Firms in the energy crisis: evidence from 2021-22

Matteo Alpino [1] Luca Citino [1] Annalisa Frigo [1]

[1] Bank of Italy

ChaMP Online Workshop – November 28, 2024

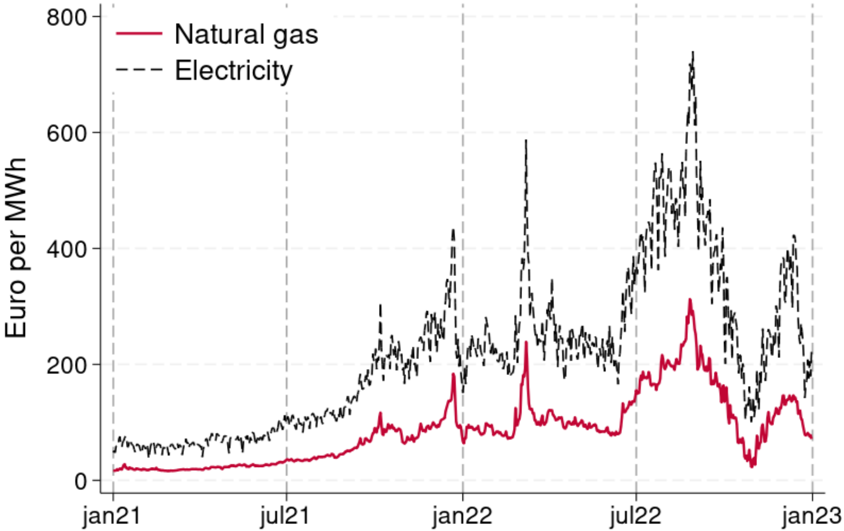


Figure: Wholesale energy prices in Italy

How do firms cope with a large and sudden upsurge in energy prices?

Little practical relevance of this question until 2021-2022 energy crisis

- Existing work on the energy crisis relies mostly on **aggregate** data or...
- ... on **micro** data predates the current crisis
- This paper: timely evidence using Bank of Italy survey data on manufacturing firms 🏭!

Understanding how firms reacted to energy price spike is useful for:

- targeting **support policies**
- informing **macro models**
- figuring out potential impacts of **green transition** as well...

Research design

- Not all firms equally exposed to the energy crisis
- Firms sign 1-2 year-long retail contracts for energy: fixed price vs variable price contract details
- Contract type and staggered expiration dates generate significant price variation *across firms*
  - **Staggered diff-in-diff**: treated vs not-yet-treated
- Study evolution of energy prices, quantities, and other outcomes around contract expiration dates.
- We use Bank of Italy survey data (Invind) on Italian manufacturing firms (50+ empl.) background on Italy

Preview of results #1

- Before the crisis, incidence of energy costs **low** on average graph
- Crisis hits firms in *staggered* way: expiration of fixed-price contract leads to:
  - ≈ **45%** higher electricity unit costs 💡
  - ≈ **30%** higher gas unit costs 🔥
- Firms react but very *heterogeneously*:
  - Firms do not cut electricity 💡, neither in 2021 nor 2022
  - Firms cut natural gas 🔥 by ≈ **35%** but only in **2022h2**. Implied elasticity ≈ **-1.1**
  - Gas intensive firms declare gas is *fundamental* input and respond by **less** ≈ Leontief

Preview of results #2

- Among EU ETS firms, limited substitution with other fossil fuels
- Small negative effect on capacity utilization 🏭
- Negative average impact on output prices growth 💲 but..
  - ... positive among gas intensive firms
- Negative impact on margins 💰

Data and design

Survey data: Invind

- Annual business survey by the Bank of Italy run in spring to collect info on the previous year
- Representative sample of Italian firms
- Good quality and often used for research
  - Guiso and Parigi '99, Rodano et al. '16, Schivardi et al., '21, Pozzi and Schivardi '16
- We design an *ad hoc* energy section and administer it to industrial firms with at least 50 employees
- Data cleaning and validation with price from Eurostat and admin micro data on quantity detail

Survey questions on 2021

(designed in 2021h2; answered in 2022h1)

Rising energy prices

At the beginning of 2021, did your firm own any instruments that protected it, wholly or partly, from energy price increases over the second half of the year? **E11**

1 No
2 Yes, fixed-price contracts
3 Yes, financial derivatives
4 Yes, other instrument

	In the first half of the 2021		In the second half of the 2021	
Please indicate, even approximately, the purchased quantity and the respective cost of the following products:	Purchased quantity	Total cost (thousands of euros)	Purchased quantity	Total cost (thousands of euros)
Electricity	E9A MWh	E7A €	E9B MWh	E7B €
Natural gas	E10A Scm	E8A €	E10B Scm	E8B €

Survey questions on 2022

(designed in 2022h2; answered in 2023h1)

Rising energy prices

In 2022, did your firm have instruments (for example fixed-price contracts or derivatives) to protect itself, even partially, from the rises in the prices ...				If yes, how many months did this protection last in 2022?
A ...of electricity?	(Yes/No)	E11A	⇨	E12A
B ...of gas?	(Yes/No)	E11B	⇨	E12B

Please indicate, even approximately, the amount of electricity and natural gas purchased and their costs (gross of any tax credit): *(put 0 if you didn't purchase any during the semester)*

	In the first half of the 2022		**In the second half of the 2022**	
	Purchased quantity	Total cost (thousands of euros)	Purchased quantity	Total cost (thousands of euros)
Electricity	E9A MWh	E7A €	E9B MWh	E7B €
Natural gas	E10A Scm	E8A €	E10B Scm	E8B €

- Net out government support policies with ad-hoc questions details

Three treatment cohorts and one pure control group

- Call E_i time when treated, I the protection dummy and m_i months of protection

$$E_i = \begin{cases} 2021h2, & \text{if } I^{2021} = 0 \text{ and } I^{2022} = 0 \\ 2022h1, & \text{if } I^{2021} = 1 \text{ and } I^{2022} = 0 \\ 2022h2, & \text{if } I^{2021} = 1 \text{ and } I^{2022} = 1 \text{ and } m_i = 6 \\ 0, & \text{if } I^{2021} = 1 \text{ and } I^{2022} = 1 \text{ and } m_i = 12 \end{cases} \quad (1)$$

- Exclude firms with partial protection during a semester
- Exclude firms protected in 2022 but not in 2021

Staggered diff-in-diff using both 2021 and 2022 waves

Use balanced panel of firms (i) observed during each semester (t) of 2021-2022:

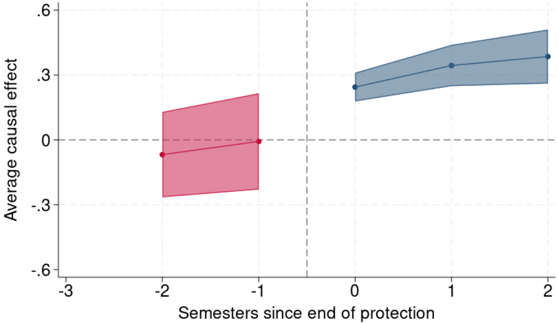
$$\log Y_{it} = \alpha_i + \gamma_t + \sum_{k=-3}^{3} \beta_{ik} \cdot \mathbf{1}(t - E_i = k) + \epsilon_{it}, \quad (2)$$

- Y_{it} either p or q, separately for electricity and gas
- **Control group**: not-yet-treated and never-treated
- E_i is the treatment cohort. $k =$ time since contract expiration
- Estimate by imputation estimator by Borusyak et al. '23 details
- All regressions weighted by survey weights. Standard errors clustered at firm level.

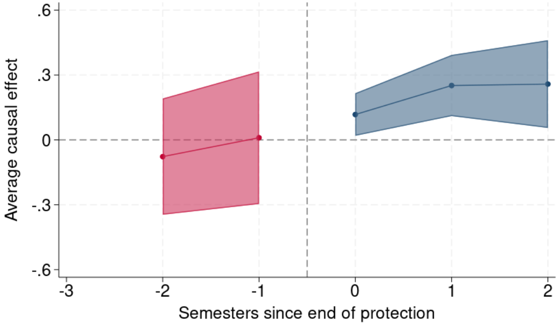
Main results

Upon contract expiration, energy prices increase

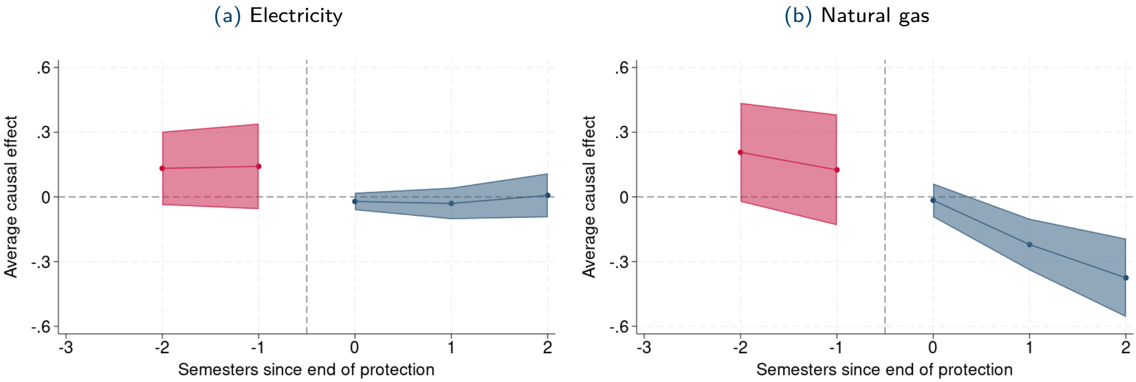
(a) Electricity



(b) Natural gas



Energy demand drops only for natural gas and with a lag



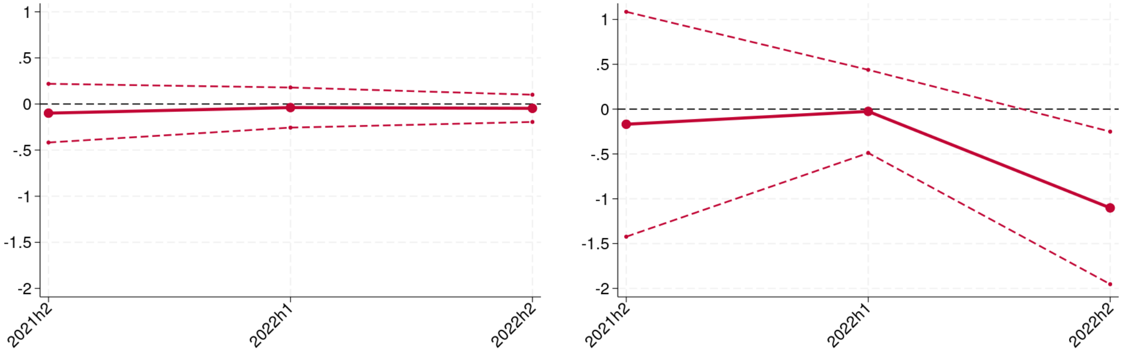
- Gas drop robust to Synthetic DiD à la Arkhangelsky et al. '21 early treated mid treated late treated
- More robustness Robustness

Treatment effect heterogeneity

- Effects on natural gas are **driven by the 2nd semester 2022 only**, irrespectively of cohort graph
  - Contrary to previous periods, in 2022h2 markets were forecasting a long-lived crisis futures
  - It is not about "time since exposure"
- In 2022h2, sizable treatment effect heterogeneity **across firms**
  - Firms for which gas is essential adjust less (-28%) than others (-42%)
  - Gas intensive firms adjust even less (-8%) Analysis on admin data

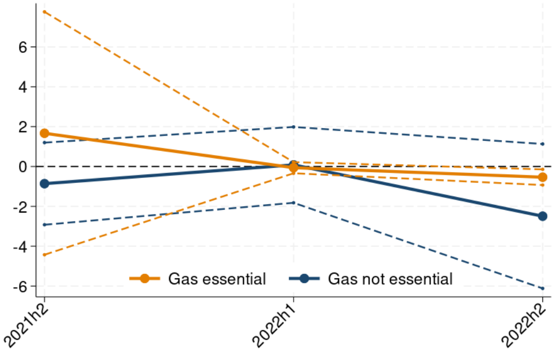
Demand elasticities by calendar period

(a) Electricity (b) Natural gas

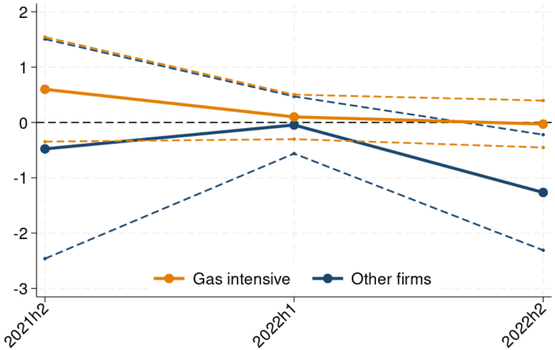


Natural gas: heterogenous gas elasticities

(a) Gas essential or not



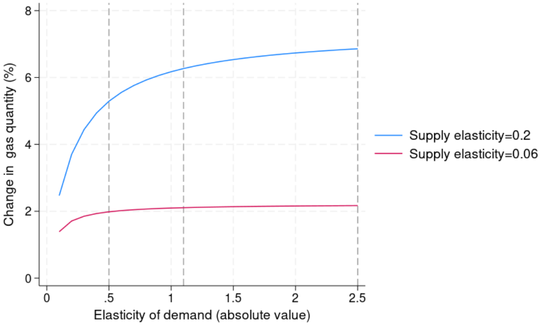
(b) Gas intensive or not



Policy implication: the effect of subsidies

- EU Governments allocated €670 billion on support measures
- Many of these measures altered marginal price of energy goods
- Fear among economists that this could increase energy demand in times of scarcity
- Standard incidence result: change in quantity depends on elasticity of demand and of supply
- Under perfect competition:

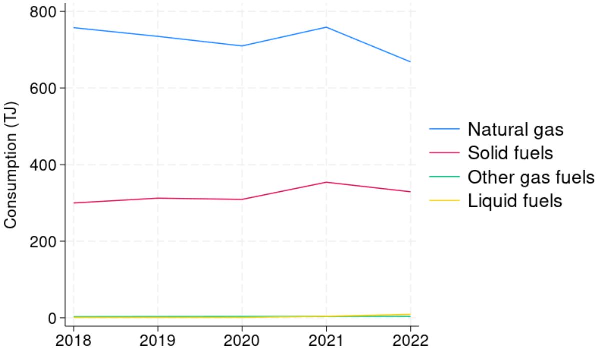
$$\frac{\partial Q}{\partial s} = \frac{\epsilon_S \epsilon_D}{\epsilon_S + \epsilon_D}\frac{Q}{P} = \frac{1}{1/\epsilon_S + 1/\epsilon_D}\frac{Q}{P}$$



Input substitution

Natural gas is the main input for EU ETS participants

Mean in the ETS-Invind matched sample



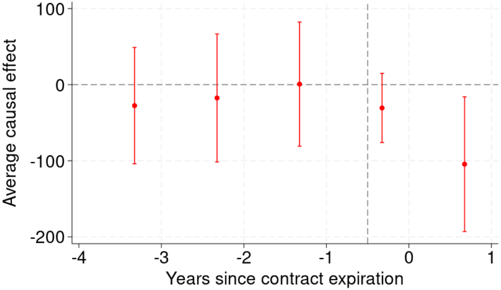
- Admin data on energy consumption by fuel among ETS firms (no electricity)
- Matched with survey data to get info on contract expiration: 107 plants (66 firms)
- We can test for input substitution

Gas drops, but so does total energy from fossil fuels

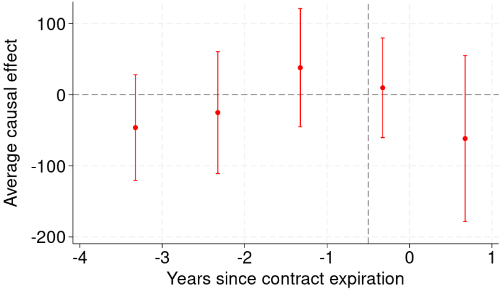
- Staggered DID on **annual** panel of plants 2018-2022. **Two treated cohorts**: 2021; 2022
- ATT on natural gas $\approx$ 100 TJ (-15%) By cohort
- ATT on total energy (right) somewhat attenuated compared to gas alone (left)

$\rightarrow$ **substitution incomplete at best**

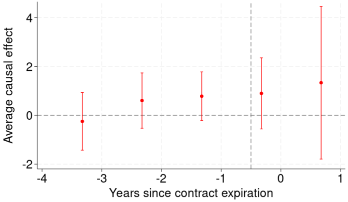
(a) Natural gas



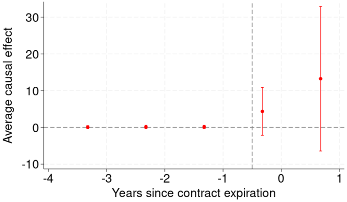
(b) Natural gas + other fossil fuels



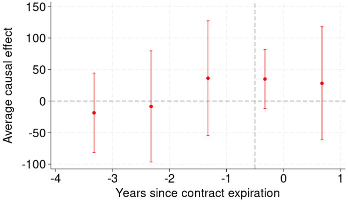
Consumption of all substitutes increases but solid dominates



Other fossil gas fuels



Other liquid fossil fuels



Other solid fossil fuels

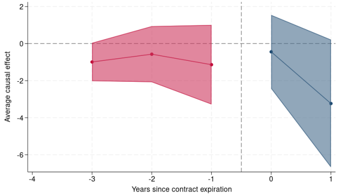
Different outcome transformations

Other margins of adjustment

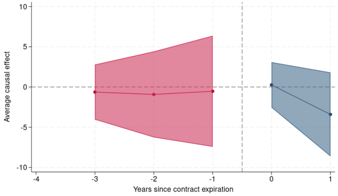
Research design using annual panel with standard survey questions

Staggered diff-in-diff model on unbalanced **annual** (t) panel of firms (i) observed since 2018.

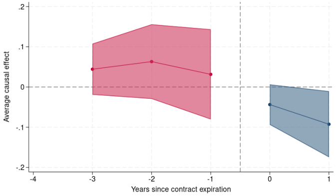
- Y_{it} is either:
  - the % change in the price of final output 💲 relative to previous year
  - capacity utilization 🏭
  - dummy for positive profit margin 💰
- **Two treatment cohorts**: treated in 2021; treated in 2022



(a) Change in price (%)



(b) Capacity utilization (%)



(c) Positive profit (0/1)

- Effects driven by 2022
- Negative effect on change in price but very large and positive for gas intensive firms (10 p.p.)
- Capacity utilization falls very little (2 p.p.)
- Probability of having positive profits drop by 10 p.p.

Conclusions

What we learned so far

+ Uncover policy relevant heterogeneity

- incidence of energy cost low
- energy price shock not the same for all
- heterogeneous adjustment to price shock:
  - electricity vs. natural gas
  - 2022h2 vs. previous semesters
  - gas essential vs. not

- Open questions

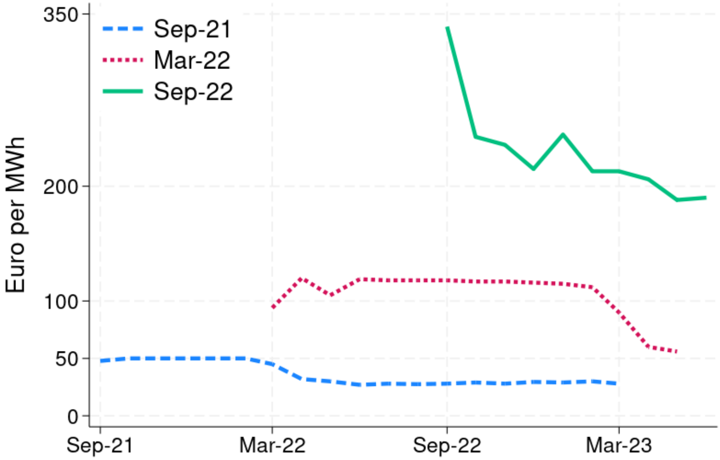
- Input substitution or output reduction?
- Output falls very little in our analysis
- Limited substitution via fossil inputs
- ... what about import of energy-intensive goods ? (Moll et al. 2023) $\rightarrow$ custom data
- output fall in '23? in progress with latest wave

Thank you

annalisa.frigo@bancaditalia.it

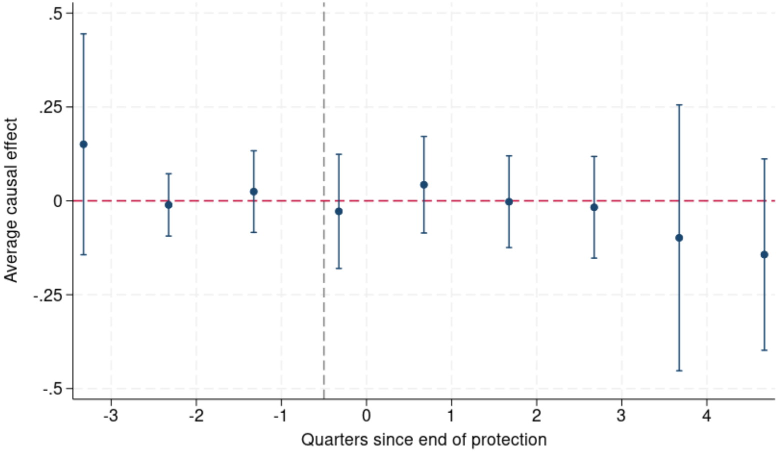
Back-up slides

TTF futures



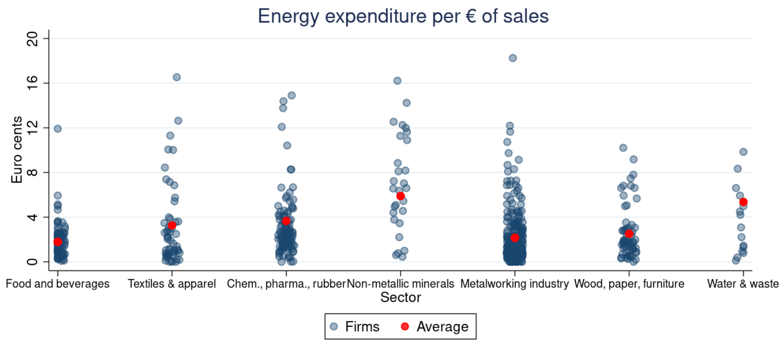
back to ATT heterogeneity

Sample of gas intensive firms, admin data. Effect on log gas-



Back

Incidence of energy costs on sales across sectors



back

Robustness checks

1. Robust to Synthetic diff-in-diff à la Arkhangelsky et al. '21 early treated mid treated late treated
2. Robust to attrition based on observables, benchmark attrition on unobservables attrition
3. Robust to different DiD estimators prices quantities
4. Robust to the inclusion of covariate-specific trends prices quantities

back

Italy entering the energy crisis

Energy statistics:

- Natural gas was the main energy source (42% in 2020)
- Natural gas accounted for 50% of electricity generation $\rightarrow P_{gas} \approx P_{electricity}$ in wholesale market
- Net imports accounted for 93% of fossil fuel consumption
- Natural gas consumption concentrated in few sectors and in few plants therein

Economic statistics:

- Italy has second largest manufacturing sector in the EU (13% of EU GVA)
- Manufacturing accounts for 17% of the Italian GVA

back

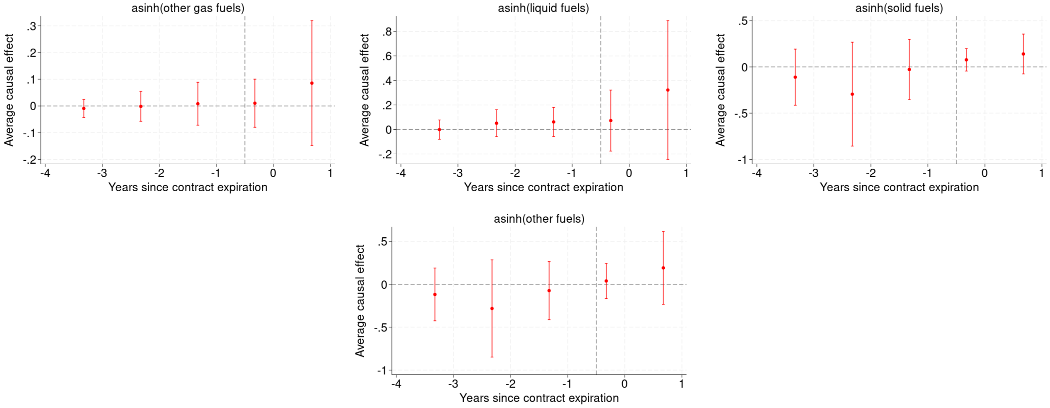
Sondtel survey

- Business Outlook Survey of Industrial and Service Firms
- Shorter and more qualitative survey conducted after summer to collect timely information on the first three quarters of the year

24 At the beginning of 2022, was gas an essential* input for your firm's manufacturing process?	**P182**
Legend: *1 = no; 2 = yes; 9= do not know, do not wish to answer.*	
* Inputs are essential when – given the plants and machinery installed and used in the manufacturing process and/or the type of services provided – the total or partial lack thereof would make it impossible to produce the good and/or provide the service in the short term.	

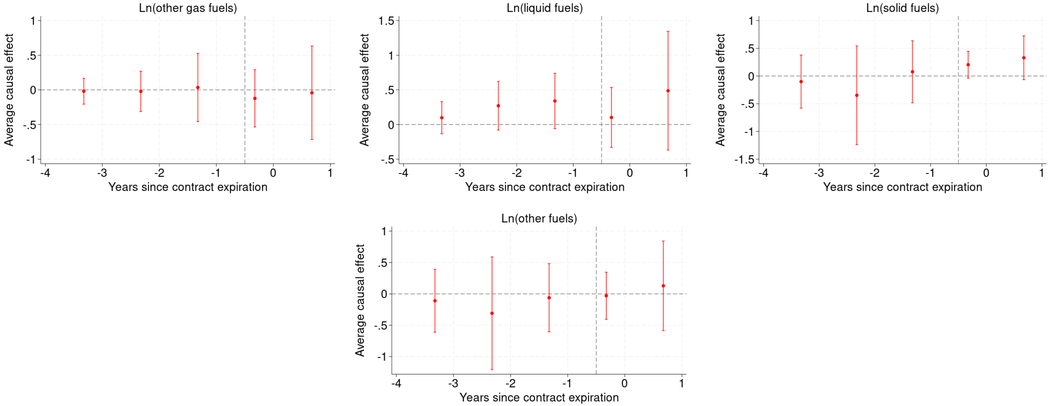
back

Input substitution in asinh transformation



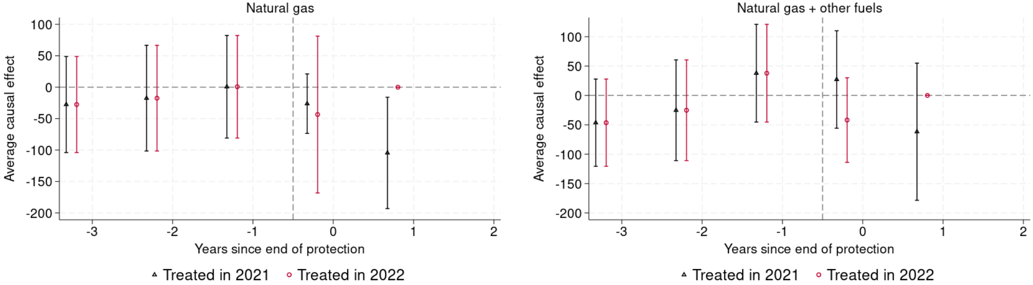
back

Input substitution in logs

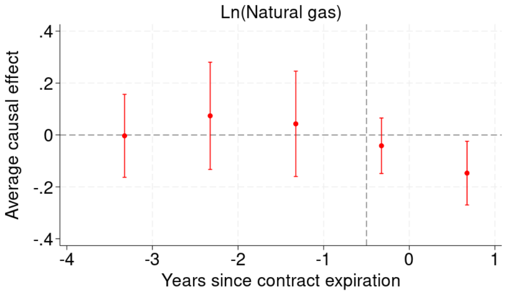


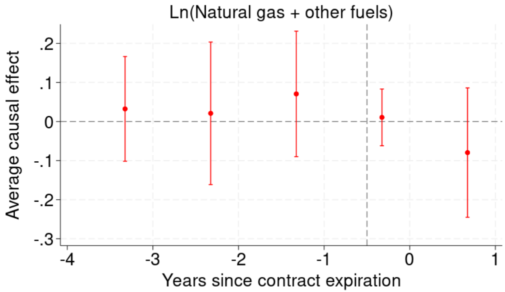
back

Effects driven by early treated in 2022



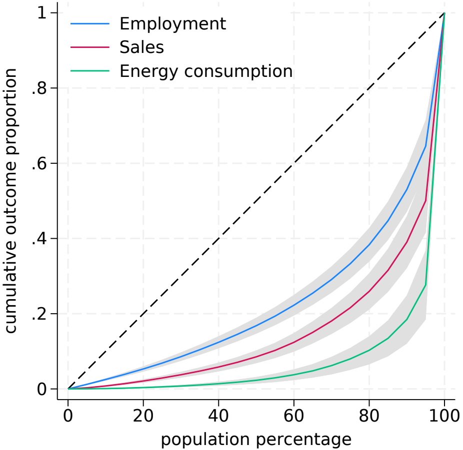
back


Ln(Natural gas)
Average causal effect
.4
.2
0
-.2
-.4
-4
-3
-2
-1
0
1
Years since contract expiration


Ln(Natural gas + other fuels)
Average causal effect
.2
.1
0
-.1
-.2
-.3
-4
-3
-2
-1
0
1
Years since contract expiration

Back

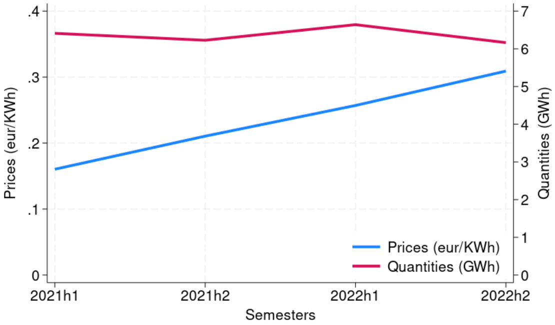
Energy consumption distribution highly skewed



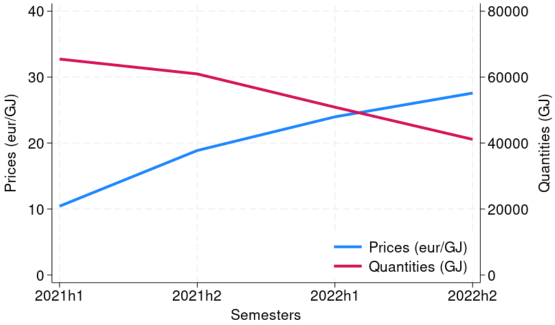
back

Energy price increases and quantity drops

(a) Electricity



(b) Natural gas



back

We define four treatment cohorts

1. **Early treated**: shock hits in 2021h2

2. **Mid treated**: shock hits in 2022h1
3. **Late treated**: shock hits in 2022h2
4. **Pure control group** shock does not hit

in math

⚠️

back to survey

We define four treatment cohorts

1. **Early treated**: shock hits in 2021h2
   - Had no fixed price contract at beginning of 2021 (perhaps never buy insurance)
   - Had a fixed price contract at the beginning of 2021 which expires in 2021h2
2. **Mid treated**: shock hits in 2022h1
3. **Late treated**: shock hits in 2022h2
4. **Pure control group** shock does not hit

in math

⚠️

back to survey

We define four treatment cohorts

1. **Early treated**: shock hits in 2021h2
2. **Mid treated**: shock hits in 2022h1
3. **Late treated**: shock hits in 2022h2
4. **Pure control group** shock does not hit

in math

NB ⚠️: being in 2 vs. 3 vs. 4 just matter of luck! It depends on when you last **SIGNED** the contract

back to survey

Treatment variable

- Call E_i time when treated, I the protection dummy and m_i months of protection

$$E_i = \begin{cases} 2021h2, & \text{if } I^{2021} = 0 \text{ and } I^{2022} = 0 \\ 2022h1, & \text{if } I^{2021} = 1 \text{ and } I^{2022} = 0 \\ 2022h2, & \text{if } I^{2021} = 1 \text{ and } I^{2022} = 1 \text{ and } m_i = 6 \\ 0, & \text{if } I^{2021} = 1 \text{ and } I^{2022} = 1 \text{ and } m_i = 12 \end{cases} \tag{3}$$

- Exclude firms with partial protection during a semester
- Exclude firms protected in 2022 but not in 2021

back

Borusyak, Jaravel and Spiess '23 imputation estimator

Assume **parallel trends** (PT) and **no-anticipation** (NA).

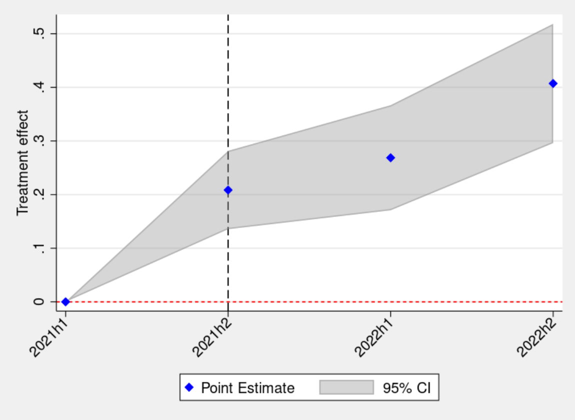
Three-step estimator:

1. Estimate $\log y_{it} = \alpha_i + \gamma_t + u_{it}$ on untreated observations, and get predicted values
   - Under PT+NA this identifies counterfactual: $\widehat{\log y_{it}} = \log y_{it}(0)$
2. For every individual (treated) observation compute $\hat{\tau}_{it} = \log y_{it} - \widehat{\log y_{it}} = \log y_{it}(1) - \log y_{it}(0)$
   - Individual ATT inconsistent (fundamental problem of causal inference)
3. Average τ_{it} across desired dimensions of interest.
   - Averages of τ_{it} consistent for CATT under PT+NA

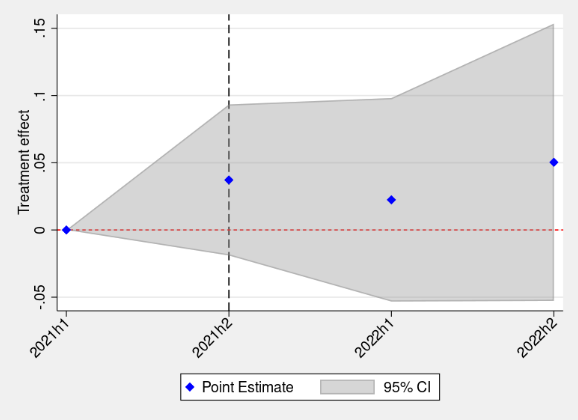
Important: pre-trend coefficients estimated separately. back

Effects on electricity for 2021h2 cohort (SDID)

(a) log(prices)

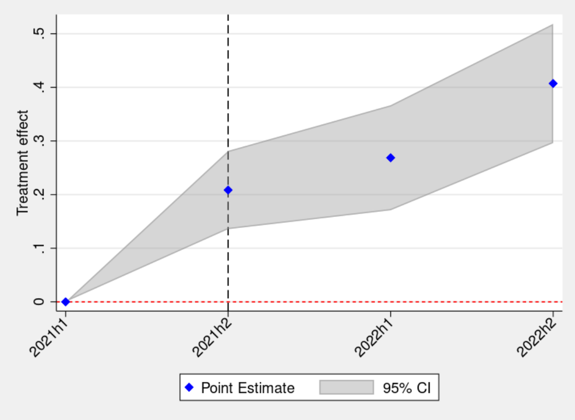


(b) log(quantities)

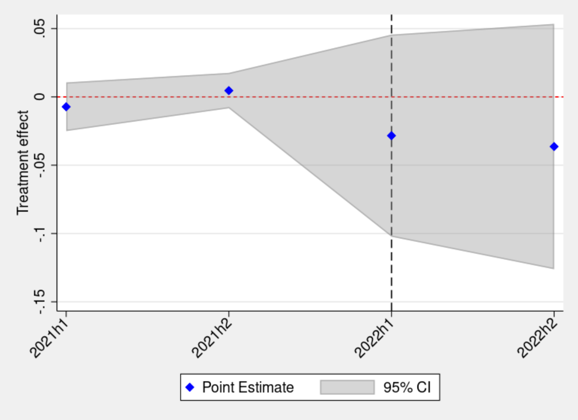


Effects on electricity for 2022h1 cohort (SDID)

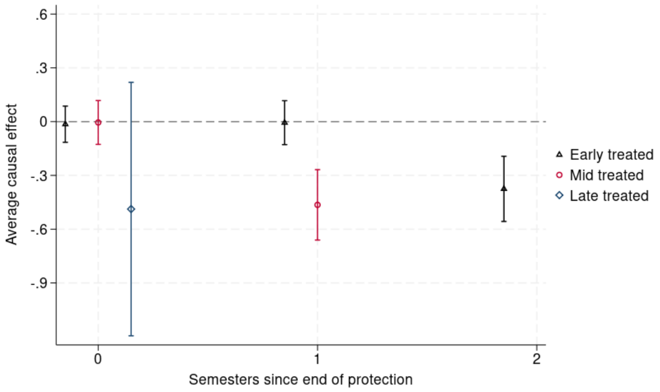
(a) log(prices)



(b) log(quantities)



Effects on natural gas driven by 2022h2 only

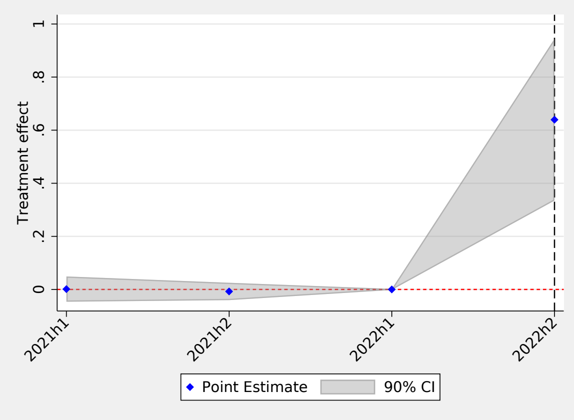


- Event time (time since contract expires) do not matter

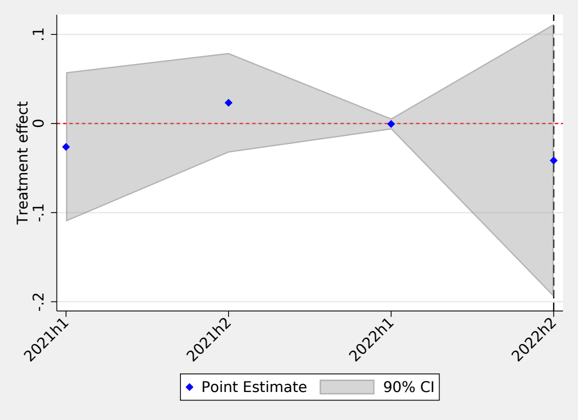
effect on gas price
back to ATT heterogeneity

Effects on electricity for 2022h2 cohort (SDID)

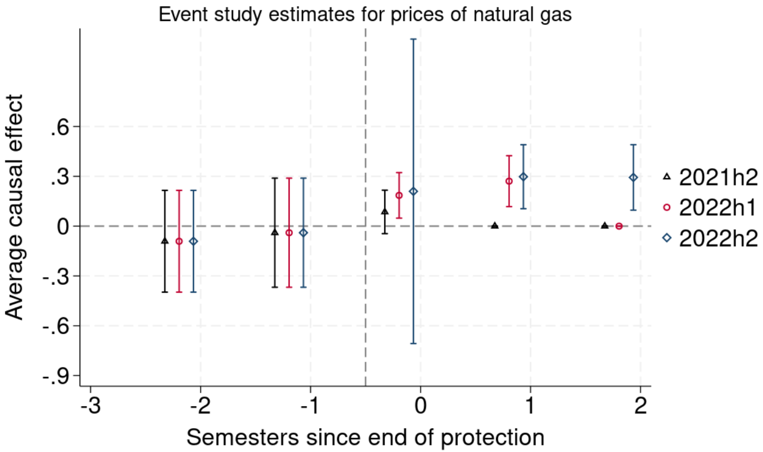
(a) log(prices)



(b) log(quantities)

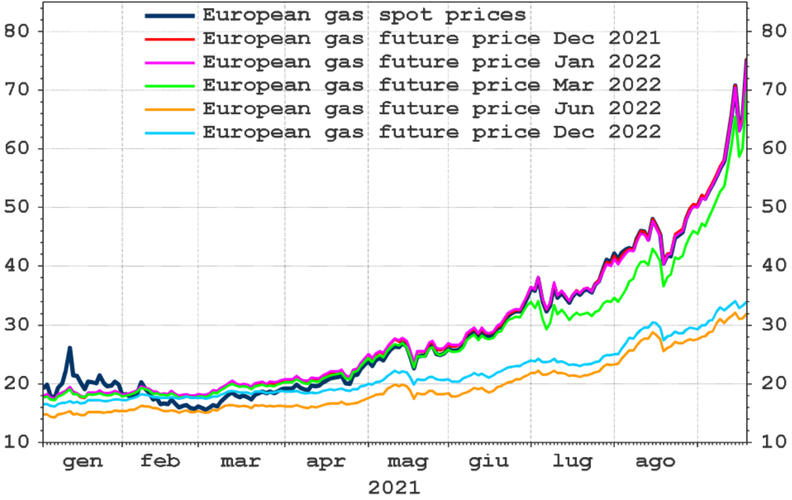


Effect on gas price by calendar time



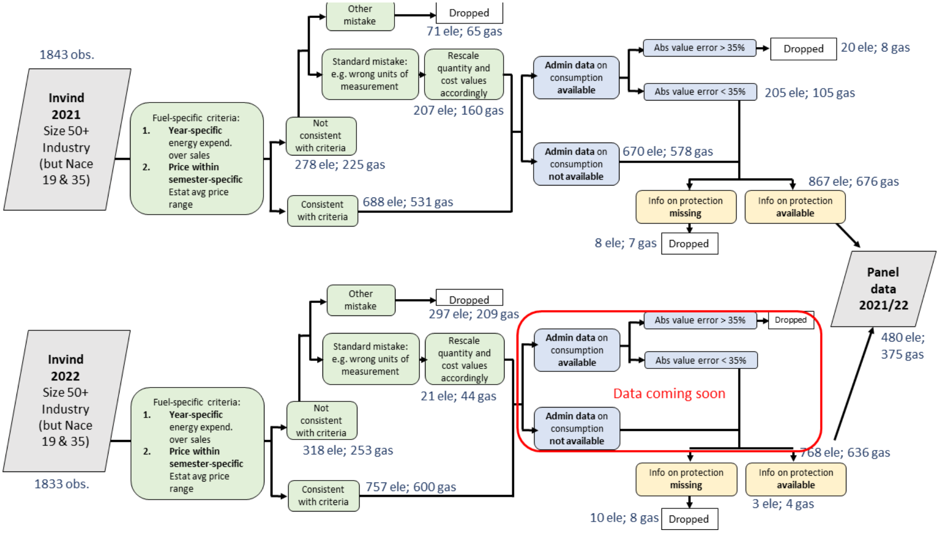
back

Figure 4. European natural gas futures (euros/MWh)



back

Data validation procedure



back

Detected mistakes and manipulation of data on gas

Cost-share criterion	Price-range criterion	Expenditure	Quantity	Prevalence '21	Prevalence 22
✓	✓	'000 €	scm	70%	90%
✗ - upper tail	✗ - higher price ('000-fold)	€	scm	3%	0%
✓	✗ - higher price ('000-fold)	'000 €	'000 scm	18%	4.9%
✓	✗ - higher price (milion-fold)	'000 €	million scm	0%	0.7%
✗ - lower tail	✗ - lower price	Million €	'000 scm	0%	0.8%
Residual observations (dropped)				9%	3.6%
Total				100%	100%

back

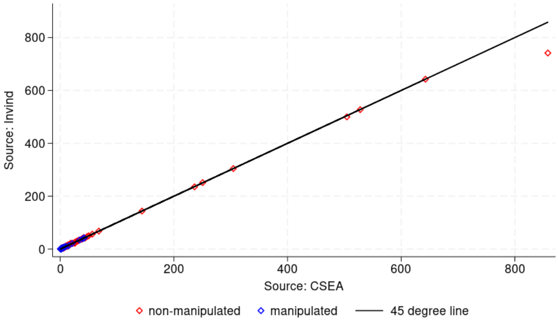
Detected mistakes and manipulation of data on electricity

Cost-share criterion	Price-range criterion	Expenditure	Quantity	Prevalence	
				'21	22
✓	✓	'000 €	Mwh	74.3%	93.5%
✓	✗ - lower price	'000 €	Kwh	14.2%	1.8%
✗	✗ - higher price	€	Mwh	2%	0%
✗	✓	€	Kwh	2.3%	0.1%
✓	✗ - higher price	'000 €	Gwh	0%	0.7%
✗ - lower tail	✓	Million €	Gwh	0%	0.2%
✗ - lower tail	✗ - lower price	Million €	Mwh	0.1%	0%
✗ - lower tail	✗ - lower price	Million €	Twh	0.1%	0%
Residual observations (dropped)				7%	3.7%
Total				100%	100%

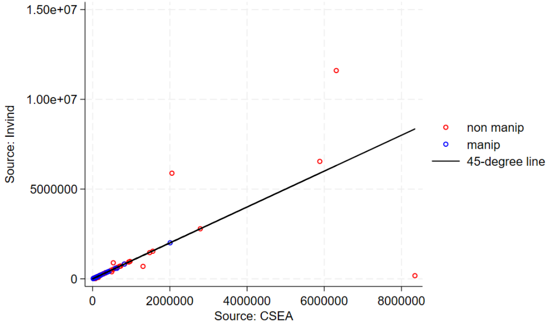
back

Consistency with admin data on quantities

(a) Electricity



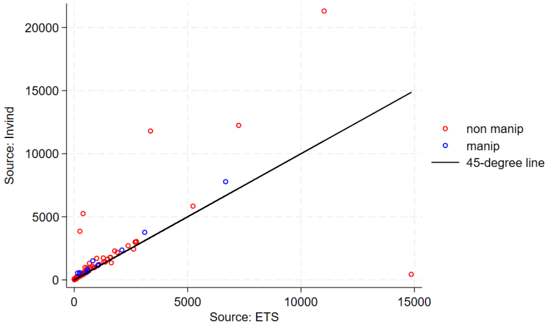
(b) Natural gas



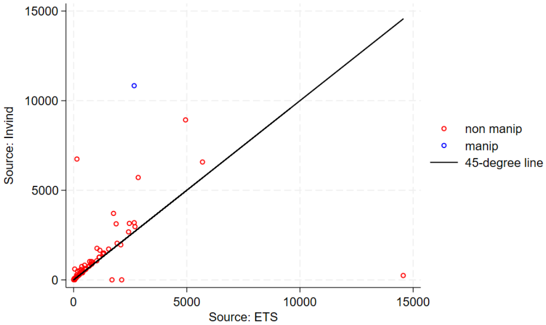
back

Consistency with admin data on gas quantities

(a) 2021



(b) 2021



back

Netting out government policies

1. **Temporary tax and fees cuts** on electricity and natural gas bills (since 2021h2)
2. **Tax credit** rebating a fixed fraction of energy bill (since 2022q1).

Netting out government policies

1. **Temporary tax and fees cuts** on electricity and natural gas bills (since 2021h2)
2. **Tax credit** rebating a fixed fraction of energy bill (since 2022q1).

Average unitary costs in our data:

- Include 1. by construction, as contained in energy bill
- Exclude 2. as they are not contained in energy bill

Netting out government policies

1. **Temporary tax and fees cuts** on electricity and natural gas bills (since 2021h2)
2. **Tax credit** rebating a fixed fraction of energy bill (since 2022q1).

Average unitary costs in our data:

- Include 1. by construction, as contained in energy bill
- Exclude 2. as they are not contained in energy bill

⇒Use Invind data about €-amount of tax credit to build **net-of-tax-credit** unitary costs tax credit questions

back to survey

Questions on the tax credit

In 2022, was your firm granted any tax credits to offset at least part of the higher costs incurred in purchasing electricity and/or natural gas? (Yes/No)		E13
If yes, indicate, with reference to the tax credits accrued in each semester:	**1st semester**	**2nd semester**
the amount of tax credit granted for purchasing electricity (*in thousands of euros*)	E14A	E14B
the amount of tax credit granted for purchasing natural gas (*in thousands of euros*)	E15A	E15B
the primary use of the tax credit (1)	E16A	E16B
(1) ***Legend:*** *1 = in compensation; 2 = assignment of credit.*		

back back to survey

Nonresponse bias

Selection on observables

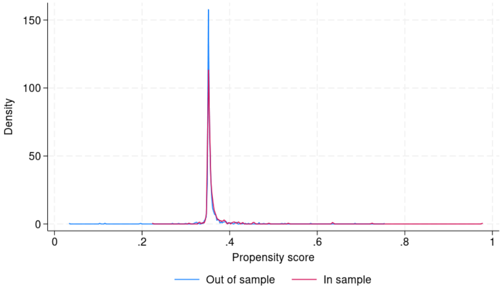
- Compare firms in estimation sample to firms answering to Invind standard questions
  - They are bigger, large consumers, over-represent certain sectors
- Estimate propensity score (logit) of being in sample based on covariates
- Re-weight regressions by inverse of propensity score (Wooldridge, 2002; Stantcheva, 2022)

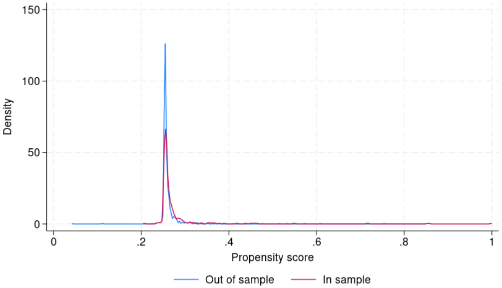
Selection on unobservables

- Check if firms that are insured in 2021 more likely to drop out of Invind in 2022

back

Common support

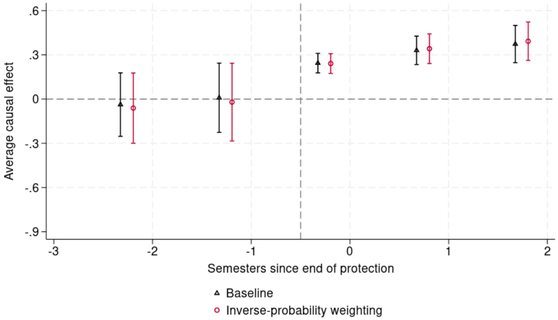


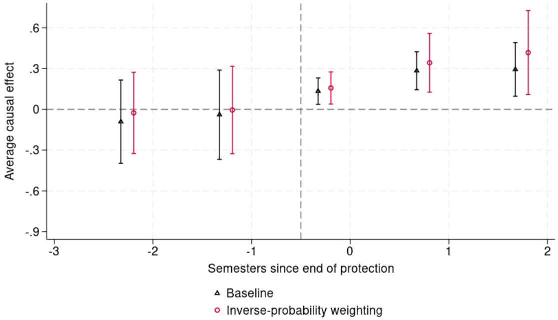


- Common support test passed (`pscore` command)

back

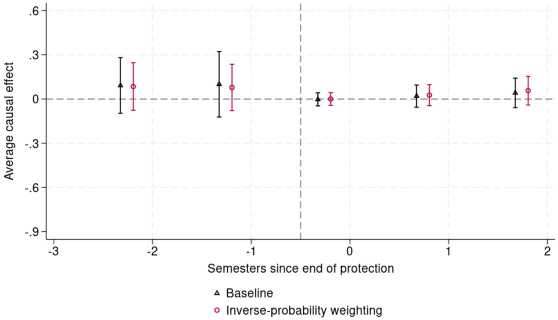
Inverse Probability Weighting for price regressions

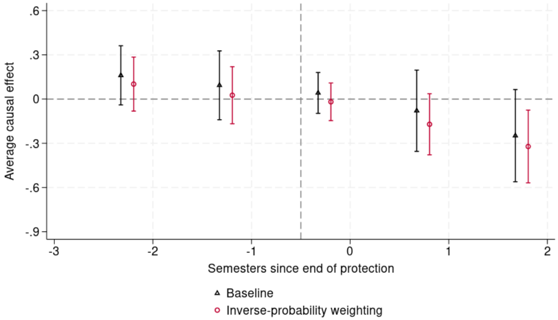




back

Inverse Probability Weighting for quantity regressions





back

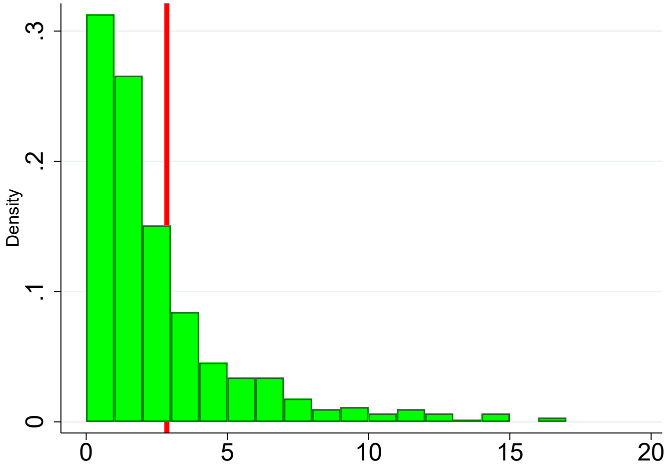
Selection on unobservables

$$\mathbf{1}(\text{in '21 and '22 sample})_i = \theta_0 + \theta_1 \mathbf{1}(\text{insured in '21}_i) + \theta_2 \mathbf{1}(\text{uninsured in '21}) + u_i \tag{4}$$

	(1) Electricity	(2) Gas
insured	0.452***	0.358***
	[0.409,0.494]	[0.316,0.400]
uninsured	0.365***	0.253***
	[0.322,0.407]	[0.215,0.290]
$H_0: \theta_1 - \theta_2 = 0$, p-value	0.005	0.000
Observations	1152	1162

back

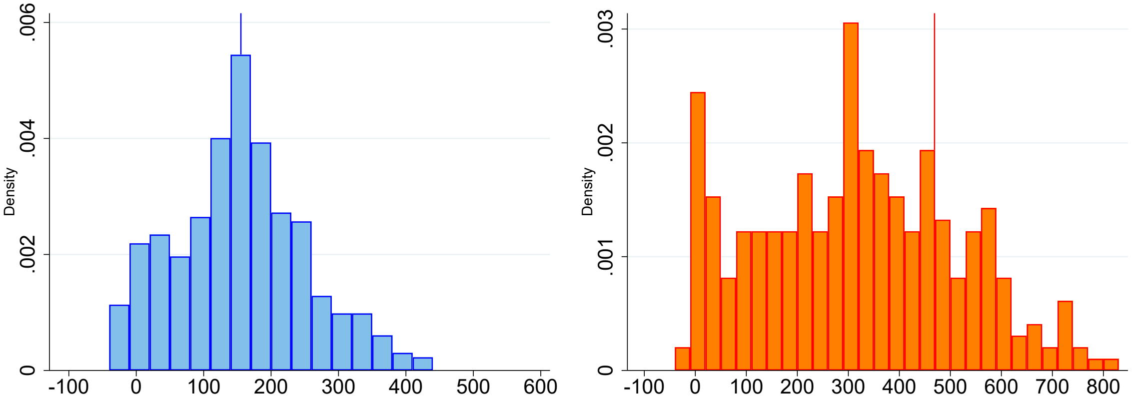
Incidence of energy costs on sales



back

% Price changes 2022h2 vs 2021h1

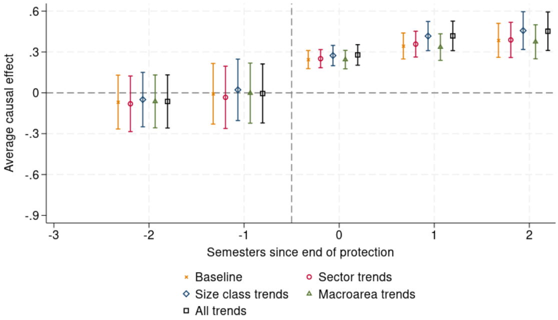
electricity and natural gas



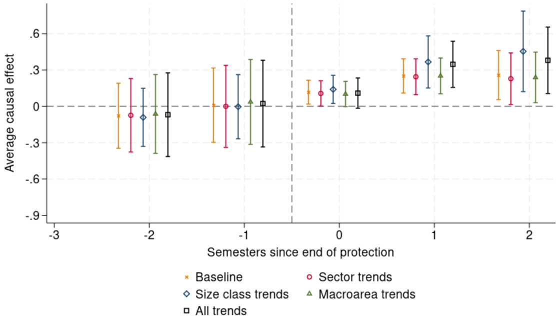
back

Inclusion of trends in price regressions

(a) Electricity



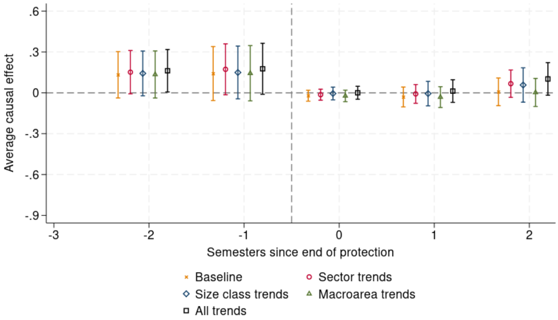
(b) Natural gas



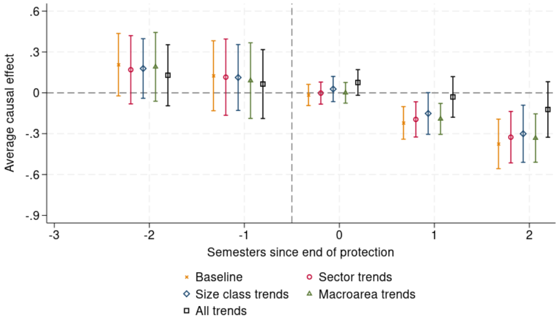
back

Inclusion of trends in quantity regressions

(a) Electricity



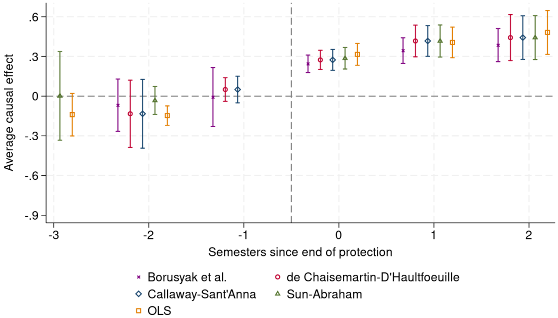
(b) Natural gas



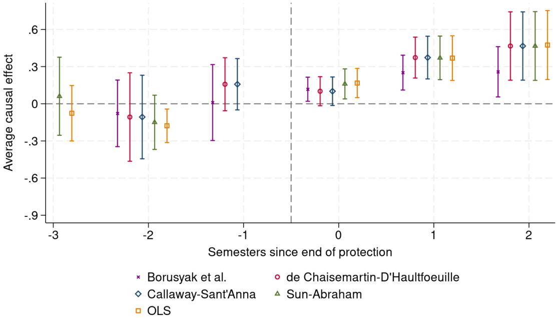
back

$$\log p_{it} = \alpha_i + \gamma_t + \sum_{k=-3}^{3} \beta_k \cdot \mathbf{1}(t - E_i = k) + \epsilon_{it}, \quad (5)$$

(a) Electricity



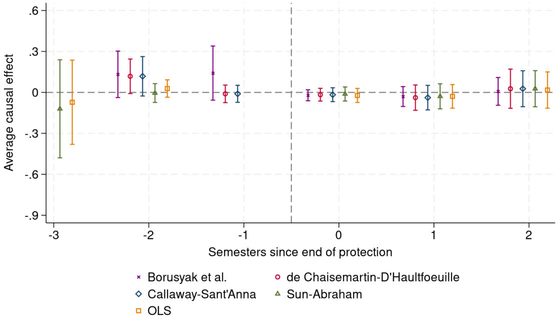
(b) Natural gas



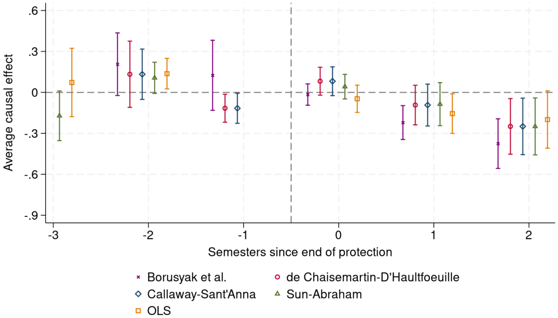
back

$$\log q_{it} = \alpha_i + \gamma_t + \sum_{k=-3}^{3} \beta_k \cdot \mathbf{1}(t - E_i = k) + \epsilon_{it}, \tag{6}$$

(a) Electricity



(b) Natural gas



back

Electricity **prices** results for 2021 on the 2021-2022 sample

	(1) Always protect.	(2) Late treated.	(3) Both
Early-treated × 2021h2	0.206***	0.165***	0.178***
	[0.0928,0.319]	[0.0710,0.259]	[0.0925,0.263]
Observations	510	690	840

95% confidence intervals in brackets

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

back

Electricity **quantity** results for 2021 on the 2021-2022 sample

	(1)	(2)	(3)
	Always protect.	Late treated.	Both
Early-treated × 2021h2	0.0346	-0.00266	0.00898
	[-0.0448,0.114]	[-0.0818,0.0765]	[-0.0625,0.0805]
Observations	510	690	840

95% confidence intervals in brackets

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Gas **prices** results for 2021 on the 2021-2022 sample

	(1) Always protect.	(2) Late treated.	(3) Both
Early-treated × 2021h2	0.144	0.0874	0.103
	[-0.0728,0.361]	[-0.0927,0.267]	[-0.0607,0.267]
Observations	368	528	630

95% confidence intervals in brackets

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

back

Gas **quantities** results for 2021 on the 2021-2022 sample

	(1) Always protect.	(2) Late treated.	(3) Both
Early-treated $\times$ 2021h2	-0.0563	0.0203	-0.00117
	[-0.179,0.0661]	[-0.107,0.147]	[-0.115,0.112]
Observations	368	528	630

95% confidence intervals in brackets

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

back

Retail prices of energy are heterogeneous

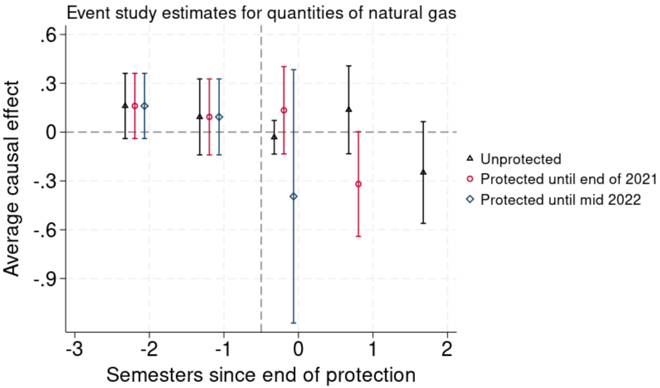
- Almost exclusively negotiated on the free market
- Retail price includes several components
  - fees for transport and distribution
  - taxes and levies (lower for large consumers)
  - quantity of energy (MWh)
  - power capacity (MW)
- Some of these components are fixed costs i.e. not a function of quantity purchased

$\rightarrow$ **average price declines with quantity**

- Two main types of contracts for the energy component:
  - **Fixed price** for typically 12 to 24 months **(rolling basis)**
  - **Floating price**, indexed to wholesale price

back

Gas consumption by cohort: both early and late treated adjust in 2022h2



back

Synthetic diff-in-diff (SDID), Arkhangelsky et al., 2021

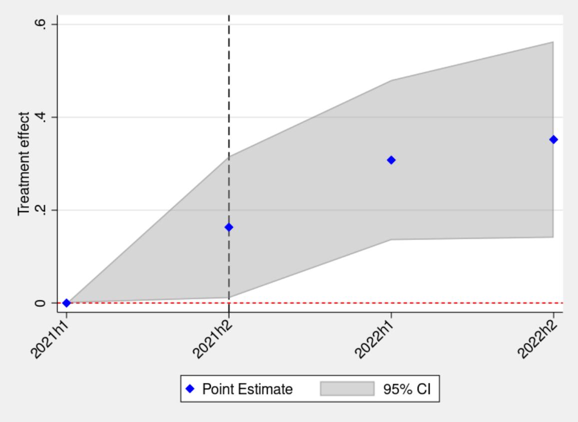
Intuition of SDID

- Construct synthetic control group such that pre-trends are as **parallel** as possible
  - put more weight on control **units** with parallel pre-trends in Y
  - put more weight on control **periods** that predict well post-treatment control trends[1]
- Diff-in-diff between treated and synthetic control group
- **cohort approach** that compares treated firms with always protected firms
  - application of SDID to staggered case, as in Burgess et al. (2023)
  - Cluster bootstrap (firm id) standard errors – 100 reps

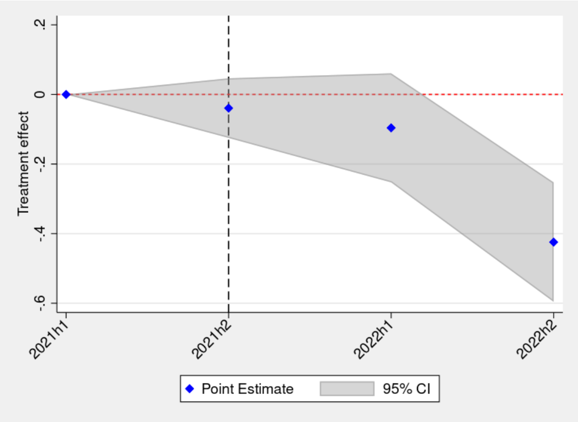
[1] In standard event-study regressions, k-1 gets all the weight.

Effects on natural gas for 2021h2 cohort (SDID)

(a) log(prices)



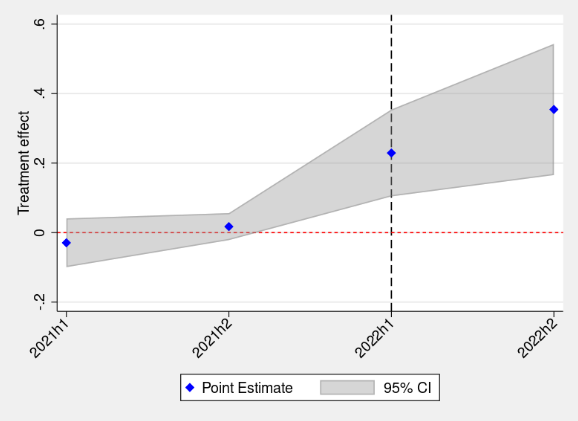
(b) log(quantities)



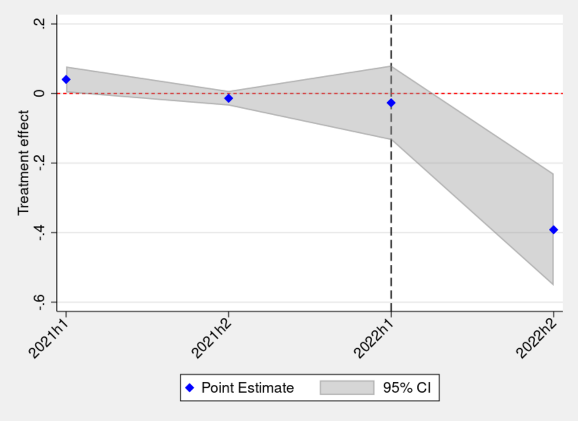
back to robustness   back to main results

Effects on natural gas for 2022h1 cohort (SDID)

(a) log(prices)



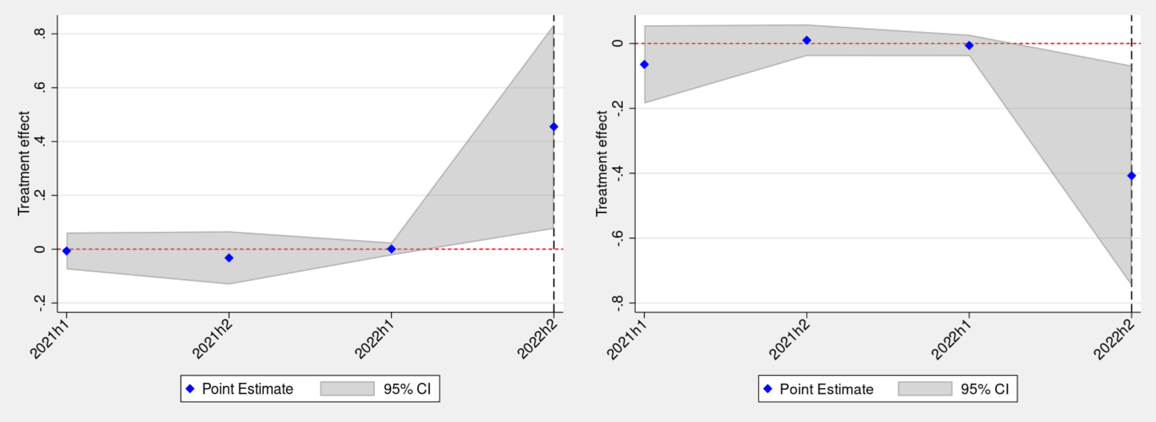
(b) log(quantities)



back to robustness | back to main results

Effects on natural gas for 2022h2 cohort (SDID)

(a) log(prices) (b) log(quantities)



back to robustness back to main results