CompNet The Competitiveness Research Network

Energy transition
a CompNet/MDI-based Assessment

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Roadmap

- Energy research:
  1. Energy prices' role in energy use (FINPRO4)
  2. Price signaling (joint with OECD)
  3. Energy use by product (Mola, A., Bighelli, T.)

- Next steps using MDI

Motivation

- By mid-century, electricity demand 75% higher than today (IEA 2022)
- Net zero emissions (NZE) targets require ~3x more clean energy and energy efficiency (IEA 2023)
- NZE 2050 demands EU fossil fuel cut from 73% to 20%; current policies only reach ~60% (ECB 2024)

Literature

- Keeping output constant, firms can reduce energy use via

1. price signals
   - with low impact on employment/competitiveness (Marin & Vona, 2021 EER: 2019 JEEM)
   - depending on their pass-through/market power (Ganapati et al., 2020 AER)

2. efficiency/innovation (technical change literature) (Acemoglu et al. 2012; 16 AER)

- Challenges: asset turnover, externality, credit constraints, rebound effects, behavior failures → underinvestment

Data

- Micro data infrastructure (MDI), created under the *EU Technical Support Instrument project**

- Main datasets: ENER, PRODCOM, SBS, and BS

- Main analysis is focused on France and Austria (partially), 2000-2020.
  - To be expanded to Portugal, and partially to Slovenia and Finland

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MDI energy-related available data

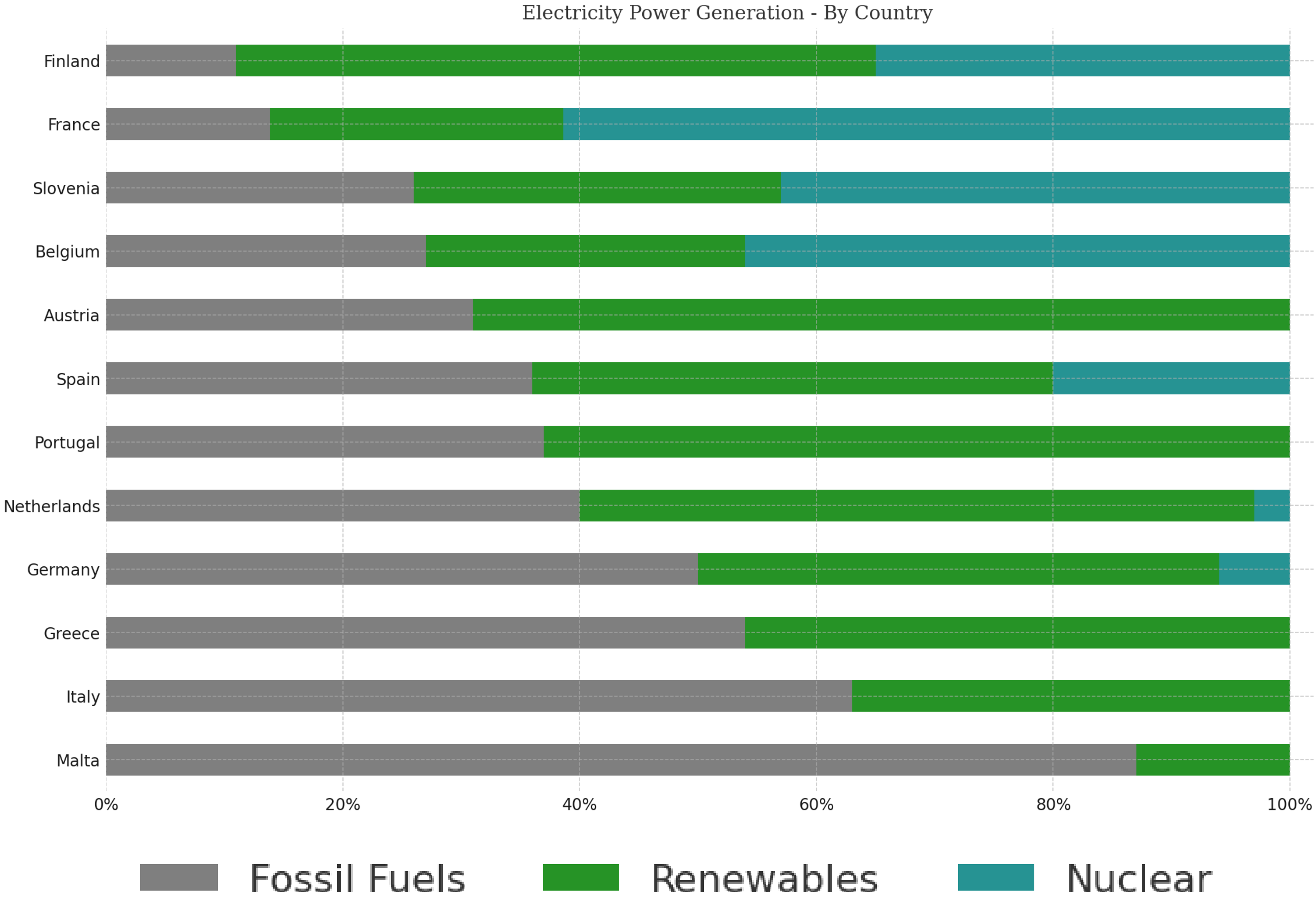
- Countries available: FR, PT, SI, AT, FI

- **MDI BS:** Energy input (FI, PT, SI)
  - Sub-item of intermediate inputs; all expenses of the firm for energy covering all sorts of fuels, heat or electricity (e.g. solid fuels like coal or wood, liquid fuels like gasoline, gas fuels like natural gas).

- **MDI ENER:** Energy total expenditure, total consumption → prices (FR, PT, AT)
  - natural gas, light fuel oil, district heating, steam, liquid petroleum gas, coal and coal products, other petroleum products, other gas products, renewable energy, other non-renewable

1) Energy prices: their role in energy use

- **Green transition:**
- 2 markets
  1. Make power generation plants greener (Fabra, N., Imelda, 2023 AER)

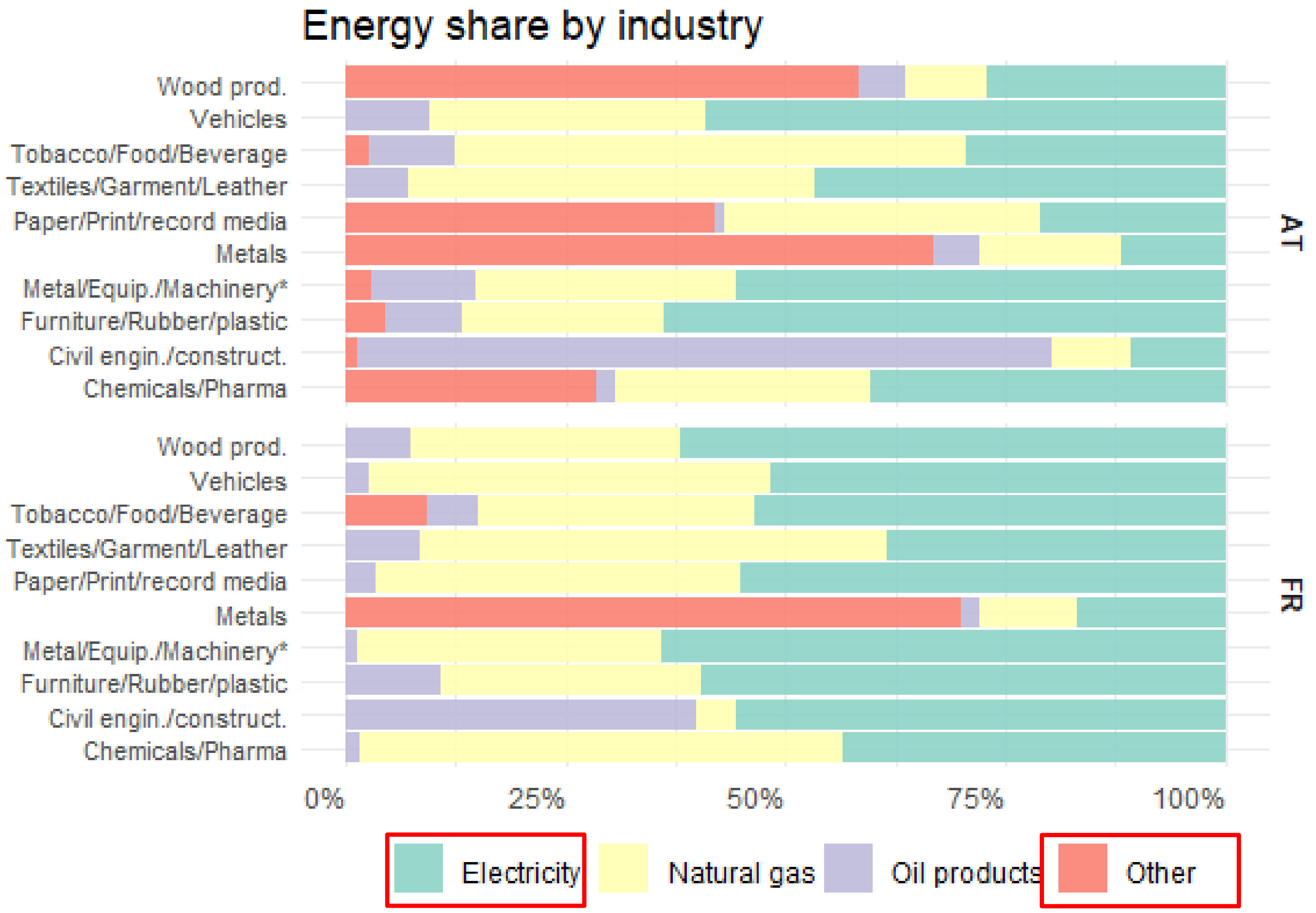


* source: Eurostat

1) Energy prices: their role in energy use

- Green transition:
- 2 markets
  1. Make power generation plants greener (Fabra, N., Imelda, 2023 AER)

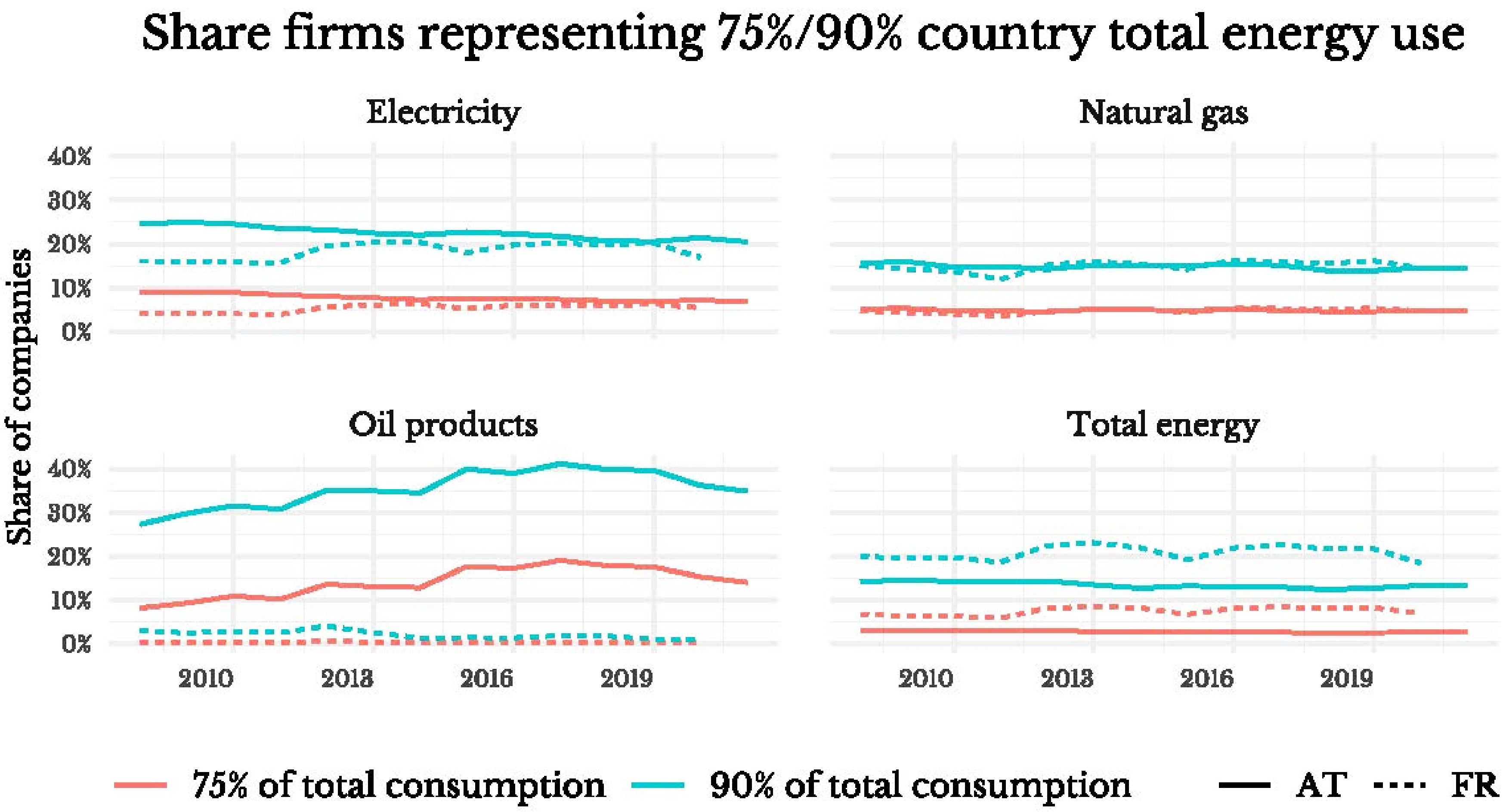
  2. Firms can reduce energy use via
     - i) less output
     - ii) efficiency
     - iii) switch to clean sources ← prices



*Fabricated metal/Computer & Electrical equip./Machinery

1) Energy prices: their role in energy use

- Green transition:
  - Few firms consume most of the countries' energy:
    - They are larger
    - Pay lower prices (quantity discount)



Energy prices decomposition:

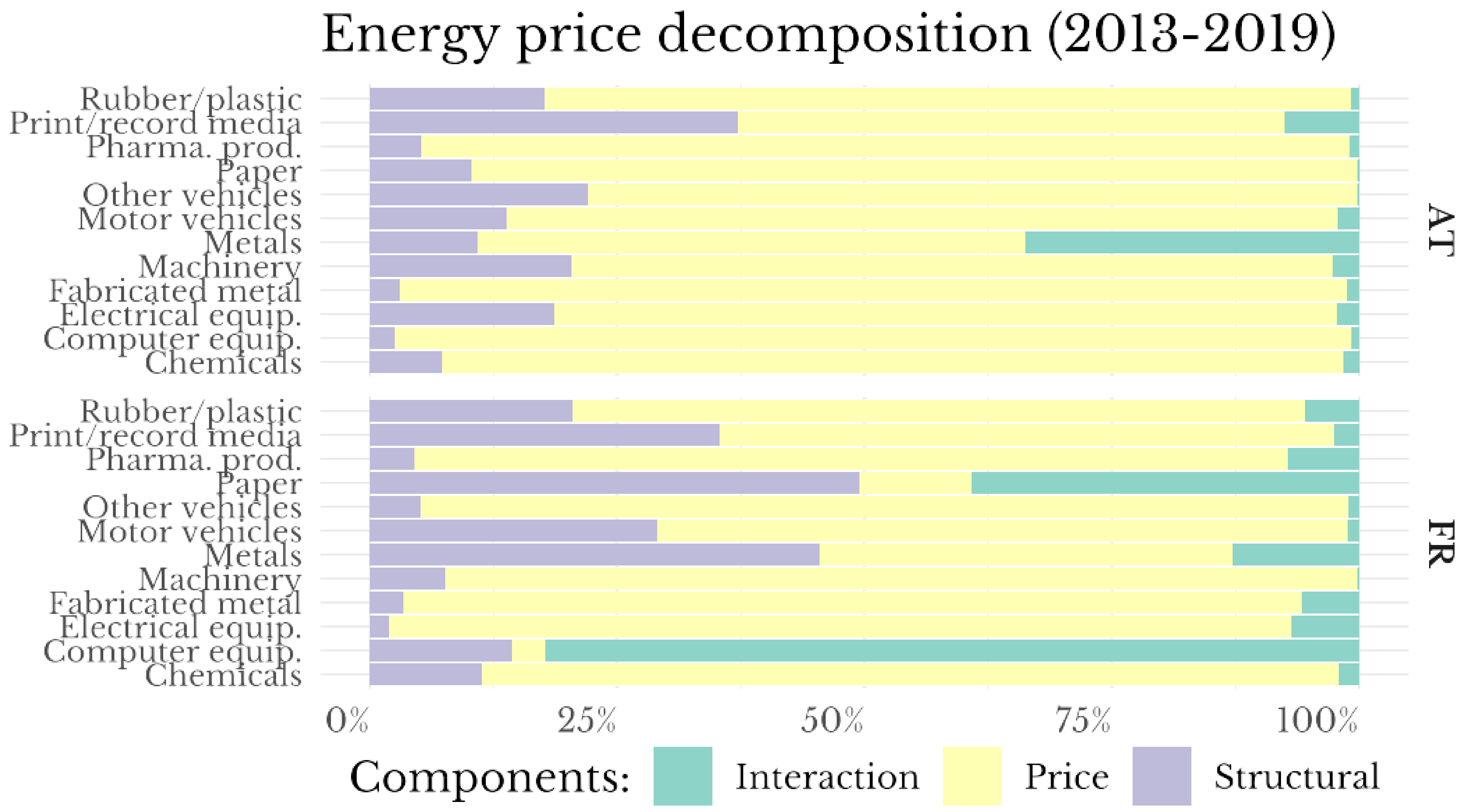
- Decompose industry price index (EPI) change into price, structure, and interaction
- Also tested LDMI** which decomposes index into price and structure

$$\Delta EPI_S = \sum_i p_{s,t-h,i} \times \Delta w_{s,t,i} + \sum_i \Delta p_{s,t,i} \times w_{s,t-h,i} + \sum_i \Delta p_{s,t,i} \times \Delta w_{s,t,i}$$

- *EPI: industry price index*
- *i: energy source*
- *s: industry*
- *w: share of i in total quantity of energy used in industry s at time t*

** Aditive and multiplicative logarithmic mean Divisia index
(Ang, 2005; Amg & Wang 2015)

1) Energy prices: their role in energy use



1) Energy prices: their role in energy use

- At what extent energy prices reduce energy consumption?
  - $EnerQ_{ist} = \beta p_{ist} + \theta_i + \sigma_{st} + \varepsilon_{ist}$
    - σ_{st}: elasticity identified on differences to the sector-average price shock
    - $\boldsymbol{p_{ist}}$: endogenous due to firms' bargaining power (e.g., quantity discount)
      - Shift-share IV (Fontagne et al., 2024): $p_{ist}^{IV} = \left[\frac{p_{i,s,t0}}{\bar{p}_{s,to}}\right] \times \bar{p}_{st}$
        - » Relative firm-sector energy price at *t0* shift to sectoral prices at *t*

1) Energy prices: their role in energy use

- Energy prices (more idiosyncratic than structural) elasticity of energy demand should
  - matter to big consumers and especially
  - be particularly important to dirty energy

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        - » Relative firm-sector energy price at *t0* shift to sectoral prices at *t*

1) Energy prices: their role in energy use

- Important disparity controlling for price endogeneity:
  - ↑10% → ~↓2%
    - Low for dirty energy
- Higher natural gas price elasticity (↑10% → ↓12%)
  - Robustness includes 3 lags as control: effect concentrated at *t*

Price elasticity of energy demand

DV: Energy (i) demand (log)

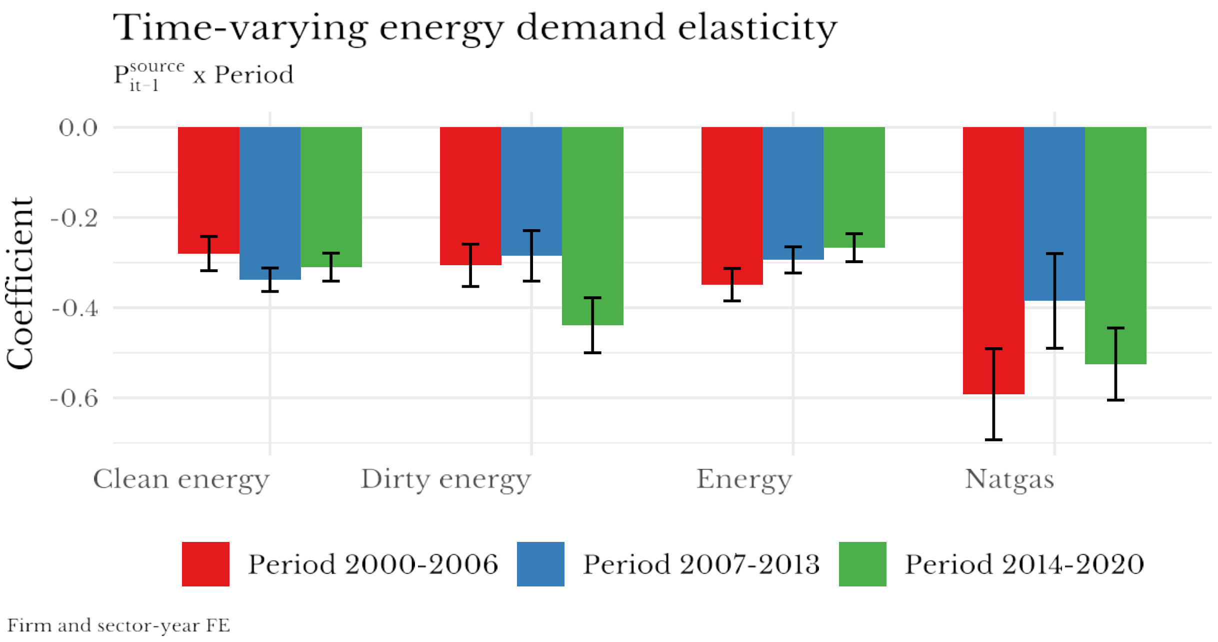
	Energy	Clean Energy	Dirty Energy	Natgas
(log Energy Price)	-1.15***	-0.96***	-1.03***	-1.25***
	(0.03)	(0.03)	(0.05)	(0.07)
Obs.	151849	151753	128901	92772
R2 Adj.	0.96	0.95	0.93	0.94
FE: firmid & Sec-Year	x	x	x	x
(lag-log Energy Price)	-0.30***	-0.31***	-0.35***	-0.48***
	(0.02)	(0.02)	(0.04)	(0.08)
Obs.	122144	122072	101797	72814
R2 Adj.	0.96	0.95	0.93	0.95
FE: firmid & Sec-Year	x	x	x	x
(Energy Price IV)	-0.22**	-0.17**	-0.20*	-1.19***
	(0.08)	(0.07)	(0.13)	(0.35)
Obs.	150848	150679	120461	79436
R2 Adj.	0.94	0.93	0.91	0.93
1st stage	0.55***	0.63***	0.44***	0.29***
FE: firmid & year	x	x	x	x

Robust standard errors, clustered at firm level.
Regressions weighted by employment at t0.
*** $p< 0.01$, ** $p< 0.05$, * $p< 0.1$

* source: FR microdata

1) Energy prices: their role in energy use

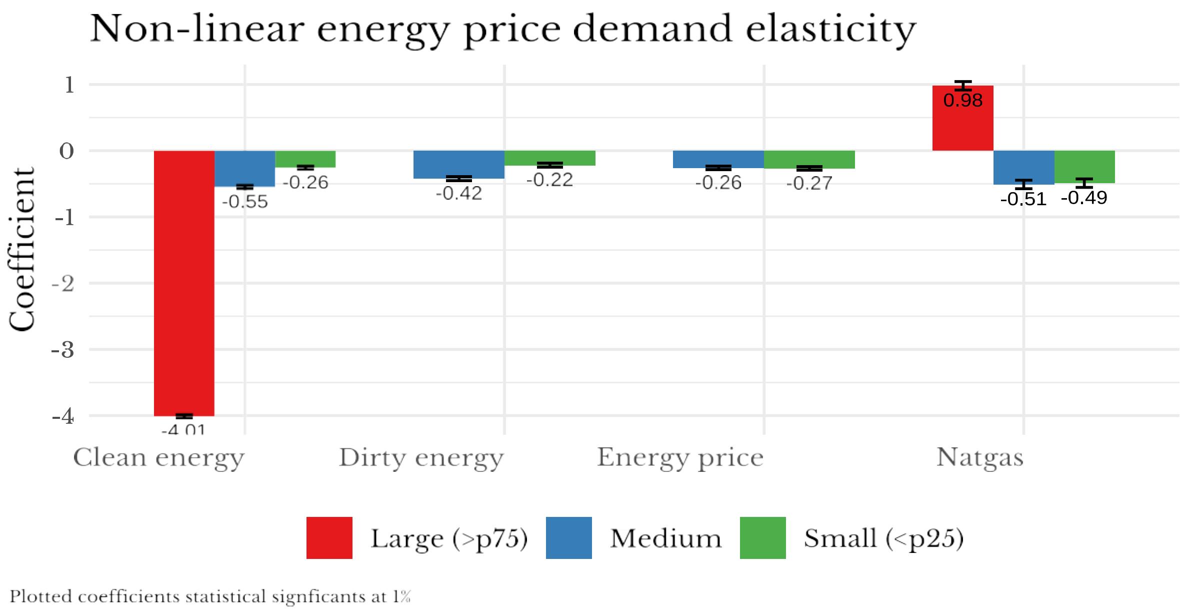
- Estimates relatively stable over time
  - Elasticities evolved over time (e.g., dirty vs. energy), but rather stable



* source: FR microdata

1) Energy prices: their role in energy use

- Larger shocks are important to clean energy and natural gas:
  - High negative impact on clean energy consumption (↑10% → ↓40%)
  - Positive impact on natural gas →
    - Contemporaneous inelasticity

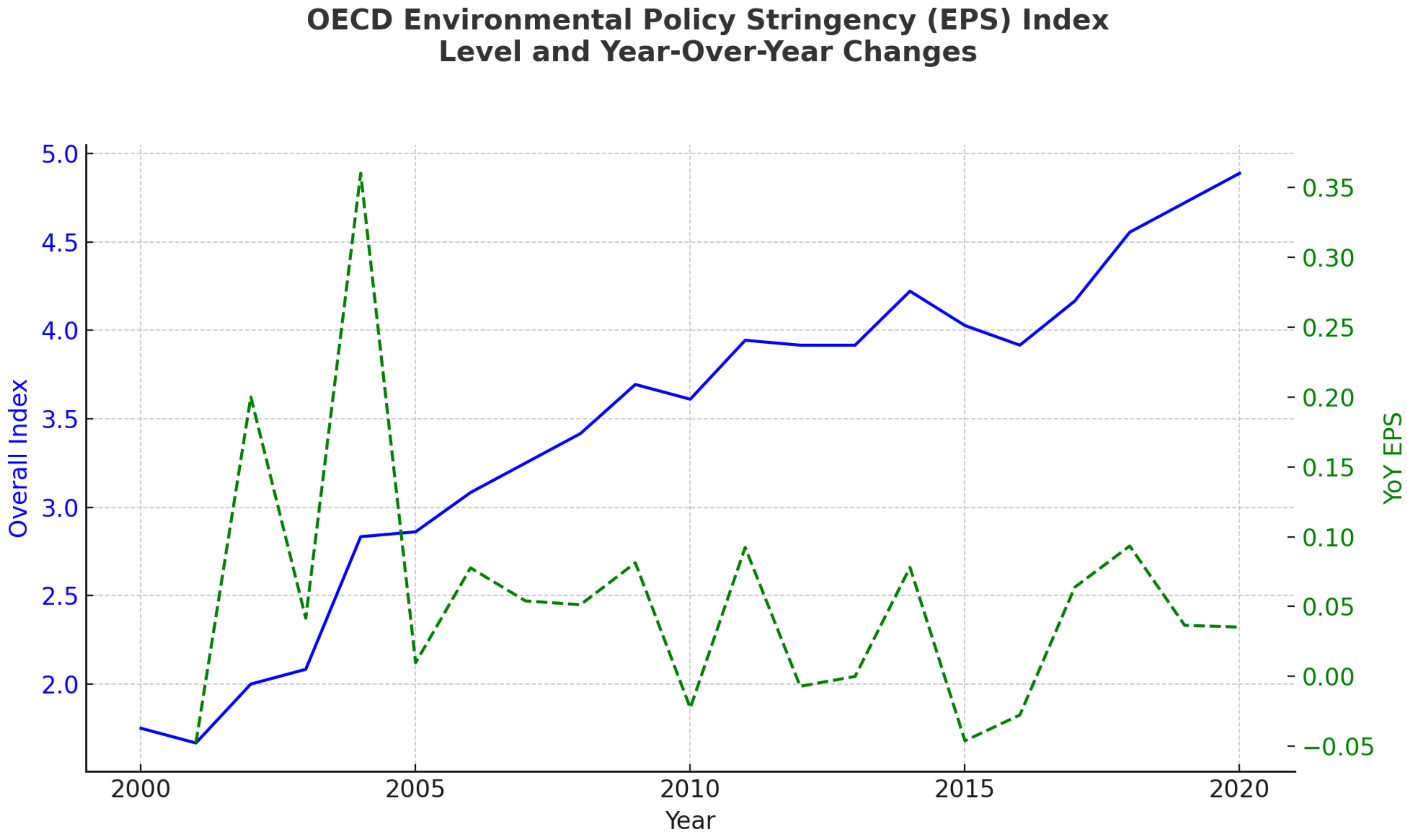


* source: FR microdata

2) Price signaling (joint with OECD)

- Price signaling key to speed green transition (André et al.2023)

- Energy prices react to:
  - External shocks (e.g., Ukrainian war)
  - Carbon taxes:
    - To what extent? for which type of firms?



Governments are increasingly implementing policies to drive the green transition

2) Price signaling; energy mix (joint with OECD)

- Price signaling → firms' energy mix
  - CES production function: output function of low (L) and high(H) carbon energy inputs
  - $Y = \left(\alpha q_L^{\frac{\sigma-1}{\sigma}} + (1-\alpha) q_H^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$ → Max π: $\max PY - (P_L q_L + P_H q_H)$
    - α: input share
    - σ: elasticity substitution between q_L and q_H
    - P: output price
    - $P_L q_L + P_H q_H$: firms' total energy expenditure
  - Optimal fuel mix is a function of energy prices:
    - $\frac{q_L}{q_H} = \left(\frac{P_H}{P_L} \frac{\alpha}{1-\alpha}\right)^{\sigma}$ → *To increase the low-carbon fuel share* $\left(\frac{q_L}{q_H}\right)$ → *high-carbon fuels needs to become relatively more expensive*
      - *Carbon taxes :* $p_H = (1+\tau_H)\, p_H$
      - *Subsidies:* $p_L = (1-\tau_L)\, p_L$

2) Price signaling; carbon tax & subsidies (joint with OECD)

- Price signaling → firms' energy mix
  - CES production function: output function of low (L) and high(H) carbon energy inputs
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      - *Subsidies:* $p_L = (1-\tau_L)\, p_L$

2) Price signaling; policies (joint with OECD)

- Higher EPS should correlate with higher relative cost of H to L carbon fuels:
  - $\frac{P^H_{isct}}{P^L_{isct}} = \alpha_i + \beta EPS_{ct} + \gamma X'_{isct-1} + \varepsilon_{isct}$
    - i: firm
    - s: sector
    - c: country
    - $t: year$
  - To reduce endogeneity and introduce firm variation:
    - multiply EPS index by firms' initial ratio of dirty to clean quantities: $\frac{q^H_{isct0}}{q^L_{isct0}}$
    - Initial results at firm and sectoral level indicate a positive, but low, correlation between EPS and the ratio, especially for EPS component of clean energy subsidy

3) Energy use by product (with Mola, A. & Bighelli, T.)

- At the product-level (PRODCOM), how energy price shocks alter firms' production process?
  - Do they keep producing the same products, but more efficiently (i.e., using less energy per product)?
  - Or do they change their product composition/mix?

- Lack of evidence using firm-product-level data

3) Energy use by product: new database (with Mola, A. & Bighelli, T.)

- To respond these questions, we build a new database:
  - Energy-use by product
    - No consensus on how to link inputs usage to a specific product line
  - Proposal:
    - Empirical approach
    - Production function estimation

Figure 1: Energy use/VA by product (avg): industry mean

Focus on single-product firms: total energy consumption adjusted by VA and by n° of produced goods.

3) Energy use by product: single-product (with Mola, A. & Bighelli, T.)

- To respond these questions, we build a new database:
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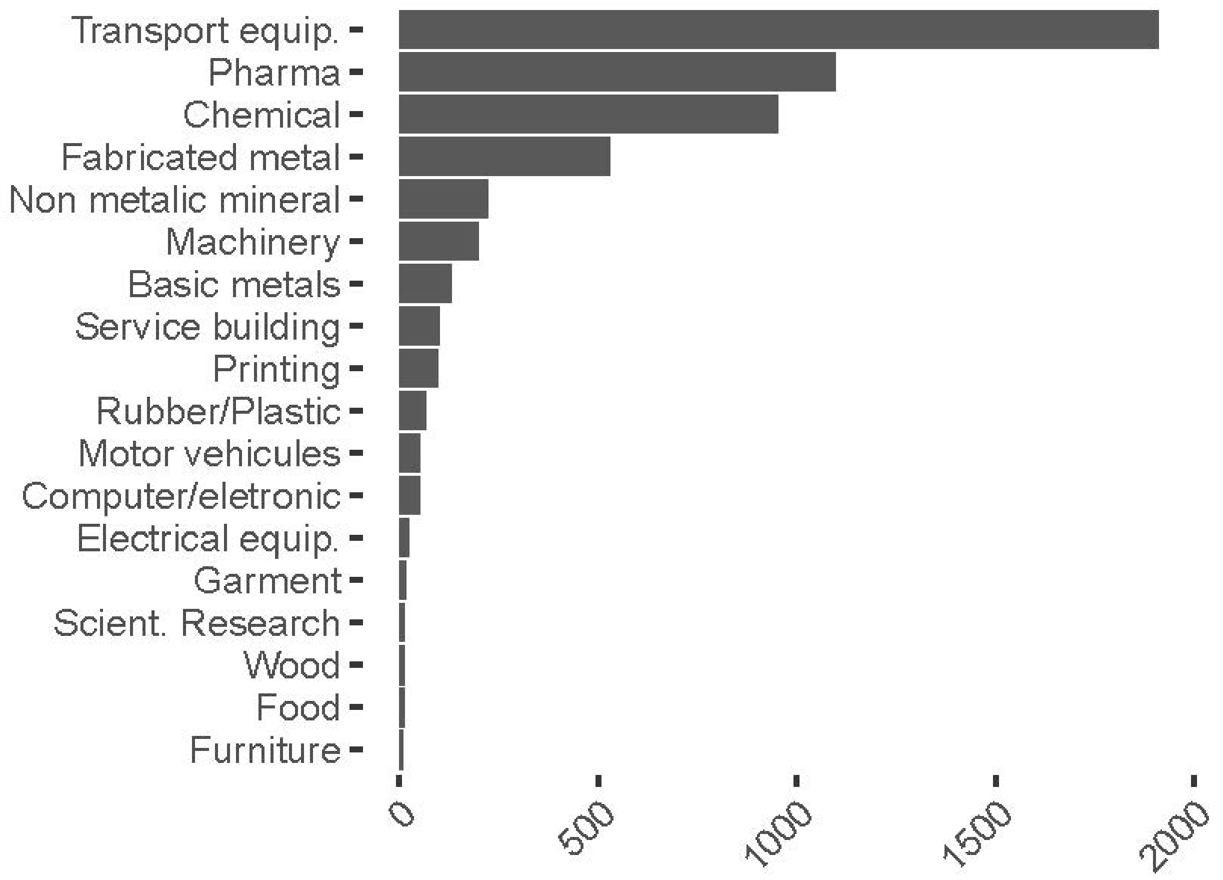
      - 1st: focus single-product firms

Figure 1: **Energy use/VA by product (avg): industry mean**



Focus on single-product firms: total energy consumption adjusted by VA and by n° of produced goods.
1541 products

3) Energy use by product: single-product (with Mola, A. & Bighelli, T.)

- To respond these questions, we build a new database:
  - Energy-use by product
  - Proposal:
    - Empirical approach:
      - 1st: focus single-product firms
        - » Taking the distribution of each product:
          - Larger and more energy-intensive at bottom percentiles
          - Have higher energy costs over their total costs

Characteristics firms along distribution[5]

	Cost	Intensity	Employees
P01	0.10	0.52	67.74
P05	0.05	0.26	75.27
P10	0.05	0.23	72.76
P25	0.04	0.21	69.56
P50	0.04	0.21	62.59
P75	0.03	0.14	52.50
P90	0.03	0.12	44.16
P95	0.04	0.11	39.25
P99	0.02	0.15	37.60

Mean energy costs, intensity, & n° employees of firms at each percentile

3) Energy use by product: algorithm (with Mola, A. & Bighelli, T.)

- To respond these questions, we build a new database:
  - Energy-use by product
    - Empirical approach:
      - 1st: focus single-product firms
      - 2nd: expand to multiple-product:
        - » Single-product energy-use distribution
        - » Expand to double-product firms matching by firm characteristics (e.g. size)
          - E.g., 2 prod firm: prod A – match prod B from single-prod dist. match
        - » Expand to three & four product firms (80% production coverage)
      - 3rd: product energy usage based on product revenue
      - Placebo: fuzzy match

Table 1: Energy-use by product methods: correlation matrix

	Algorithm	Fuzzy match	Revenue-based measure
Algorithm	1.000		
Fuzzy match	0.233	1.000	
Revenue-based measure	0.736	0.266	1.000

3) Energy use by product: prod. function (with Mola, A. & Bighelli, T.)

- To respond these questions, we build a new database:
  - Energy-use by product
    - Empirical approach
    - Production function estimation approach: (De Locker et al., 2016) framework
      - Estimate the production function parameters for the single-product firms
      - Use those parameters to retrieve inputs allocation across product
        - » Assume: production function parameters the same for single-product firms and single production lines in multi-product firms

Next steps using MDI

- Keeping output constant, firms could reduce energy demand by switching to clean sources via
  - Prices (idiosyncratic) ← EPS + supply (temporary vs permanent) shocks (not tested)
    - Price elasticity clean and dirty (oil essentially) energy similar
    - Natural gas price elasticity higher
  - Prices → ↑ Efficiency vs rebound effect (not tested)
- Mechanisms & heterogeneity (TBD)
  - How effective is price signaling to big consumers? Consider market power (energy price pass-through)

Next steps using MDI

- Energy research:
  1. Their role in energy use:
     - Evaluate estimates during the EU energy crisis (2022)
     - Expand findings to technical change literature
       - Include energy efficiency component – Stochastic Frontier analysis
  2. Price signaling (joint with OECD)
     - Evaluate policies (FR and PT identified)
  3. Energy use by product (Mola, A., Bighelli, T.)
     - Pursue 2^{nd} approach and test energy shocks

Thank you!

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