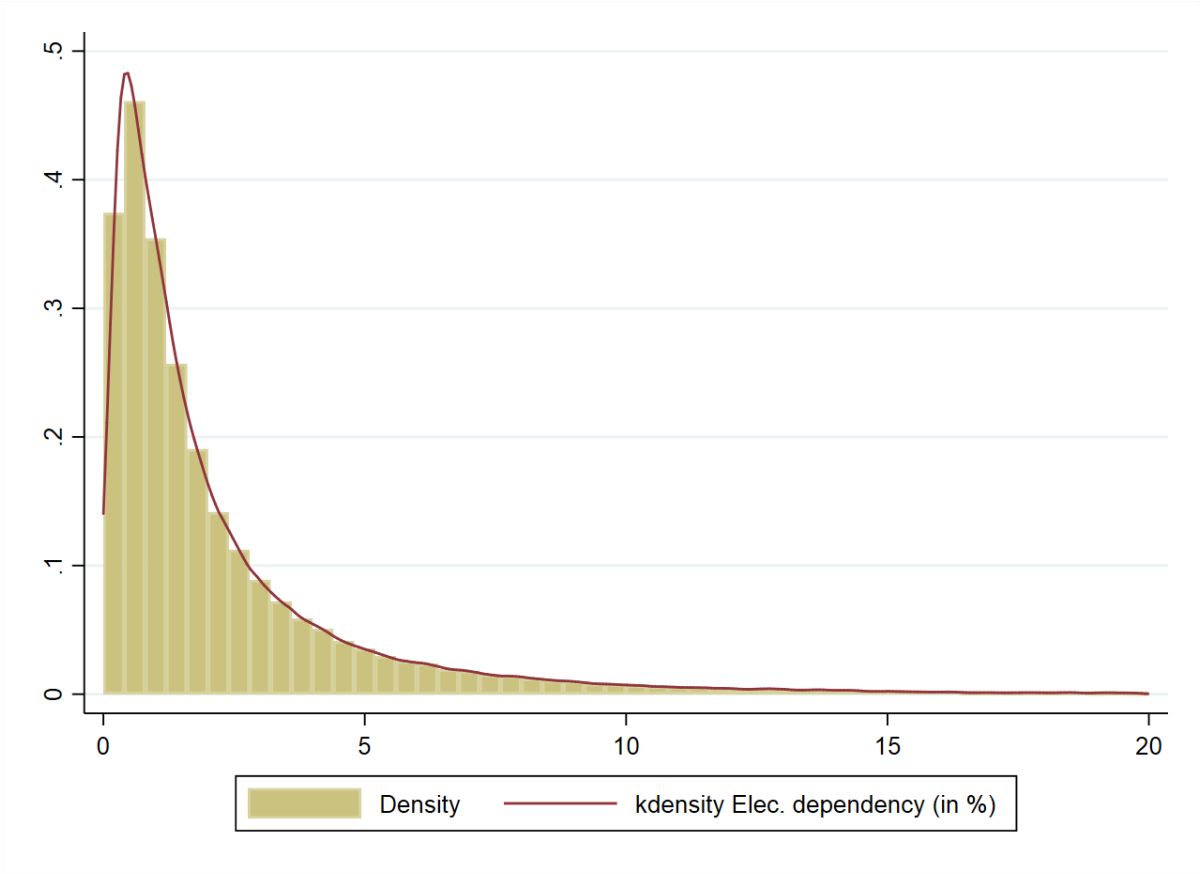
Figure: Gas price over time.



Source: Authors' calculations on EACEI data.

Descriptive Statistics

Figure: Empirical distribution electricity dependency.



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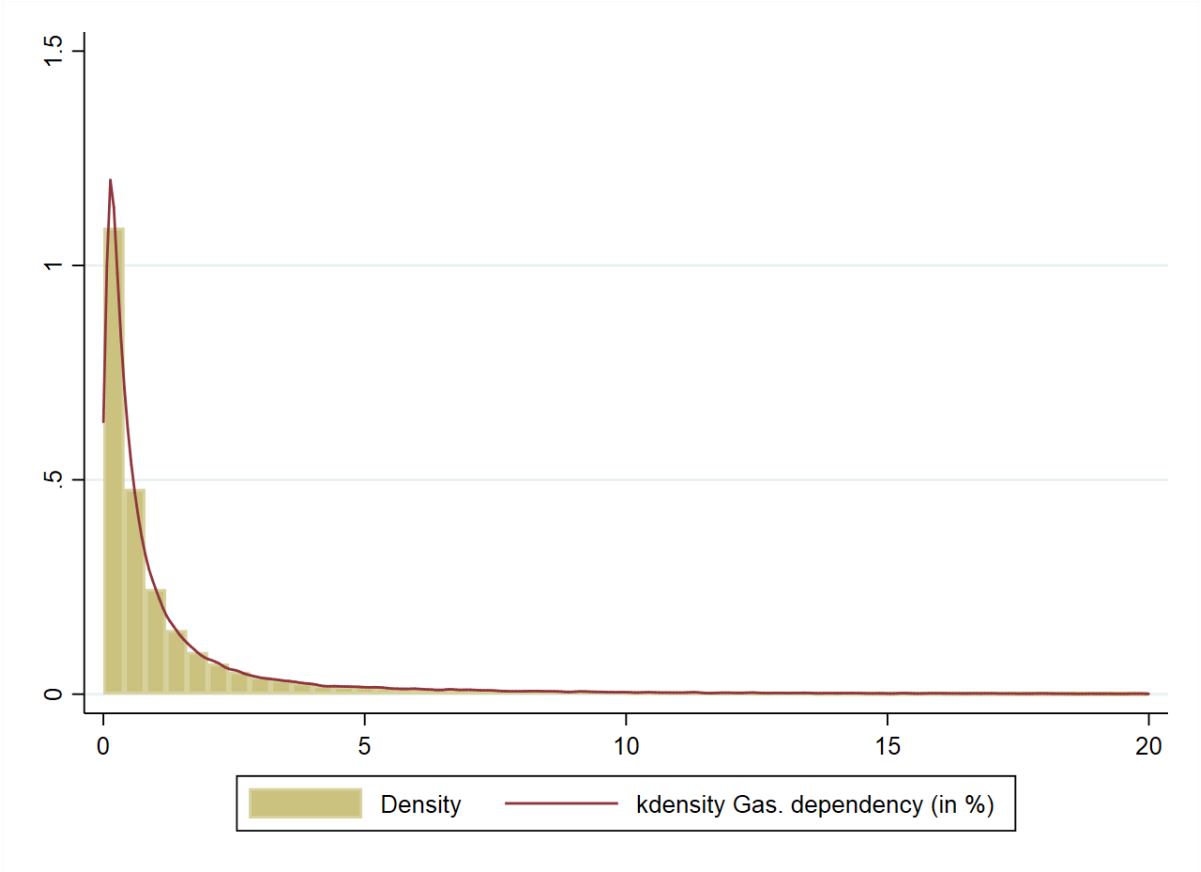
Descriptive Statistics

Figure: Empirical distribution gas dependency.



Source: Authors' calculations on EACEI data.

Energy demand 1/4

Table: Electricity demand price elasticity

Dep Var:	*Firm electricity demand (ln)*				
	(1)	(2)	(3)	(4)	(5)
Electricity price (ln)	-1.089***...			-0.628***	-0.376**
	(0.183)			(0.091)	(0.192)
Elec. Price (ln) lag		-0.536***	-0.466**		
		(0.197)	(0.199)		
Value Added (ln)			0.352***		
			(0.030)		
Estimator	OLS				2SLS
Firm FE	yes	yes	yes	no	yes
Sec-Year FE	yes	yes	yes	yes	yes
Firm-Period FE	no	no	no	yes	no
IV^{Elec}					0.262***
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. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.**

Energy demand 2/4

Table: Gas demand price elasticity

Dep Var:	*Firm gas demand (ln)*				
	(1)	(2)	(3)	(4)	(5)
Gas price (ln)	-1.762***			-0.944***	-1.236***
	(0.270)			(0.147)	(0.130)
Gas. Price (ln) lag		-0.922***	-0.899***		
		(0.209)	(0.217)		
Value Added (ln)			0.287***		
			(0.032)		
Estimator	OLS				2SLS
Firm FE	yes	yes	yes	no	yes
Sec-Year FE	yes	yes	yes	yes	yes
Firm-Period FE	no	no	no	yes	no
IV^{Gas}					0.472***
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. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.**

Energy demand 3/4

Table: Non-linear energy price demand elasticity

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

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.**

Energy demand 4/4

Table: Time-varying energy demand elasticity

Dep Var:	Electricity Demand	Gas Demand
	(1)	(2)
$p^{Elec}_{i,t-1}$ × Period 96-03	-0.622**	-0.196
	(0.286)	(0.228)
$p^{Elec}_{i,t-1}$ × Period 04-11	-0.506***	-0.322**
	(0.136)	(0.151)
$p^{Elec}_{i,t-1}$ × Period 12-19	-0.327**	-0.240
	(0.146)	(0.158)
$p^{Gas}_{i,t-1}$ × Period 96-03	-0.292***	-1.408***
	(0.083)	(0.204)
$p^{Gas}_{i,t-1}$ × Period 04-11	-0.077	-0.506***
	(0.065)	(0.125)
$p^{Gas}_{i,t-1}$ × Period 12-19	-0.271	-0.755***
	(0.186)	(0.245)
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. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.**

Competitiveness

Table: 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. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.**

Production, employment, energy efficiency and profits (OLS)

Dep Var:	*Emplo. (ln)*	*Value Add. (ln)*	*Erg Eff. (ln)*	*Profit (ln)*
	(1)	(2)	(3)	(4)
Elec. 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. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.**

Production, employment, energy efficiency and profits (IV)

Table: 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. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.**

Multi-plant firms

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. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.**

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. ***** $p < 0,01$; ****** $p < 0,05$; ***** $p < 0,1$.

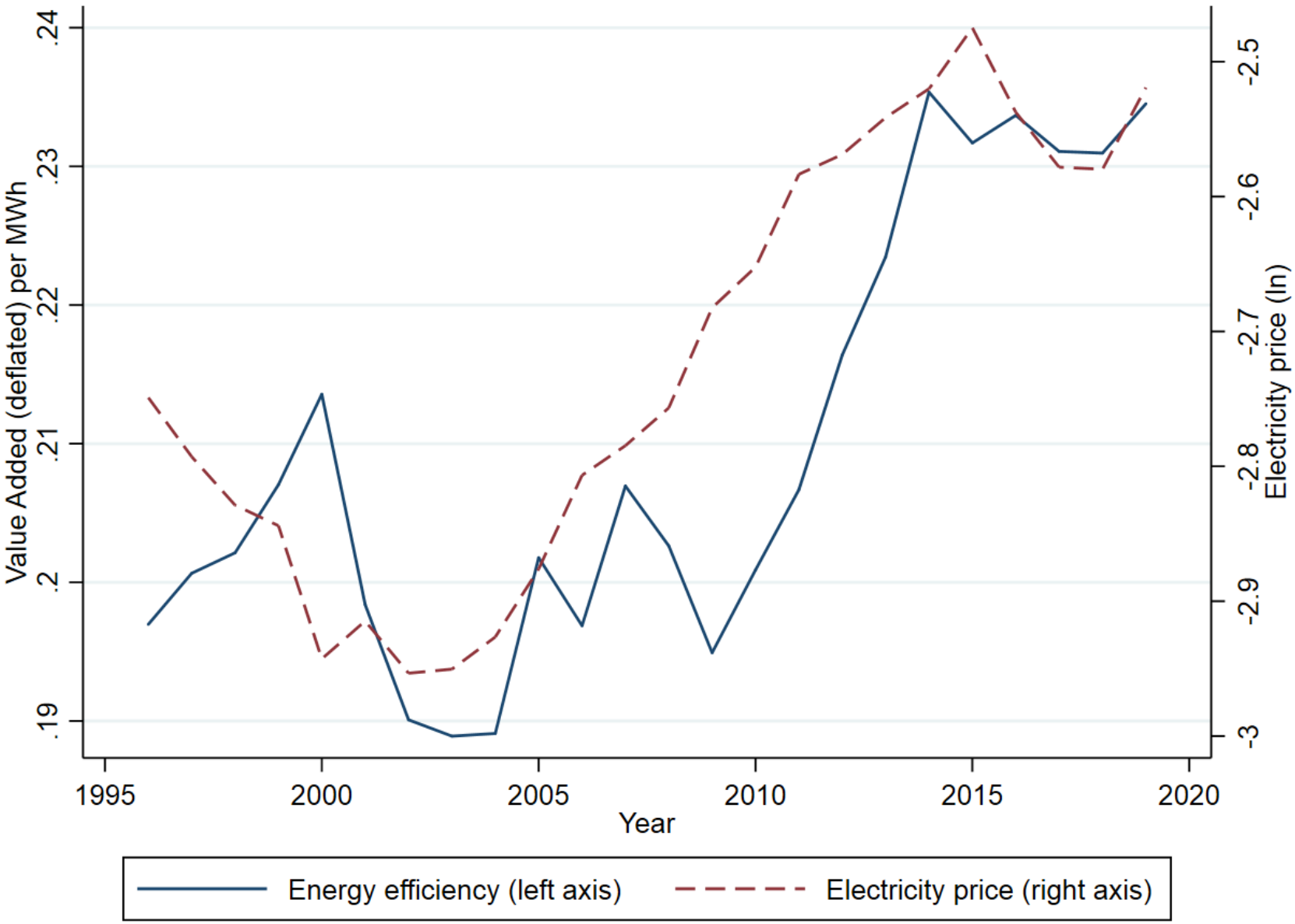
The current energy shock in the lens of our estimates

- Are our firm-level estimates useful to understand the current situation ?
- Back of the envelope calculation for comparison: average 2019-21 vs 2022:
  - What was observed at aggregate level:
    - Price of manufactures : + 21.5%
    - Price of electricity : + 47.6% (contract $>$ 36 K)
    - Real electricity price: +26%.
    - French manuf. prod. : -5% ; employment : + 1.2%
  - What the model predicts (using smaller elasticities for later period and large shocks)
    - Expected electricity demand: -4%
    - Employment, VA, profits $\simeq$ -5%

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) 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: Energy efficiency and electricity price.



Extra slides

Additional tables

- Control for energy dependency
- Export
- Within plant substitution
- Substitution of imports to energy use

Control for energy dependency

Table: Other firm-level outcomes

Dep Var:	*Emplo. (ln)*		*VA (ln)*		*Erg Eff. (ln)*		*Profit (ln)*	
ln **of:**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
P^E_{t-1}	-0.15***	-0.18*	-0.16***	-0.09	0.21	0.61*	-0.17*	-0.05
	(0.04)	(0.09)	(0.04)	(0.09)	(0.16)	(0.35)	(0.09)	(0.17)
$P^E_{t-1} \times dep$		0.01		-0.04		-0.23**		-0.07
		(0.04)		(0.04)		(0.11)		(0.07)
P^G_{t-1}	-0.02	0.12*	-0.01	0.15**	0.38***	0.49***	-0.01	0.14
	(0.04)	(0.06)	(0.04)	(0.07)	(0.13)	(0.18)	(0.07)	(0.11)
$P^G_{t-1} \times dep$		-0.21**		-0.24***		-0.16		-0.23***
		(0.09)		(0.06)		(0.11)		(0.08)
Obs.	90,384	89,952	89,720	89,297	89,720	89,297	73,098	72,742

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. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.**

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

Dep Var:	Employment	Value added
	(1)	(2)
Elec. Price (ln) lag	-0.133***	-0.152***
	(0.038)	(0.046)
Elec. Price (ln) lag × 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
Firm FE	yes	yes
Sec-Year FE	yes	yes

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

Time varying

Table: Time-varying elasticity on other outcomes

Dep Var:	Employment	Value added	Energy efficiency	Profit
	(1)	(2)	(3)	(4)
$p^{Elec}_{i,t-1}$ × Period 96-03	-0.242***	-0.280***	0.153	-0.491***
	(0.078)	(0.075)	(0.236)	(0.137)
$p^{Elec}_{i,t-1}$ × Period 04-11	-0.192***	-0.160***	0.249*	-0.123
	(0.045)	(0.049)	(0.138)	(0.134)
$p^{Elec}_{i,t-1}$ × Period 12-19	-0.059	-0.070	0.209	0.069
	(0.050)	(0.062)	(0.151)	(0.132)
$p^{Gas}_{i,t-1}$ × Period 96-03	-0.110	-0.067	0.558***	0.021
	(0.085)	(0.074)	(0.105)	(0.139)
$p^{Gas}_{i,t-1}$ × Period 04-11	-0.018	0.011	0.190**	0.040
	(0.052)	(0.069)	(0.089)	(0.106)
$p^{Gas}_{i,t-1}$ × Period 12-19	0.043	0.007	0.384*	-0.074
	(0.040)	(0.046)	(0.205)	(0.089)
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. *** $p < 0,01$; ** $p < 0,05$; * $p < 0,1$.**

Descriptive Statistics

Table: 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

Descriptive Statistics

Table: 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