Households' energy demand

The effects of carbon pricing in Italy

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Motivation

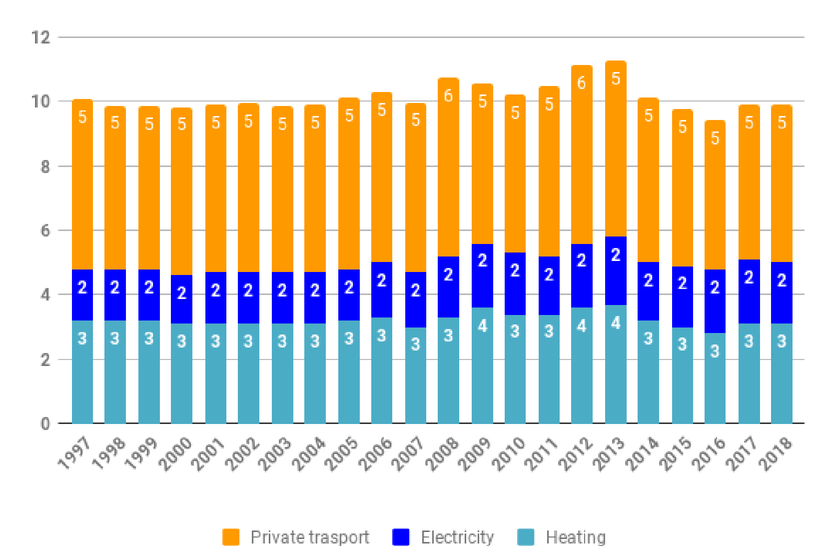
- understanding energy demand and its drivers is crucial to govern net-zero transition and it is key in a present energy crisis;
- policies for a just transition should consider the distributive effects of carbon pricing;
- to be sustainable, policies to tackle persistent high energy prices should target the vulnerables.

Main results

- We develop a microsimulation model for households (HHs) energy demand in Italy, modelling the price elasticity for electricity, heating and private transport;
- elasticities are estimated for a combination of households characteristics and welfare (proxied by the equivalent expenditure);
- short run elasticities have the expected sign and are lower than long run elasticities;
- a carbon tax will significantly affects HHs, especially energy poor, abate up to 13% of total emissions and raise up to €15.5 billion;
- revenue-recycling to mitigate effects on more vulnerable households (and increase policy acceptance).

Data and identification strategy

Share of expenditure by energy use



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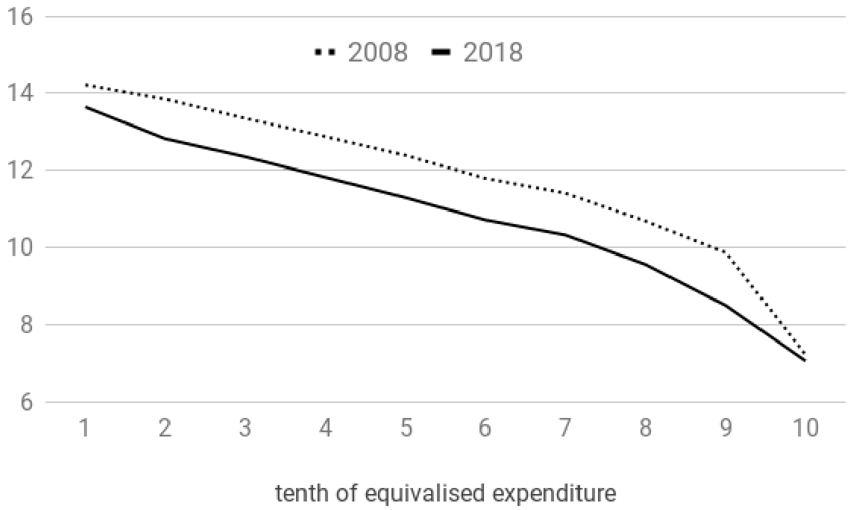
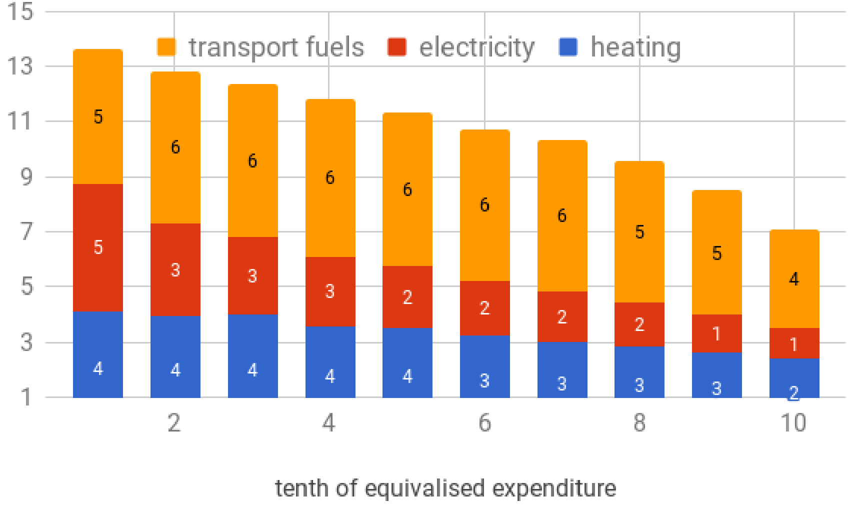
Energy share by tenth of expenditure: 2008 vs 2018



Energy share by tenth of expenditure in 2018



Data

- Italian Household budgey survey (HBS) from Istat (1997-2018); $\sim$ 16-20.000 obs per year;
- semi-annual retail electricity and natural gas prices from Eurostat;
- price components from ARERA;
- monthly gasoline and gasoil prices from MISE;
- HICP from Istat;
- wholesale electricity (PUN) and natural gas (PSV) prices and Brent from Bloomberg;

Identification strategy

- HBS is a cross section study, not a panel;
- *quasi*-panel (Deaton,1985);
- *strata*: (9) household type (from Istat) x (4) quartile of the equivalent expenditure distribution = 36 strata;
- 36 strata x 22 years x 12 months = $\sim$ 9.500 obs

Estimating energy demand

for each household i at time t

$$S^E_{i,t} = \frac{(E^E{}_{i,t} + E^H{}_{i,t} + E^T{}_{i,t})}{Exp_{i,t}} \tag{1}$$

where

- E^E is the electricity expenditure;
- E^H is the heating expenditure;
- E^T is the private transportation expenditure;
- Exp is the total expenditure.

Estimating electricity (heating) demand

$$E^{E}_{i,t} = (P^{vE}_{i,t} Q^{E}_{i,t} + P^{fE}_{i,t})(1 + T_t) \quad (2)$$

where

- $P^{vE}_{i,t}$ is the variable price per kWh (Gj for natural gas);
- $Q^{E}_{i,t}$ is the quantity of electricity demanded (unknown);
- $P^{fE}_{i,t}$ is a fixed price component;
- $(1 + T_t)$ are taxes (VAT).

Solving for $Q^{E}_{i,t}$, it follows

$$Q^{E}_{i,t} = (\frac{E^{E}_{i,t}}{1 + T_t} - P^{fE}_{i,t}) * \frac{1}{P^{vE}_{i,t}} \quad (3)$$

All quantites are calibrated

Estimating private transport demand

- In Italy there are 3 fuels used for private transportation: gasoline, gasoil and LPG/CNG ($\sim 9\%$). Up to 2014, data on Gasoil and LPG/CNG expenditures are merged;
- In the bottom tenth less than two thirds of the households owns a cars while in the top tenth, 9 out of 10 households possess a private vehicle;
- retail price is competitive (more than 15k fuel pumps);

$$Q_{it}^{T} = \frac{E_{i,t}^{G}}{P_{t}^{G}} + \frac{E_{i,t}^{D}}{P_{t}^{D}} \tag{4}$$

where

- E^G and P^G are gasoline expenditure and price;
- E^D and P^D are diesel expenditure and price;

All quantites are calibrated

Estimating elasticity

We take average demand by *strata* and we estimate the (short and long run) price and income elasticities separately for three energy services $z = E, H, T$:

$$logQ^z_{s,t} = \lambda_s logQ^z_{s,t-1} + \beta_s logP^z_{s,t} + \gamma_s logE_{s,t} + w + s + t + t^2 + \epsilon_{s,t} \quad (5)$$

- a lagged term, $logQ^z_{s,t-1}$;
- the (real) price of the fuel ($logP^z_{s,t}$);
- household' total expenditure ($logE_{s,t}$);
- a set of time trend (t and t^2) and seasonal dummies (w for autumn and winter months and s for summer).

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Results

Results: short and long run price elasticities

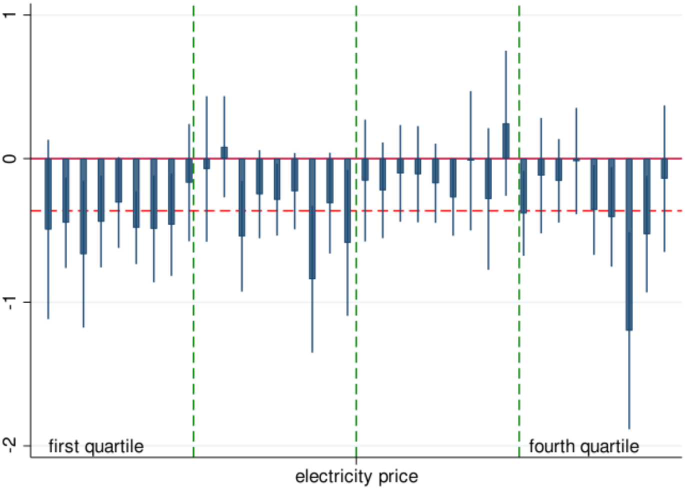
	Short run price elasticities			
	LS	stratum-level LS	2SLS	long run
Electricity	-0.36***	-0.29*	-0.40***	-1.17***
Heating	-0.40***	-0.44**	-0.44***	-1.23***
Transport	-0.17**	-0.45**	-0.66***	-1.46***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

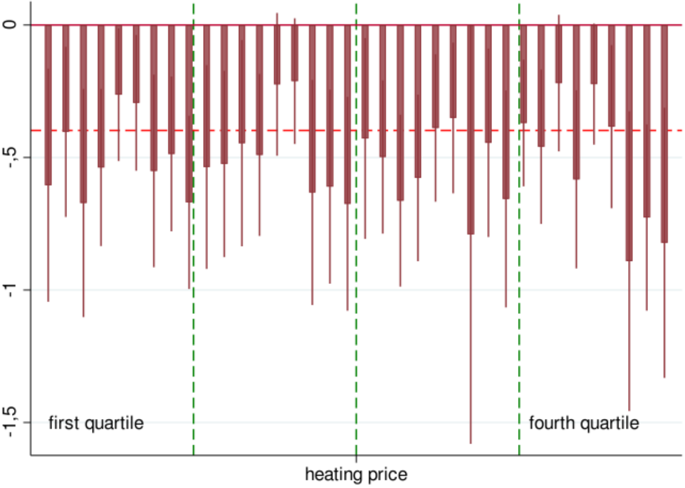
Robustness checks:

- (robust) test for endogeneity (Wooldridge, 1995): strongly reject exogeneity only in Transport;
- test for weak instruments: Cragg-Donald/Stock and Yogo (2005) approach unfeasible; F-stat $>$ 104 (Lee et al 2020) in all cases;
- Im-Pesaran-Shin test (2003) reject the null hypothesis of non-stationarity

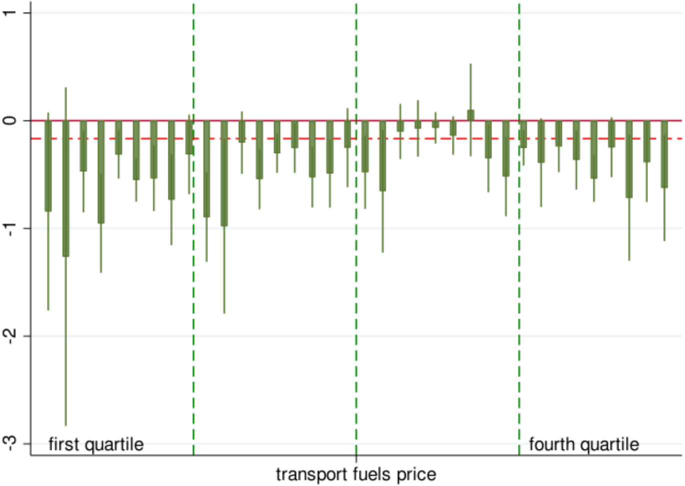
Short run price elasticity of electricity by stratum



Short run price elasticity of heating by stratum



Short run price elasticity of transport fuels by stratum



An application: a carbon tax in Italy

A carbon tax in Italy

- Italy belongs to the EU-ETS; currently, there is no national carbon pricing scheme;
- we choose to focus on 4 possible CTs: €50 (average of the EU-ETS in 2021), €100 (current EU-ETS value, COP21 compliant), €200 and €800 (peak values *orderly* and *disorderly* NGFS scenarios, v1.0);
- we use the specific carbon emission factors from official sources for each fuel to estimate the impact of each carbon tax on final energy prices;

carbon emission factors per fuel

ton CO2 per GJ

Electricity	Heating	Petrol	Diesel
0.078167	0.055820	0.067903	0.068301

Effects of the CT on final energy prices

	Carbon taxes			
€ per ton of CO2	50	100	200	800
Price variation				
Electricity	+6.3	+12.6	+25.2	+100.8
Heating	+11.8	+23.6	+47.2	+188.7
Transport fuels	+7.9	+15.9	+31.8	+127.2
% change compared with the baseline year (2018)				

Using 2018 prices as baseline, the introduction of a carbon tax of e50 per ton, is equivalent to add: €0.014 to each kWh of electricity; €2.8 to each GJ of gas and €0.12 to each litre of gasoline or gasoil.

Adjustment to our microsimulation model

Use price variations and previously estimated elasticities to get new demand:

$$\hat{Q}^{z}_{is|(\tau=CT)} = \hat{\beta}_s * [logP^z * (1 + \tau^z_{CT})] + \hat{\epsilon}_s \quad (6)$$

where

- β_s are the estimated elasticity for each stratum s;
- is the implied price changes τ^z_{CT};
- $\hat{\epsilon}_i \sim \mathcal{N}(0, R\hat{M}SE_i)$

...and new, counterfactual, total expenditure:

$$Exp_{is|\tau=CT} = Exp_{is} + (E_{is|\tau=CT} - E_{is|\tau=0}). \quad (7)$$

Results of the simulations (1 out of 2)

	Carbon taxes			
€ per ton of CO2	50	100	200	800
Energy demanded				
Electricity	-1.7	-3.4	-6.3	-19.6
Heating	-5.1	-9.7	-17.7	-48.1
Transport fuels	-2.6	-5.1	-9.5	-28.3
Total energy demand	-4.2	-7.7	-13.8	-38.0
Expenditure				
Electricity	+4.5	+8.9	+17.3	+61.6
Heating	+6.6	+12.6	+22.9	+54.1
Transport fuels	+5.1	+10.0	+19.2	+62.6
Total energy expenditure	+5.4	+10.6	+20.0	+59.8
Total expenditure	+0.5	+1.0	+2.0	+5.9

Results of the simulations (2 out of 2)

	Carbon taxes			
€ per ton of CO2	50	100	200	800
Effect on inflation (2018)*	+0.7	+1.4	+2.8	+11.3
CO2 Emissions and revenues				
% var	-3.7	-7.0	-12.9	-36.4
Emissions (ΔMtCO2e)	-4.8	-9.3	-17.0	-48.0
Revenues (billion of €)	+4.2	+8.2	+15.5	+42.1

* Additional percentage points to the Italian consumer price index (NIC).

(Total GHG emissions in 2018: 438 MtCO2eq - 112 from HHs)

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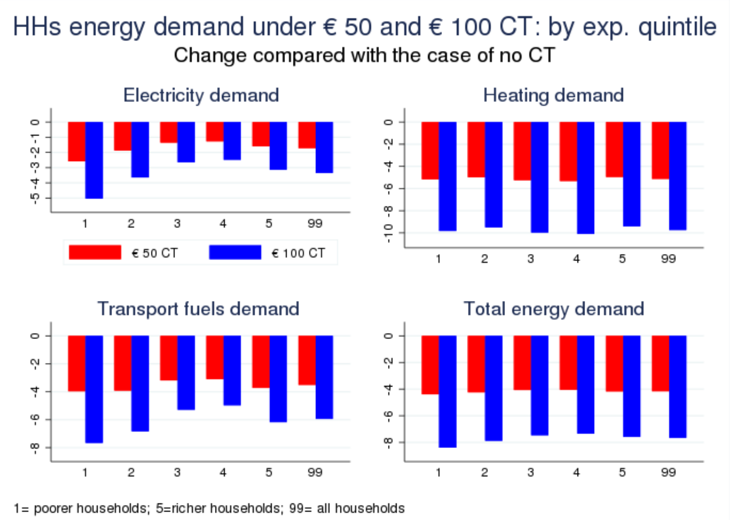
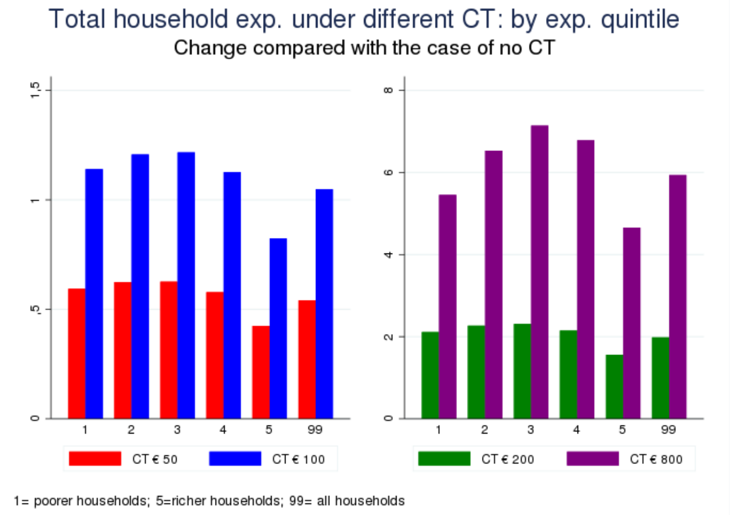
Greater reduction in energy demand for poorer households



Carbon tax would be regressive



Conclusions

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- a carbon tax will significantly affects HHs, especially energy poor, abate up to 13% of total emissions and raise up to €15.5 billion;
- revenue-recycling to mitigate effects on more vulnerable households (and increase policy acceptance).
- an application of the model to evaluate the Italian Government' price interventions in 2021 suggest they were partially effective and regressive (Faiella and Lavecchia, 2022).
- an application to evaluate Italian HHs and firms financial vulnerability to transition risk (bottom-up climate stress test - Faiella et al., Journal of policy modeling, 2022)

Thank you for your attention!

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Appendix

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Energy demand as % change compared to the baseline

Tenth of equiv. expenditure	Electricity €/ton CO2 50	100	200	800	Heating €/ton CO2 50	100	200	800	Transport fuels €/ton CO2 50	100	200	800
1	-2.6	-5.1	-9.6	-29.6	-5.2	-9.8	-17.9	-48.2	-4.0	-7.7	-14.3	-42.1
2	-2.6	-5.0	-9.4	-28.7	-5.2	-9.8	-17.8	-48.1	-4.0	-7.7	-14.3	-42.4
3	-2.1	-4.2	-7.9	-24.2	-5.0	-9.5	-17.4	-46.9	-3.5	-6.7	-12.5	-36.8
4	-1.6	-3.2	-6.0	-18.6	-5.0	-9.5	-17.4	-47.3	-2.9	-5.6	-10.5	-31.0
5	-1.6	-3.1	-5.9	-18.4	-5.0	-9.5	-17.2	-46.5	-3.0	-5.9	-10.9	-32.6
6	-1.1	-2.2	-4.2	-13.0	-5.5	-10.4	-19.0	-51.4	-1.6	-3.1	-5.9	-17.7
7	-1.1	-2.2	-4.2	-13.0	-5.5	-10.5	-19.0	-51.5	-1.7	-3.3	-6.2	-18.6
8	-1.4	-2.7	-5.1	-15.8	-5.1	-9.8	-17.7	-48.0	-2.3	-4.5	-8.5	-25.0
9	-1.7	-3.3	-6.2	-19.2	-4.9	-9.4	-17.0	-46.2	-2.7	-5.3	-9.9	-29.6
10	-1.5	-3.0	-5.7	-18.0	-5.0	-9.5	-17.2	-47.1	-2.6	-5.0	-9.4	-28.0
Total	-1.7	-3.4	-6.3	-19.6	-5.1	-9.7	-17.7	-48.1	-2.6	-5.1	-9.5	-28.3

Expenditure as % change compared to the baseline

	Electricity				Heating				Transport fuels			
Tenth of equiv.	€ /ton CO2				€ /ton CO2				€ /ton CO2			
expenditure	50	100	200	800	50	100	200	800	50	100	200	800
1	3.6	6.9	13.2	41.6	6.5	12.4	22.5	53.2	3.6	7.0	12.9	31.4
2	3.6	7.0	13.5	43.4	6.6	12.6	23.0	54.7	3.6	7.0	12.9	30.7
3	4.1	8.0	15.4	52.7	6.7	12.8	23.3	56.9	4.2	8.1	15.3	43.2
4	4.6	9.1	17.9	64.3	6.8	12.9	23.4	56.1	4.8	9.4	18.0	56.6
5	4.7	9.2	18.0	64.9	6.8	13.0	23.8	59.4	4.6	9.1	17.3	52.6
6	5.1	10.1	20.0	74.8	6.3	11.9	21.3	45.2	6.2	12.3	24.0	87.0
7	5.1	10.1	19.9	74.5	6.2	11.8	21.2	44.5	6.1	12.1	23.6	84.6
8	4.8	9.6	18.8	69.2	6.6	12.6	23.1	55.4	5.4	10.7	20.7	70.4
9	4.5	9.0	17.5	62.7	6.8	13.0	23.9	59.1	5.0	9.8	18.8	60.1
10	4.7	9.2	18.0	64.6	6.7	12.7	23.3	56.0	5.1	10.1	19.4	63.5
Total	4.5	8.9	17.3	61.6	6.6	12.6	22.9	54.1	5.1	10.0	19.2	62.6