Net zero emissions and price signalling

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Outline

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- Motivation
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- Model
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- Conclusion

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Motivation

- To reach NZE by 2050, the EU needs to cut fossil fuel use from 73% to 20%, but current policies only achieve 60% (*ECB* 2024)
- Social costs of carbon estimates (Hambel, Van den Bremer, and Van Der Ploeg, 2024) of 182\$/t Co2 are more than 3x the world average carbon prices (WB, 2024)
- Price signals are crucial for accelerating the green transition
  - via energy efficiency (André et al., 2023)
  - by directing technology towards green innovation (technical change literature, see review Hémous and Olsen, 2021)

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This paper

- Investigates the efficacy of energy prices in accelerating the green transition
  - by studying how firms responds to energy shocks via
    - their capacity to change their energy mix (elasticity of substitution)
    - their innovation (clean/dirty) incentives (technical change bias)

- Roadmap:
  1. Sample
  2. Price elasticity of energy demand estimates
  3. Model & parameters calculation
  4. Energy price simulations
  5. Technical change bias

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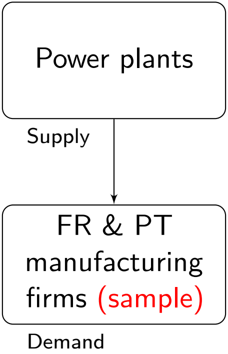
Energy market

Supply-demand



- generate electricity using mainly clean sources (renewables and nuclear);
  - France: +80% clean
  - Portugal: +60% clean

- consume clean and dirty energy sources to produce output:
  - Clean: electricity, steam, renewable
  - Dirty: natural gas, oil and fossil fuel related

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Data

Microdata infrastructure (MDI)

- Sample: France (2000-2020) and Portugal (2010-2020)
  - to be expanded to Slovenia, Austria, and Germany
- Datasets used:
  - SBS[1] and BS (balance-sheet): used to recover firms' characteristics (e.g., size, age, turnover, etc.)
  - Energy: firms' energy expenditure and consumption → prices
    - disaggregated by energy source (natural gas, coal, fossil fuel related, electricity, etc.)

[1] Structural business statistics (Eurostat): detailed structure, economic activity, and performance of businesses over time

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How do energy prices impact firm-level energy consumption?

- Estimate log-log within-firm identification strategy:

$$E_{i,s,t} = \beta P_{i,s,t} + \theta_i + \theta_{s,t} + \epsilon_{i,s,t} \tag{1}$$

E & P: energy consumption and price, i: firm, t: year, s: sector

- β likely to be endogenous due to OVB[2]
  - To identify (1) shift-share IV à la Fontagné, Martin, and Orefice, 2024:
    - $p^{IV}_{i,s,t} = \left[\frac{p_{i,s,t_0}}{\overline{p}_{s,t_0}}\right] \times \overline{p}_{s,t}$ (exclude the i price on s average).
    - I.e., it multiplies P_i at t_0 (i.e., when firm enters the sample) by the growth rate of the sectoral average price at year t.

[2] E.g., Demand and technological shocks relate to inputs and energy prices consumed and negotiated by firms.

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Stylized facts

Price elasticity of energy demand: results

Table: Price elasticity of clean and dirty energy demand

Dependent Variable: *Firm E_{type} demand* (ln)				
	FR		PT	
E_c price (ln)	-0.7501***	-0.1725*	-0.9030***	-0.9691***
	(0.0432)	(0.073)	(0.0076)	(0.0469)
Obs	150,336	149,271	478,959	469,140
R2	0.946	0.944	0.937	0.936
1st stage		0.6345***		0.5178***
F-test (IV)		31,890.2		30,855.6
E_d price (ln)	-0.9568***	-0.1719	–0.9129***	-0.8519***
	(0.1112)	(0.1298)	(0.0127)	(0.0759)
Obs	127,555	119,190	323,308	281,420
R2	0.92818	0.927	0.962	0.963
1st stage		0.4775***		0.1146***
F-test (IV)		12,636.8		2,736.3

Notes: Significance levels: * p<0.1; ** p<0.05; *** p<0.01.
Standard errors clustered at firm-level. Year and firm fixed effects added.

- Why such a difference between countries?

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Firm's problem

Nested-CES

Top-Level CES in X and E

Production is a function of energy (E) and other inputs (X);

$$Y = \left[\delta\, X^{\phi} + (1-\delta)\, E^{\phi}\right]^{\frac{1}{\phi}}, \quad \phi < 1, \quad 0 < \delta < 1 \qquad (2)$$

$\sigma_{XE} = \frac{1}{1-\phi}$: elasticity of substitution between X and E;

Inner CES Clean vs Dirty Energy

Clean (E_c) and dirty (E_d) energy combined; A efficiency;

$$E = \left[\alpha\,(A_c\, E_c)^{\rho} + (1-\alpha)\,(A_d\, E_d)^{\rho}\right]^{\frac{1}{\rho}}, \quad 0 < \alpha < 1, \qquad (3)$$

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Maximization

Lemmas

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Top-Level CES in X and E

- Min costs ($C = w\,X + p_E\,E$) w.r.t. X & E yields E demand;
- Partial own-price elasticity of E w.r.t. p_E:

$$\eta_{E,p_E} \;=\; -\,\sigma_{XE}\,\theta_E \tag{4}$$

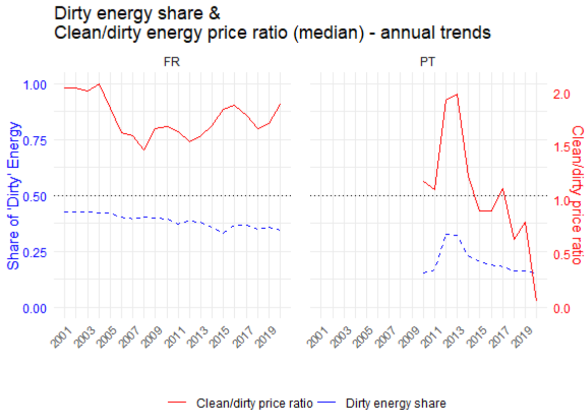
where θ_E is firms' energy cost share.

Inner CES Clean vs Dirty Energy

- Minimizing energy costs w.r.t E in (3) yields

$$\frac{E_c}{E_d} = \frac{\alpha}{1-\alpha}\left(\frac{p_d/A_d}{p_c/A_c}\right)^{\frac{1}{1-\rho}} \tag{5}$$

$\sigma_{cd} = \frac{1}{1-\rho}$: elasticity of substitution between E_c and E_d



- P_c has fallen more sharply than P_d, especially in PT;
- Share of E_d has declined gradually in both countries.

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Model parametrization

Elasticity of substitution between E_d and E_c (σ_{cd})

- To identify σ_{cd}, I log-linearize (5) and instrument prices as in (1):

$$\ln\left(\frac{E_d}{E_c}\right) = -\ln\left(\frac{\alpha}{1-\alpha}\right) + \frac{1}{1-\rho}\left[\ln\left(\frac{p_c}{p_d}\right) + \ln\left(\frac{A_c}{A_d}\right)\right] \quad (6)$$

Table: Long-Run Elasticity of Substitution

Dependent Variable: $\ln\left(\frac{E_{d,it}}{E_{c,it}}\right)$				
	Portugal		France	
	(OLS)	(IV)	(OLS)	(IV)
$\ln\left(\frac{P_{c,it}}{P_{d,it}}\right)$	0.8822***	0.9803***	1.892***	2.767***
	(0.0029)	(0.0086)	(0.0588)	(0.1240)
Industry FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
Observations	299,470	250,587	126,788	92,306
R2	0.74	0.88	0.24	0.31
F-test (IV only)		76,459.2		12,835.4

Significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Standard errors are clustered at the firm level.

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Calibration

P_E changes simulation

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- Intuitively, keeping Y constant, following an $\uparrow$ in P_E:
  - a high σ_{cd} allows firms to buffer $\uparrow P_E$ by switching energy mix;
  - a low σ_{cd} forces a stronger $\downarrow$ overall E.

Table: Mean parameters

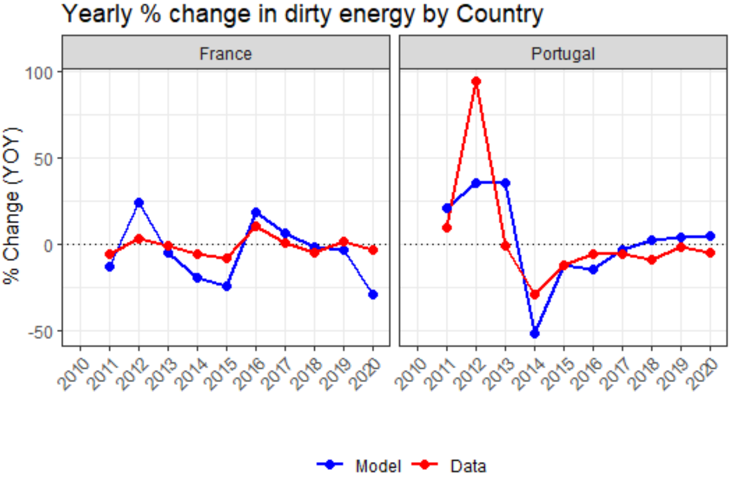
Country	$\overline{p_c}$	$\overline{p_d}$	$\overline{\theta_E}$	σ_{cd}	σ_{XE}
Portugal	0.015	1.200	0.042	0.95	1.0
France	0.98	0.60	0.017	2.75	1.0

σ_{XE}=1 $\rightarrow$ Cobb–Douglas assumption. θ_E: energy costs. P in K€/GJ

- From (4), if $P_E \uparrow by + k\% \rightarrow E$ changes by $-\sigma_{XE}\,\theta_E k\%$.
  - PT: $\Delta E = -1 \times 0.042 \times 10\% = -0.42\%$. (+400% → -16.8%)
  - FR: $\Delta E = -1 \times 0.017 \times 10\% = -0.17\%$. (+400% → -6.8%)

Calibration

Changes in E_d shares



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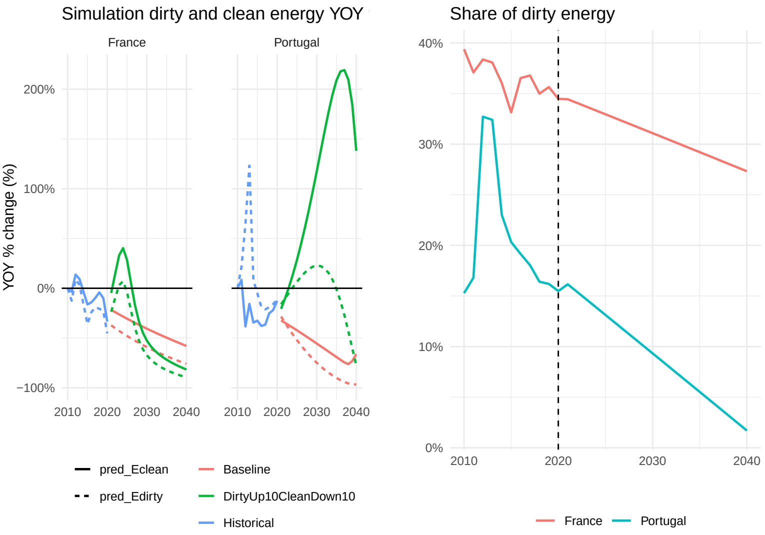
Forecast

E_d shares



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Technical change bias

Market size vs price effects

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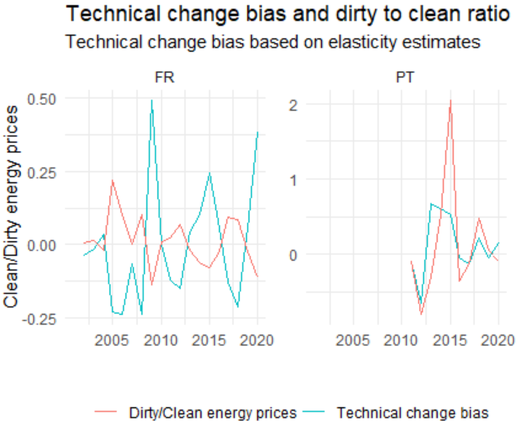
- Technical change literature relates ρ to innovation bias:
  - Market size: innovation towards abundant and cheaper energy ($\sigma_{cd} > 1 : E_c, E_d$ substitutes)
  - Price effects: innovation towards more expensive energy source ($\sigma_{cd} < 1 : E_c, E_d$ complementarity)
- Following Jo, 2024, plug σ_{cd} in (5) to calculate technical change bias, $\frac{A_c}{A_d}$, and relate to price ratio, $\frac{Pc}{Pd}$.

Technical change bias



- When $\frac{Pd}{Pc}$ increases $(P_d > P_c)$, $\frac{A_c}{A_d}$ decreases $(A_d > A_c)$ (FR)
  - Opposite in PT

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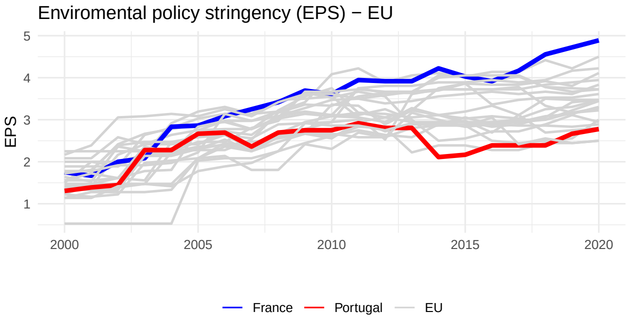
1. Increasing $\frac{P_d}{P_c}$ (e.g., via carbon taxes) has a lower impact
   - in countries with higher σ_{cd} firms can relocate energy inputs (FR);
   - lower σ_{cd} forces firms to reduce E and improve efficiency (PT).
2. Direction of innovation can amplify price ratio effects in the long-run.
3. Limitations/next steps:
   - Different σ_{cd} by industry and firm-size (Jo, 2024)
   - Endogenous elasticity substitution (VES vs CES) matters (i.e., σ_{cd} varies across years) (Jo and Miftakhova, 2024)

Box 1: CompNet-OECD[3] collaboration

To what extent environmental policies influence firm-level relative fuel prices



- Sectoral energy mixes stay stable despite stricter EPS.
- We examine the impact of environmental policies on firm-level relative fuel prices.

[3] With Fatih Ozturk, Filiz Unsal - OECD

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Box 1: CompNet-OECD collaboration

Specification

- Our initial specification includes

$$\frac{P^d_{i,t}}{P^c_{i,t}} = \beta EPS_t \times \frac{EI^d_{i,t_0}}{EI^c_{i,t_0}} + \theta_s \times \delta_t + \epsilon_{i,t} \quad (7)$$

- Unobservables impact firm prices → EPS → simultaneity (Benatti et al., 2024)
  - Attenuate it by interacting *EPS* with energy intensity ratio at firm-level at time t_0:
    - Interaction creates firms' ex-ante exposure to changes in EPS
- Firms' tend to delay their reaction to EPS; we capture it via
  - local projection approach à la Jordà, 2005 with a horizon of five years.

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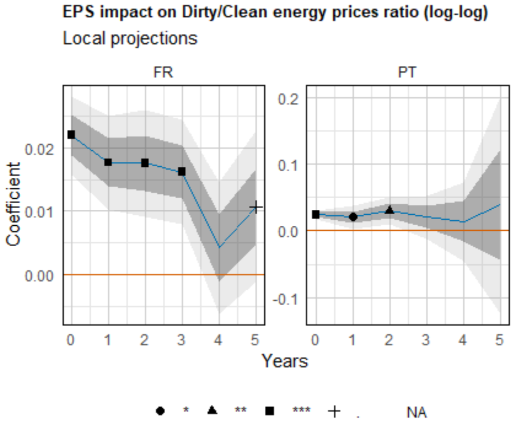
Box 1: CompNet-OECD collaboration

Initial results



- Similar coefficients (about 0.02), no precision in PT.
- Cumulative response of about 0.6% for a ↑ 10% in EPS

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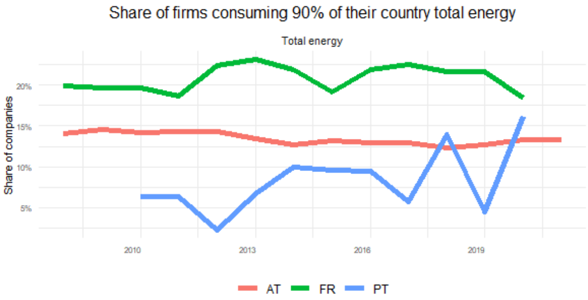
Box 2: CompNet-OeNB[4] collaboration

Energy prices and use: decomposition and concentration



- About 15% of the firms consume up to 90% of their countries' total energy

[4] With Sellner, R., Reinstaller, A. Austrian productivity board (OeNB)

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Box 2: CompNet-OeNB collaboration

Energy prices and use: decomposition and concentration

- These ‘mega-consumers’ pay lower energy prices[5] have more employees, turnover, and energy costs, and are much more energy efficient.

Firms consuming 90% of country energy vs rest firms - comparison

group	Country	% firms	E Price	Empl	Turnover	E costs	L costs	Clean eff	Dirty eff
E	FR	0.23	0.67	5.13	6.2	2.86	0.76	4.25	6.87
E	PT	0.08	0.4	7.3	7.26	1.86	1.2	18.04	7.26
E_{clean}	FR	0.26	0.75	5.27	6.39	2.42	0.77	4.56	3.72
E_{clean}	PT	0.1	0.52	6.09	6.41	1.36	1.26	16.5	2.3
E_{dirty}	FR	0.2	0.75	4.25	4.92	2.83	0.78	2.97	8.07
E_{dirty}	PT	0.11	0.02	8.47	9.69	1.75	1.18	3.53	6.4

[5] E.g., FR mega-consumers pay about 33% less in energy, column 4.

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Next steps

- NZE and price signaling:
  - Document time-varying (VES) micro elasticities of substitution between energy inputs;
  - recover macro elasticities from micro ones
- CompNet-OECD collaboration:
  - Fine-tune specifications;
  - Use tested IV with LP;
  - Test DiD policy in FR
- Energy-use by product : presented at the last TSI trainning.
  - First results in FR compared to CBAM values;
  - Expand to other countries and test energy shocks.

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Thank you!
Q & A

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