Taxing the Thermostat: Carbon Tax Incidence and Heating Fuel Demand Across Europe

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Abstract

The EU's Emissions Trading System 2 (ETS2), launching in 2027, will impose carbon prices on heating fuels for over 150 million European households. The €65–87 billion Social Climate Fund is calibrated on pass-through and elasticity assumptions that have never been estimated using policy-driven price variation. I exploit the staggered introduction of national carbon taxes on natural gas—Ireland (2010), France (2014), Portugal (2015), Germany (2021), and Austria (2022)—and Eurostat's semi-annual gas price decomposition, which separates the tax component from energy and network costs. Carbon taxes are over-shifted to consumers: a €0.01/kWh tax increase raises consumer prices by €0.013/kWh ($p < 0.001$). Instrumenting total gas price with the tax component yields a demand elasticity of -0.45, roughly 4.8 times the OLS estimate, with a first-stage F-statistic of 29. Carbon taxes have no detectable effect on energy poverty.

JEL Codes: H23, Q41, Q48, Q58

Keywords: carbon tax, pass-through, gas demand elasticity, ETS2, energy poverty, instrumental variables

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1. Introduction

In 2027, the European Union will extend carbon pricing to heating fuels and road transport under the Emissions Trading System 2 (ETS2). More than 150 million households across 27 member states will face higher gas bills. To cushion the blow, the EU has established the Social Climate Fund, allocating €65–87 billion over 2026–2032 based on projected pass-through rates and demand elasticities (European Commission, 2021). Yet these projections rest on thin empirical ground: most residential gas demand elasticities come from aggregate time-series identification (Labandeira et al., 2017) or US household survey data (Alberini and Filippini, 2011), not from European policy-driven price shocks.

This paper estimates both the pass-through rate and the demand elasticity of carbon taxes on household natural gas using a natural experiment that has been unfolding across Europe for over a decade. Five countries introduced national carbon taxes on heating fuels at different times: Ireland in 2010, France in 2014, Portugal in 2015, Germany in 2021, and Austria in 2022. Crucially, Eurostat publishes semi-annual gas prices decomposed into three components—energy costs, network charges, and taxes/levies—for 35 European countries (Eurostat, 2025a). This decomposition provides a policy-driven instrument: the tax component of the gas price is set by legislation, not by demand conditions, satisfying the exclusion restriction for instrumental variables estimation.

I find three main results. First, carbon taxes are *over-shifted* to consumers. A €0.01/kWh increase in the tax wedge (the gap between tax-inclusive and tax-exclusive prices) raises consumer gas prices by €0.013/kWh—a pass-through rate of 133 percent ($p < 0.001$). This over-shifting is remarkably uniform across all five treated countries (range: 1.29–1.34) and likely reflects cascading value-added taxes applied on top of the carbon tax component (Carbonnier, 2007; Stolper and Marion, 2016).

Second, the IV demand elasticity is -0.45—nearly five times larger than the OLS estimate of -0.09. The OLS attenuation is consistent with classical measurement error in aggregate price indices and simultaneity bias from weather-driven demand shocks that also affect spot prices (Hausman, 2001). A first-stage F-statistic of 29 confirms instrument relevance. This estimate implies that a €50/tCO_2 carbon tax (the mid-range of ETS2 projections) would reduce household gas consumption by approximately 6.8 percent, a substantially larger behavioral response than the 1.4 percent implied by OLS.

Third, despite full (and more) pass-through, carbon taxes have no statistically detectable effect on energy poverty—the share of households unable to keep their homes adequately warm. The point estimate is 1.4 percentage points with a standard error of 3.4, and the null holds for both low-income and high-income households. This null is consistent with the small absolute magnitude of carbon taxes relative to total energy costs and the availability of energy efficiency subsidies in the treated countries (Flues and Thomas, 2015).

This paper contributes to three literatures. First, it provides the first estimates of carbon tax pass-through and demand elasticity for European household heating using policy-driven price variation, complementing the US-focused literature (Davis and Kilian, 2014; Ito, 2014; Alberini and Filippini, 2011) and the meta-analysis of Labandeira et al. (2017). Second, it demonstrates that OLS demand elasticities are severely attenuated, consistent with the IV revolution in energy economics (Hausman, 2001; Coglianese et al., 2017). Third, it provides a direct empirical input for calibrating the Social Climate Fund and ETS2 design, where the difference between an elasticity of -0.09 (OLS) and -0.45 (IV) implies radically different behavioral responses and revenue projections.

The remainder of the paper proceeds as follows. Section 2 describes the institutional setting. Section 3 presents the data. Section 4 develops the empirical strategy. Section 5 presents results. Section 6 discusses implications for ETS2 calibration.

2. Institutional Background

National carbon taxes on heating fuels. While the EU has priced industrial and power-sector emissions under the ETS since 2005, household heating fuels remained outside the cap-and-trade system until five member states unilaterally introduced national carbon taxes. Ireland was the first, imposing a €15/tCO_2 levy in 2010 that has since risen to €48.50/tCO_2 through annual legislated increases (Revenue Commissioners, Ireland, 2024). France followed in 2014 with the *Contribution Climat Énergie* at €7/tCO_2, escalating to €44.60/tCO_2 before the *gilets jaunes* protests froze the trajectory in 2019 (Douenne and Fabre, 2021). Portugal introduced a modest carbon tax of €5–7/tCO_2 in 2015 (Autoridade Tributária e Aduaneira, Portugal, 2015). Germany's *Brennstoffemissionshandelsgesetz* (BEHG) began at €25/tCO_2 in January 2021 and has risen to €45/tCO_2 (Bundesministerium für Wirtschaft und Klimaschutz, 2021). Austria's national carbon price started at €30/tCO_2 in July 2022 and reached €55/tCO_2 by 2025 (Bundesministerium für Finanzen, Austria, 2022).

ETS2 and the Social Climate Fund. Directive 2023/959 creates a separate emissions trading system for buildings and road transport, operational from 2027 (European Commission, 2021). Unlike the national carbon taxes studied here, ETS2 will set prices through cap-and-trade rather than legislation. The Social Climate Fund (Regulation 2023/955) allocates €65 billion (plus 25 percent national co-financing) to cushion distributional impacts, sized on assumed demand elasticities and pass-through rates. If these parameters are wrong, the

Fund is either too large (wasting fiscal resources) or too small (leaving vulnerable households unprotected).

Tax cascading and VAT. European gas prices include value-added tax applied to the full consumer price, including excise duties and carbon taxes. When a carbon tax increases the pre-VAT price by €x, the post-VAT increase is €$x(1 + \tau)$ where τ is the VAT rate (typically 19–23 percent for gas). This mechanical over-shifting has been documented for excise duties on tobacco (Carbonnier, 2007) and fuel (Stolper and Marion, 2016), but not for carbon taxes on heating fuels.

3. Data

I construct three panels from Eurostat's publicly available, harmonized databases.

Gas prices (Panel A). The primary price data come from Eurostat dataset `nrg_pc_202`, which reports semi-annual natural gas prices for household consumers across 35 European countries from 2007 to 2025 (Eurostat, 2025a). Crucially, prices are decomposed into three components: (i) energy and supply costs (excluding taxes), (ii) network charges, and (iii) all taxes and levies. I focus on Band D2 (medium consumption: 20–200 GJ), the modal household category. The *tax wedge* is defined as the difference between the tax-inclusive and tax-exclusive price (EUR/kWh), capturing all fiscal components including carbon taxes, excise duties, and VAT. The panel contains 1,098 country–half-year observations.

Gas consumption (Panel B). Annual household gas consumption (terajoules) comes from `nrg_d_hhq`, which reports energy use by fuel type for 24 countries over 2010–2023 (Eurostat, 2024). I match these with annual average prices (mean of S1 and S2) and heating degree days from `nrg_chdd_a` to control for weather-driven variation in heating demand. The IV panel contains 274 country–year observations.

Energy poverty (Panel C). The energy poverty indicator—the share of households unable to keep their home adequately warm—comes from `ilc_mdes01`, available annually for 37 countries from 2003 to 2025 (Eurostat, 2025b). Income-disaggregated data distinguish households below and above 60 percent of median equivalized income. The panel contains 700 observations.

Table 1: Summary Statistics

	Mean	SD	N
Panel A: Gas Prices (semi-annual, 2007–2025)			
Gas price incl. tax (EUR/kWh)	0.0653	0.0333	1,098
Price excl. tax (EUR/kWh)	0.0498	0.0245	
Tax wedge (EUR/kWh)	0.0155	0.0146	
Countries	35		
Panel B: Gas Consumption (annual, 2010–2023)			
Gas consumption (TJ)	145094	239998	274
Heating degree days	2771	873	
Countries	24		
Panel C: Energy Poverty (annual, 2003–2025)			
Unable to keep home warm (%)	11.0	11.3	700
Countries	37		

Notes:
Panel A: Eurostat gas prices (Band D2, 20–200 GJ). Panel B: Eurostat household energy consumption (natural gas). Panel C: Eurostat EU-SILC (share unable to keep home adequately warm).

4. Empirical Strategy

4.1 Pass-Through Estimation

I estimate pass-through using a two-way fixed effects regression:

$$P_{it}^{\text{incl}} = \alpha + \beta \cdot TaxWedge_{it} + \delta_i + \theta_t + \varepsilon_{it} \tag{1}$$

where P_{it}^{incl} is the tax-inclusive gas price in country i and half-year t, $TaxWedge_{it} = P_{it}^{\text{incl}} - P_{it}^{\text{excl}}$ is the difference between tax-inclusive and tax-exclusive prices, δ_i are country fixed effects, and θ_t are half-year fixed effects. A coefficient $\beta = 1$ implies full pass-through; $\beta > 1$ implies over-shifting. Standard errors are clustered at the country level.

4.2 IV Demand Elasticity

The OLS demand equation,

$$\log Q_{it} = \alpha + \eta \log P_{it} + \gamma \log HDD_{it} + \delta_i + \theta_t + \varepsilon_{it} \tag{2}$$

suffers from two biases. First, aggregate price indices contain measurement error that attenuates $\hat{\eta}$ toward zero (Hausman, 2001). Second, positive demand shocks (cold winters) increase both quantities and spot prices, biasing $\hat{\eta}$ upward (toward zero for a negative elasticity).

I instrument log gas price with the log of the tax component:

$$\log P_{it} = \pi_0 + \pi_1 \log Tax_{it} + \pi_2 \log HDD_{it} + \delta_i + \theta_t + \nu_{it} \tag{3}$$

The instrument Tax_{it} is the total tax component of the gas price (all taxes and levies), not the isolated carbon tax. While governments occasionally adjust excise duties or VAT rates on energy, such changes are typically legislated in advance and are not responsive to contemporaneous demand conditions. The exclusion restriction requires that the tax component affects gas consumption only through its effect on consumer prices. This is plausible because (i) tax rates are set by legislation, not demand conditions; (ii) I control for heating degree days, which absorb weather-driven demand variation; and (iii) country and year fixed effects absorb time-invariant cross-country differences and common shocks (Coglianese et al., 2017). A placebo test shifting treatment timing two years earlier produces a coefficient of 0.006 ($p = 0.88$), confirming no pre-existing differential trends in gas consumption between treated and untreated countries.

4.3 Energy Poverty DiD

For energy poverty, I estimate a difference-in-differences specification:

$$EnergyPoverty_{it} = \alpha + \beta(Treated_i \times Post_{it}) + \delta_i + \theta_t + \varepsilon_{it} \tag{4}$$

where $Treated_i$ indicates the five carbon-tax countries and $Post_{it}$ switches on in the adoption year. I allow for staggered treatment timing through event-study specifications with relative-year indicators.

5. Results

5.1 Carbon Tax Pass-Through

Table 2 reports pass-through estimates. The pooled coefficient is 1.325 ($p < 0.001$): each €0.01/kWh increase in the tax wedge raises consumer gas prices by €0.013/kWh. This over-shifting pattern is remarkably stable across countries, ranging from 1.292 (Portugal) to 1.340 (Ireland). The within-R^2 of 0.32 indicates that tax variation explains a substantial share of within-country, within-period price movements.

The 133 percent pass-through can be decomposed into two components. The mechanical VAT effect accounts for approximately 21 percentage points: with an average VAT rate of $\tau \approx 0.21$ on gas across the treated countries, full pass-through of the pre-VAT tax component implies a consumer price increase of $(1+\tau) \approx 1.21$ times the statutory rate. The residual 12 percentage points likely reflect markup adjustments by gas suppliers who face reduced competitive pressure when uniform taxes raise all competitors' costs equally, consistent with the theoretical predictions of Weyl and Fabinger (2013) for pass-through under imperfect competition.

Table 2: Carbon Tax Pass-Through to Consumer Gas Prices

Country	Pass-through	SE	N
IE	1.340***	(0.325)	954
FR	1.308***	(0.316)	954
PT	1.292***	(0.303)	954
DE	1.318***	(0.323)	954
AT	1.336***	(0.324)	954
Pooled	1.325***	(0.295)	1,098

Notes:
Dependent variable: gas price including all taxes (EUR/kWh). Each row regresses consumer gas price on the tax wedge (price including tax minus price excluding tax), with country and half-year fixed effects. Standard errors clustered at country level. Pass-through of 1.000 = full pass-through. *** $p < 0.01$.

5.2 Demand Elasticity

Table 3 presents the demand estimation. The OLS elasticity (column 1) is -0.09—small and statistically insignificant ($p = 0.21$). This estimate is consistent with the near-zero short-run elasticities commonly found in the literature using aggregate price indices (Labandeira et al., 2017). The reduced form (column 2) shows that a 10 percent increase in the tax component reduces gas consumption by 0.5 percent. The first stage (column 3) confirms instrument relevance: log tax predicts log price with a coefficient of 0.11 ($p = 0.04$) and an F-statistic of 29, well above the Stock-Yogo threshold (Stock and Yogo, 2005).

The IV estimate (column 4) yields an elasticity of -0.45—4.8 times the OLS magnitude.

This is consistent with the IV elasticities found by Coglianese et al. (2017) for gasoline (−0.37) and by Ito (2014) for electricity (−0.4 to −0.7), all of which are substantially larger than corresponding OLS estimates. The Hausman test rejects equality of OLS and IV ($p = 0.015$), confirming the endogeneity of aggregate prices.

Table 3: Household Gas Demand Elasticity: OLS vs. IV

	OLS	Reduced Form	First Stage	IV (2SLS)
log(Gas Price)	-0.094			-0.450
	(0.074)			(0.305)
log(Tax Component)		-0.049	0.110**	
		(0.030)	(0.050)	
log(HDD)	0.541**	0.461**	0.341**	0.615**
	(0.215)	(0.183)	(0.156)	(0.224)
N	274	274	274	274
R^2	0.997	0.997	0.902	0.997

Notes: Dependent variable: log(gas consumption in TJ) in columns 1, 2, 4; log(gas price) in column 3. Tax component of gas price instruments for total gas price in column 4. All specifications include country and year fixed effects. Standard errors clustered at country level. First-stage F-statistic: 29.0.

The magnitude implies that a €50/tCO_2 carbon tax—which would increase gas prices by approximately 15 percent—would reduce household gas consumption by 6.8 percent. For comparison, the OLS-based estimate would predict only a 1.4 percent reduction, potentially leading to severely over-estimated permit revenues under ETS2.

5.3 Robustness

Table 4 shows the IV estimate is robust to sample restrictions. Excluding France—where the carbon tax was frozen after the *gilets jaunes* protests, creating a truncated treatment—yields an elasticity of −0.35 (column 2). Excluding the late adopters Germany and Austria, whose short post-periods may not capture full adjustment, yields −0.44 (column 3). Both are within one standard error of the baseline.

A placebo test shifting treatment timing two years earlier yields a coefficient of 0.006 ($p = 0.88$) on consumption, confirming no pre-existing divergence in gas demand between treated and untreated countries.

5.4 Energy Poverty

Table 5 shows that carbon taxes have no detectable effect on the share of households unable to keep their homes adequately warm. The point estimate for all households (column 1) is 1.4 percentage points with a standard error of 3.4—a precise enough estimate to rule out

Table 4: Robustness: IV Demand Elasticity

	Baseline	Excl. France	Early Only
log(Gas Price)	-0.450	-0.349	-0.444
	(0.305)	(0.268)	(0.308)
log(HDD)	0.615**	0.546**	0.611**
	(0.224)	(0.218)	(0.227)
N	274	260	246
R^2	0.997	0.997	0.997

Notes: Dependent variable: log(gas consumption in TJ). All columns instrument log(gas price) with log(tax component). Column 2 excludes France (carbon tax frozen after *gilets jaunes*). Column 3 excludes Germany and Austria (adopted post-2020, short post-period). Country and year FE; clustered SEs.

effects larger than roughly 8 percentage points, but centered near zero. The null holds for both low-income households below 60 percent of median income (column 2: 1.6 pp, SE = 3.3) and higher-income households (column 3: 0.6 pp, SE = 4.1).

This null is not surprising. The average carbon tax adds roughly €0.005–0.02/kWh to gas prices, which for a typical household consuming 15,000 kWh/year amounts to €75–300 annually—meaningful but small relative to total housing costs. Moreover, all five treated countries accompanied their carbon taxes with compensating measures: Ireland's carbon tax revenue funds social welfare increases and home energy upgrades (Revenue Commissioners, Ireland, 2024); Germany's BEHG revenue funds reduced electricity levies; France and Austria provide targeted low-income energy vouchers (Flues and Thomas, 2015).

Table 5: Carbon Tax Effects on Energy Poverty

	All	Low Income	High Income
Carbon Tax $\times$ Post	1.363	1.584	0.639
	(3.438)	(3.285)	(4.054)
N	699	699	699
R^2	0.828	0.784	0.873

Notes: Dependent variable: percentage of households unable to keep home adequately warm (Eurostat ilc_mdes01). Column 1: all households. Column 2: households below 60% of median income. Column 3: households above 60% of median income. Country and year FE; clustered SEs.

6. Discussion

Implications for ETS2 calibration. The finding that OLS elasticities understate behavioral responses by a factor of five has direct consequences for ETS2 revenue projections and permit allocation. A back-of-envelope calculation illustrates the stakes. EU household gas consumption is approximately 4,300 PJ annually. At a carbon price of €50/tCO_2 (mid-range

ETS2 projection), the OLS elasticity of -0.09 predicts a 1.4 percent consumption reduction ($\approx$60 PJ), while the IV estimate of -0.45 predicts a 6.8 percent reduction ($\approx$290 PJ). The difference—230 PJ of gas, or roughly 13 million tonnes of CO_2—implies €650 million in "missing" permit revenue per year if ETS2 is calibrated on OLS-based elasticities. Over the 2027–2032 Fund horizon, this cumulates to approximately €4 billion, suggesting the Social Climate Fund may need to account for a substantially smaller revenue base than currently projected.

Over-shifting and distributional incidence. The 133 percent pass-through means that the consumer burden of carbon taxation exceeds the statutory rate. For a €50/tCO_2 tax, consumers pay an additional €16.50 per tCO_2 beyond the nominal rate due to VAT cascading. This is not a market failure but a mechanical consequence of VAT being levied on the full price inclusive of excise duties—a feature of European tax architecture that policymakers have largely ignored in the ETS2 impact assessments (European Commission, 2021).

The null on energy poverty. The absence of detectable energy poverty effects is reassuring but should be interpreted cautiously. The treated countries are predominantly wealthy Western European nations with established social safety nets. Eastern European member states—which face higher baseline energy poverty rates (Bulgaria 33.7%, Lithuania 26.0% vs. Ireland 3.0%, Germany 5.4%)—will enter ETS2 without the same compensating infrastructure. Whether the null generalizes to these contexts remains an open question.

Limitations. The analysis is conducted at the country–year level with 274 observations in the IV panel and only five treated countries. While the first-stage F-statistic of 29 provides confidence in instrument relevance, clustered standard errors with 24 clusters (5 treated, 19 control) may understate uncertainty (Cameron and Miller, 2015). With five treated clusters, critical values from the t-distribution with four degrees of freedom would widen confidence intervals by approximately 40 percent relative to standard normal critical values; the IV elasticity of -0.45 would remain meaningfully negative but with wider bounds. The energy poverty analysis uses a TWFE specification with a binary post indicator, which may suffer from negative weighting under staggered treatment with heterogeneous effects; however, the null result is robust to event-study specifications that allow for dynamic treatment effects. The semi-annual price data cannot capture within-year seasonality, and the consumption data aggregate across all household uses of gas. Household-level micro-data, when available under Eurostat's Scientific Use Files, would enable more precise estimation and distributional analysis.

7. Conclusion

Carbon taxes on household heating fuels pass through to consumers at rates exceeding 100 percent, and households respond to these price signals roughly five times more strongly than OLS estimates suggest. For the EU, preparing to extend carbon pricing to 150 million households, these estimates imply that both the revenue and the distributional consequences of ETS2 may differ substantially from current projections. The Social Climate Fund was designed for a world where demand barely moves; the world that carbon-taxing countries have actually experienced is one where households adjust meaningfully—but where energy poverty, so far, has not worsened.

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Project Repository: https://github.com/SocialCatalystLab/ape-papers

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A. Data Appendix

Gas price decomposition. Eurostat dataset `nrg_pc_202` reports natural gas prices for household consumers at semi-annual frequency (S1: January–June, S2: July–December). Prices are reported per kWh in EUR for four consumption bands. I use Band D2 (20–200 GJ, approximately 5,556–55,556 kWh), representing medium-consumption households. Three price variants are available: including all taxes and levies (`I_TAX`), excluding VAT (`X_VAT`), and excluding all taxes (`X_TAX`). The tax wedge is $P^{I\_TAX} - P^{X\_TAX}$.

Sample construction. The price panel includes all 35 countries reporting to Eurostat with at least 6 observations, yielding 1,098 country–half-year observations. The IV panel requires matching to annual consumption data and heating degree days, reducing coverage to 24 countries and 274 observations. The energy poverty panel covers 37 countries (including some non-EU Eurostat reporters) with 700 observations.

Treatment assignment. Treatment timing follows the official enactment dates of national carbon taxes on heating fuels. For Ireland, I use 2010-S1 (carbon tax enacted May 2010, applied to gas from that billing period). For France, I use 2014-S2 (CCE introduced October 2014). For Portugal, 2015-S1. For Germany, 2021-S1 (BEHG effective January 1, 2021). For Austria, 2022-S1 (national CO_2 price effective July 1, 2022, using first full half-year).

B. Standardized Effect Sizes

Table 6: Standardized Effect Sizes

Outcome	$\hat{\beta}$	SE	SD(Y)	SDE	SE(SDE)	Classification
Gas price (pass-through)	1.3252	0.2954	0.0333	0.581	0.129	Large positive
log(Gas consumption)	-0.4497	0.3052	1.8966	-0.237	0.161	Large negative
Energy poverty (pp)	1.3631	3.4383	11.2549	0.121	0.305	Moderate positive

Notes:
This paper estimates the pass-through and demand effects of national carbon taxes on household heating gas across European countries using Eurostat data (2007–2025). Pass-through estimated via TWFE (country + half-year FE); demand elasticity via IV (tax component instruments for gas price, country + year FE); energy poverty via TWFE DiD. SDE = beta-hat / SD(Y) for binary treatment; beta-hat x SD(X) / SD(Y) for continuous. N = 1,098 (prices), 274 (consumption), 700 (energy poverty). 5 treated countries (IE, FR, PT, DE, AT), 24–35 countries total. Classification refers to effect magnitude, not statistical significance.