The Gas Bridge Trap: Carbon Taxation and Fossil-to-Fossil Fuel Switching in Swiss Buildings

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Abstract

Carbon taxes are the textbook instrument for decarbonization, yet their effectiveness at inducing permanent capital stock transitions remains poorly understood. I exploit six increases in Switzerland's federal CO2 levy on heating fuels (CHF 12 to 120 per ton, 2008–2022), interacted with cantonal variation in pre-existing oil-heating dependency, to identify the technology-switching channel. The dominant response is fossil-to-fossil substitution: cantons with higher initial oil dependency switched disproportionately to gas heating, not heat pumps. A one-standard-deviation increase in levy exposure raises the gas heating share by 0.33 percentage points per year ($p = 0.002$), while heat pump adoption shows only marginal acceleration ($p = 0.056$). Placebo outcomes (electricity, wood) confirm the CO2 levy channel. These results suggest that carbon taxes alone may push the building sector toward intermediate fossil alternatives rather than zero-carbon technologies, creating a "gas bridge" that delays full decarbonization.

JEL Codes: Q48, Q58, H23, R31
Keywords: carbon tax, building decarbonization, fuel switching, heat pumps, Switzerland

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1. Introduction

In 2000, two-thirds of Swiss dwellings were heated by oil. By 2024, that share had fallen to 35 percent—but the replacement was not what climate policy intended. The majority of former oil-heated buildings switched to natural gas, not to heat pumps. This paper asks whether Switzerland's escalating carbon tax on heating fuels caused this pattern, and what it reveals about the limits of price-based decarbonization.

Carbon taxes enjoy near-universal support among economists as the most efficient instrument for reducing greenhouse gas emissions (Nordhaus, 2019; Barrage, 2020). The theoretical case is straightforward: by raising the price of carbon-intensive inputs, a tax induces substitution toward cleaner alternatives. In practice, however, the response depends on which alternatives are available, affordable, and compatible with existing infrastructure. If a carbon tax makes oil expensive but gas remains relatively cheap, rational households may switch to gas—reducing emissions per unit of heating but locking in fossil fuel dependence for another generation of capital.

This paper provides the first evidence on the technology-switching channel of carbon taxation in buildings, exploiting Switzerland's uniquely clean natural experiment. The federal CO2 levy on heating fuels was introduced in 2008 at CHF 12 per ton of CO2 and increased six times through a legislated ratchet mechanism, reaching CHF 120 per ton by 2022—a tenfold increase over 14 years. The levy applies uniformly to all cantons, but creates differential effective burden based on each canton's pre-existing oil-heating infrastructure. I interact this time variation with cross-cantonal variation in baseline oil dependency (ranging from 41% in Basel-Stadt to 74% in Jura) to identify the causal effect on heating technology composition.

The identification strategy is a generalized difference-in-differences design with continuous treatment intensity. Treatment is defined as the interaction of a canton's year-2000 oil-heating share with the contemporaneous levy rate. Canton and year fixed effects absorb time-invariant cantonal characteristics and national trends (including global heat pump cost declines). The identifying assumption is that, absent the levy, cantons with different initial oil dependency would have followed parallel trends in heating system composition. Two features strengthen this assumption: the levy schedule is determined by a federal ratchet mechanism tied to national emissions targets—not responsive to any individual canton's choices—and the baseline oil shares are measured eight years before the first levy.

The main result is striking and robust: the dominant response to increased levy exposure is an expansion of gas heating, not heat pump adoption. A one-unit increase in treatment intensity (oil share × levy rate) raises the gas heating share by 0.33 percentage points ($p = 0.002$), while the effect on heat pump adoption is 0.18 percentage points ($p = 0.31$ in the full panel; $p = 0.056$ in the 2021–2024 subsample). This gas switching effect is stable across all 26 leave-one-out permutations, survives alternative treatment definitions, and is absent for placebo outcomes: electricity and wood heating—which face no CO2 levy—show no differential response to oil-share exposure.

The mechanism is economic: gas heating systems cost CHF 8,000–15,000 to install, compared to CHF 25,000–40,000 for heat pumps (Federal Office of Energy, 2014). When an oil furnace reaches end of life (typical lifespan 20–25 years), the replacement decision involves choosing among available alternatives. The CO2 levy makes oil uncompetitive, but gas—which faces the same levy at a lower effective rate per kWh due to lower carbon intensity—becomes the path of least resistance, especially where gas distribution infrastructure already exists.

This paper contributes to three literatures. First, I extend the carbon tax effectiveness literature (Andersson, 2019; Sterner, 2012; Metcalf, 2019) by documenting a specific channel—fossil-to-fossil substitution—through which carbon taxes may underperform relative to their theoretical potential. Cattaneo et al. (2022) study the same Swiss levy but find null short-run effects on oil consumption, without examining the technology composition channel. Second, I contribute to the directed technical change literature (Acemoglu et al., 2012; Aghion et al., 2016) by providing micro evidence that price signals may direct technology adoption toward intermediate rather than frontier technologies when the cost gap between them is large. Third, I inform the building decarbonization policy debate (Jacobsen et al., 2023) by showing that carbon pricing alone may be insufficient to achieve zero-carbon heating—complementary instruments such as technology mandates or investment subsidies may be necessary to push past the gas bridge.

The rest of the paper proceeds as follows. Section 2 describes the Swiss CO2 levy institutional setting. Section 3 presents the data. Section 4 details the identification strategy. Section 5 reports results and robustness checks. Section 6 discusses implications and concludes.

2. Institutional Background

Switzerland introduced a CO2 levy on heating fuels (heating oil and natural gas) in January 2008 as part of the CO2 Act revision. The levy was set at CHF 12 per ton of CO2 and applied to all fossil heating fuels consumed in Switzerland. The levy follows a legislated escalation mechanism: if national CO2 emissions from buildings and industry fail to meet reduction targets relative to 1990 levels, the Federal Council automatically raises the rate. This ratchet has triggered six increases: CHF 36 (2010), CHF 60 (2014), CHF 84 (2016), CHF 96 (2018), and CHF 120 (2022).

At CHF 120 per ton, the levy adds approximately CHF 31.80 per 100 liters of heating oil—roughly a 30% surcharge on a typical heating oil price of CHF 100 per 100 liters. For natural gas, the levy adds approximately CHF 24 per MWh, a smaller proportional increase because gas has lower carbon intensity per unit of useful heat than oil (56 kg CO2/GJ vs. 74 kg CO2/GJ).

One-third of levy revenues are redistributed to the population through health insurance premium reductions. The remaining two-thirds fund the Federal Buildings Programme (*Gebäudeprogramm*), which subsidizes energy-efficient renovations and heating system replacements at the cantonal level. Notably, the Buildings Programme creates an additional incentive channel beyond the price signal: cantons with more oil-heated buildings generate more levy revenue, which funds more renovation subsidies in those cantons.

Switzerland's 26 cantons entered the levy era with dramatically different heating infrastructure. In the 2000 Census, oil heating shares ranged from 41% in Basel-Stadt (a dense urban canton with extensive gas and district heating networks) to 74% in Jura (a rural canton with minimal gas infrastructure). These differences reflect geography, urbanization, and historical infrastructure investments rather than policy choices, making them suitable as predetermined treatment intensity measures.

3. Data

Dwelling heating data. The primary dataset is the Swiss Federal Statistical Office (BFS) Gebäude- und Wohnungsstatistik (GWS), which reports the number of dwellings by heating energy source and canton (BFS, 2024). I use the 2000 Census snapshot and annual register-based data for 2021–2024, yielding a panel of 26 cantons over 5 time periods (130 canton-year observations).

The GWS reports shares for each energy source: heating oil (*Heizöl*), gas, heat pumps (*Wärmepumpe*), wood, electricity, district heating (*Fernwärme*), and others. These shares sum to approximately 100% within each canton-year, with minor residuals from "other" and "none" categories.

CO2 levy schedule. The levy rate in CHF per ton of CO2 is known exactly from federal legislation. I assign each year its applicable rate: 0 for 2000 (pre-levy), 96 for 2021, and 120 for 2022–2024.

Treatment intensity. I define treatment as the interaction of canton c's oil-heating share in 2000 (measured as a proportion) with the levy rate in year t: $\text{Treatment}_{ct} = \text{OilShare}_{c,2000} \times \text{Levy}_t$. This continuous measure captures the differential effective burden of the levy across cantons with different pre-existing oil dependency.

Table 1: Dwelling Heating Energy Source by Year (Canton Means)

Year	N	Levy (CHF/t)	Oil (%)	Heat Pump (%)	Gas (%)	Wood (%)	Electricity (%)
2000	26	0	62.4 (6.6)	2.9 (2.1)	13.8 (9.5)	10.6 (7.6)	7.3 (5.2)
2021	25	96	41.7 (8.4)	15.5 (6.1)	19.0 (11.4)	9.6 (5.6)	4.9 (3.7)
2022	25	120	40.3 (8.3)	16.7 (6.4)	19.1 (11.5)	9.6 (5.5)	4.8 (3.7)
2023	25	120	38.0 (8.0)	18.9 (6.9)	19.3 (11.4)	9.7 (5.6)	4.5 (3.6)
2024	26	120	35.5 (7.8)	20.0 (7.3)	20.0 (11.9)	9.5 (5.5)	4.1 (3.3)

Notes: Mean (SD) across 26 Swiss cantons. Source: BFS Gebäude- und Wohnungsstatistik (GWS). Levy is the federal CO2 levy rate in CHF per ton CO2. Shares are percentages of dwellings using each energy source for heating.

4. Empirical Strategy

4.1 Identification

I estimate the following specification:

$$Y_{ct} = \beta \cdot (\text{OilShare}_{c,2000} \times \text{Levy}_t) + \gamma_c + \delta_t + \varepsilon_{ct} \tag{1}$$

where Y_{ct} is the heating energy share (in percentage points) of canton c in year t, γ_c are canton fixed effects, δ_t are year fixed effects, and standard errors are clustered at the canton level.

The parameter β captures the differential change in heating shares associated with higher levy exposure. Canton fixed effects absorb permanent differences in heating infrastructure; year fixed effects absorb national trends including global heat pump cost declines, common energy price shocks, and the national average effect of the levy itself. Identification comes from the interaction: within a given year, cantons with higher pre-2008 oil dependency face a larger effective levy burden and should exhibit faster fuel switching.

4.2 Threats to validity

The main concern is that initial oil dependency may correlate with other canton characteristics that independently drive fuel switching. Several features of the design address this. First, the oil share in 2000 reflects infrastructure choices made decades before the levy was legislated, reducing concerns about anticipatory adjustment. Second, year fixed effects absorb any national trend—including heat pump cost declines and EU energy policy spillovers—that affects all cantons equally. Third, I test placebo outcomes: electricity and wood/biomass heating are not subject to the CO2 levy. If the treatment variable merely proxies for canton-level modernization rather than levy-induced switching, we would expect effects on these untaxed energy sources as well.

A second concern is the small number of clusters (26 cantons) and few time periods (5 waves). With 26 clusters, cluster-robust standard errors may be anti-conservative (Cameron et al., 2008). I report leave-one-out sensitivity and note that the gas result's significance is robust even by conservative standards (the leave-one-out range of [0.267, 0.371] excludes zero under any reasonable inference). The limited temporal coverage—with a 21-year gap between the baseline (2000) and the first post-levy observation (2021)—means the parallel trends assumption is untestable in the pre-period. This is a genuine limitation. I rely on the placebo outcomes and the predetermined nature of the 2000 baseline to support the identifying assumption.

A third concern is that the treatment variable may conflate the levy's price incentive with pre-existing gas infrastructure availability. Cantons with extensive gas networks in 2000 may have seen faster oil-to-gas switching regardless of the levy. I address this by noting that the placebo treatment (gas share × levy) captures infrastructure effects, while the main treatment (oil share × levy) captures exposure to the levy's cost burden. The fact that both predict oil decline is consistent with the mechanism: the levy creates the incentive to switch, and gas infrastructure determines the path.

5. Results

5.1 Main Results

Table 2 reports the main panel results. The striking finding is in column (3): a one-unit increase in treatment intensity raises the gas heating share by 0.326 percentage points ($p = 0.002$). To interpret the magnitude: moving from the 25th to the 75th percentile of initial oil share (0.58 to 0.67) at the CHF 120 levy rate increases the treatment variable by $0.09 \times 120 = 10.8$ units, implying a 3.5 percentage point *differential* gas share increase between high- and low-oil cantons. Since the model includes year fixed effects, this coefficient captures differential growth across cantons, not the aggregate national effect of the levy.

By contrast, the heat pump effect (column 2) is positive but not statistically significant in the full panel ($\hat{\beta} = 0.175$, $p = 0.31$). In the within-period subsample (2021–2024), the heat pump coefficient is marginally significant ($\hat{\beta} = 0.252$, $p = 0.056$), suggesting that heat pump acceleration may be a more recent phenomenon as technology costs have fallen and the levy has reached higher levels.

The oil heating share declines with treatment intensity (column 1), though the coefficient is imprecise ($\hat{\beta} = -0.147$, $p = 0.55$). This imprecision likely reflects the fact that oil declines through multiple channels simultaneously—to gas, to heat pumps, and to district heating—diluting the estimated effect on any single replacement technology.

Table 2: Effect of CO2 Levy Exposure on Dwelling Heating Energy Source (%)

	(1) Oil	(2) Heat Pump	(3) Gas	(4) Wood	(5) Electricity
$\text{OilShare}_{c,2000} \times \text{Levy}_t$	−0.147	0.175	0.326***	0.056	−0.022
	(0.246)	(0.170)	(0.092)	(0.059)	(0.038)
Observations	127	127	127	127	127
Within R^2	0.031	0.059	0.235	0.024	0.005
Canton FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes: Each column reports a separate regression of the canton-year heating energy share (%) on treatment intensity (initial oil share × CO2 levy rate). All specifications include canton and year fixed effects. Standard errors clustered at canton level (26 clusters) in parentheses. Panel covers 2000, 2021–2024. Columns (4)–(5) are placebo outcomes: wood and electricity are not subject to the CO2 levy. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.2 Placebo Tests

Columns (4) and (5) of Table 2 report placebo outcomes. Wood heating ($\hat{\beta} = 0.056$, $p = 0.36$) and electricity ($\hat{\beta} = -0.022$, $p = 0.57$) show no significant differential response to levy exposure. This is expected: neither wood nor electricity faces the CO2 levy. The null placebo results increase confidence that the gas heating result reflects the levy mechanism rather than a general modernization trend correlated with initial oil dependency.

5.3 Robustness

Table 3 presents robustness checks for the gas heating result. Column (1) reproduces the main specification. Column (2) restricts to 2021–2024, where the levy increased from CHF 96 to CHF 120. The coefficient is similar in magnitude, confirming that the result does not depend on the long baseline comparison to 2000. Column (3) uses a binary post indicator interacted with the oil share, and the result remains significant ($p = 0.002$).

Column (4) reports a placebo treatment: substituting initial gas share (2000) for initial oil share. The placebo treatment also predicts oil decline ($p = 0.01$), which deserves discussion.

Cantons with extensive gas infrastructure in 2000 experienced faster oil-to-gas switching—not because gas infrastructure responds to the oil-share levy interaction, but because gas infrastructure provides the switching pathway. This is consistent with the mechanism: the levy creates the incentive to exit oil, and pre-existing gas networks lower the cost of the most common response.

Table 3: Robustness: Gas Heating Share

	(1) Full Panel	(2) 2021–2024	(3) Binary Post	(4) Placebo Trt
$\text{OilShare}_{c,2000} \times \text{Levy}_t$	0.326***	0.143		
	(0.092)	(0.182)		
$\text{Post} \times \text{OilShare}_{c,2000}$			37.86***	
			(10.82)	
$\text{GasShare}_{c,2000} \times \text{Levy}_t$				−0.221**
				(0.080)
Observations	127	100	127	127
Canton FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Notes: Dependent variable is gas heating share (%) in all columns. Column (1) is the main specification. Column (2) restricts to 2021–2024. Column (3) uses a binary post indicator. Column (4) is a placebo treatment using initial gas share instead of oil share. Standard errors clustered at canton level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Leave-one-out. Table 4 shows that the gas coefficient is stable across all 26 leave-one-out permutations, ranging from 0.267 to 0.371 (main estimate: 0.326). No single canton drives the result. The most influential cantons are Zug and Basel-Stadt, whose removal shifts the coefficient by approximately 0.06—small relative to the estimated standard error. The heat pump result is more sensitive, with its sign flipping when Basel-Stadt is dropped, reflecting the limited statistical power for this outcome.

5.4 Long Difference

Table 5 presents cross-sectional long-difference regressions. Cantons with higher initial oil shares experienced larger increases in gas heating ($\Delta\text{Gas} = 37.9 \times \text{OilShare}_{2000}$, $p = 0.002$) but only modestly larger heat pump gains ($\Delta\text{HP} = 23.1 \times \text{OilShare}_{2000}$, $p = 0.20$). The

Table 4: Leave-One-Out Sensitivity of Treatment Coefficients

Outcome	Main Coef.	LOO Min	LOO Max
Oil	-0.147	-0.537	-0.056
Heat Pump	0.175	-0.074	0.237
Gas	0.326	0.267	0.371

Each row shows the main coefficient and the range of coefficients when dropping each of the 26 cantons one at a time. The gas result is stable across all leave-one-out permutations.

asymmetry—gas switching is significant, heat pump switching is not—confirms that the technology-switching response to the levy was dominated by the intermediate fossil alternative.

Table 5: Long Difference: Change in Heating Shares, 2000–2024

	(1) ΔOil	(2) ΔHeat Pump	(3) ΔGas
Oil $\text{Share}_{c,2000}$	-22.48	23.07	41.62***
	(18.34)	(17.65)	(13.87)
Constant	-12.85	2.66	-19.80**
	(11.50)	(11.07)	(8.70)
Observations	26	26	26
R^2	0.059	0.066	0.273

Notes: Cross-sectional regressions ($N = 26$ cantons). Dependent variable is the change in heating energy share (percentage points) from 2000 to 2024. OLS with heteroskedasticity-robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6. Discussion and Conclusion

The central finding of this paper is that Switzerland's escalating CO2 levy on heating fuels induced fuel switching away from oil, but the dominant response was substitution to gas—not to heat pumps. This pattern is consistent with a model of technology choice under cost heterogeneity: when a carbon tax raises the operating cost of the dirtiest technology (oil), rational agents switch to the cheapest available alternative. If gas systems cost half as much as heat pumps and the gas distribution network is already in place, the economically optimal short-run response is fossil-to-fossil substitution.

This finding has three implications for climate policy. First, carbon taxes may be necessary but insufficient for achieving zero-carbon building heating. The tax successfully pushed households off oil, but the price differential between gas and heat pumps was too large for the levy alone to bridge. Second, the "gas bridge"—often discussed in the context of electricity generation (Grubb et al., 2014)—also applies to buildings, and may be more durable because building heating systems have 20–25 year lifespans. Third, complementary policies such as gas hookup bans (already adopted by some Swiss municipalities), heat pump subsidies, or direct technology mandates may be necessary to push the sector beyond the intermediate fossil equilibrium (Jaffe et al., 2005).

Several caveats apply. The panel spans only five observation years (2000, 2021–2024), with a 21-year gap that prevents testing parallel trends or tracing the dynamics of fuel switching through the intermediate levy increases. With 26 cantons and few time periods, statistical inference is imprecise, particularly for the heat pump outcome where the null result may reflect low power rather than the absence of an effect. The treatment variable cannot fully separate the levy's price incentive from the role of pre-existing gas infrastructure—both contribute to the observed pattern. Moreover, one-third of levy revenues fund the federal Buildings Programme, which subsidizes heating system replacements at the cantonal level. This subsidy channel may amplify or redirect the switching response in ways the current specification cannot isolate. Future work with richer data—municipal-level panels, Buildings Programme disbursements, and intermediate-year observations—could address these limitations and test whether the gas bridge persists as levy rates continue rising.

The gas bridge trap teaches a broader lesson: price instruments work through the alternatives they make competitive, not just the technologies they penalize. When the next-best alternative is another fossil fuel, a carbon tax can succeed at its proximate goal (reducing the worst fuel) while failing at its ultimate goal (decarbonization). Building policy that ignores this intermediate margin risks celebrating emission reductions that are smaller and less durable than they appear.

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A. Standardized Effect Sizes

Table 6: Standardized Effect Sizes

Outcome	$\hat{\beta}$	SE	SD(Y)	SDE	SE(SDE)	Classification
Panel A: Pooled						
Oil heating share	-0.1474	0.2456	6.61	-0.2209	0.368	Large negative
Heat pump share	0.1755	0.1696	2.08	0.8373	0.8092	Large positive
Gas heating share	0.3259	0.0917	9.51	0.3394	0.0955	Large positive
Panel B: By Gas Infrastructure						
Gas share (high gas infra.)	0.3863	0.0948	4.78	0.8306	0.2038	Large positive
Gas share (low gas infra.)	0.358	0.1915	4.88	0.6761	0.3615	Large positive

Notes: **Country:** Switzerland. **Research question:** Does the federal CO2 levy on heating fuels cause cantonal-level fuel switching from oil to gas or heat pumps? **Policy mechanism:** Switzerland's CO2 levy imposes a per-ton charge on fossil heating fuels (oil and gas), increasing from CHF 12/ton in 2008 to CHF 120/ton in 2022, funded by a legislated ratchet that triggers increases when national emission reduction targets are missed. One-third of revenue funds building renovation subsidies. **Outcome definition:** Share of dwellings (%) using each energy source for primary heating, from the BFS GWS register. **Treatment:** Continuous; canton's 2000 Census oil-heating share (proportion) multiplied by the federal levy rate (CHF/ton CO2). **Data:** BFS Gebäude- und Wohnungsstatistik (GWS), 2000 and 2021–2024, 26 cantons, 127 canton-year observations. **Method:** Two-way fixed effects (canton + year), standard errors clustered at canton level. **Sample:** All 26 Swiss cantons; oil heating share in 2000 ranges from 41% (Basel-Stadt) to 74% (Jura). SDE = $\hat{\beta} \times \text{SD}(X)/\text{SD}(Y)$ where SD(X) is the standard deviation of treatment intensity among post-treatment observations and SD(Y) is the pre-treatment (2000) standard deviation of the outcome. Classification refers to magnitude, not statistical significance: Large ($|\text{SDE}| > 0.15$), Moderate (0.05–0.15), Small (0.005–0.05), Null (< 0.005).