TECHNISCHE UNIVERSITÄT CHEMNITZ

Faculty of Economics and Business Administration

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Teresa Schäfer

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Chemnitz University of Technology
Faculty of Economics and Business Administration
Thüringer Weg 7
09107 Chemnitz, Germany

Phone +49 (0)371 531 26000
https://www.tu-chemnitz.de/wirtschaft/index.php.en
wirtschaft@tu-chemnitz.de

From Taxes to Transition: The Impact of the Swiss CO_2 Levy on Residential Heating Energy Demand

Teresa Schäfer*

*Chemnitz University of Technology. teresa.schaefer@wiwi.tu-chemnitz.de.

Abstract. This paper assesses the impact of the Swiss CO_2 levy on residential heating energy demand and the associated CO_2 emissions. Using the synthetic control method, the results show that the levy led to an average annual reduction in CO_2 emissions of 6.5% during the post-treatment period (2008–2021), corresponding to a decrease of 0.1 metric tons of CO_2 per capita per year. Furthermore, the empirically estimated price elasticities for heating oil indicate that the short-run elasticity for the retail price is -0.055, while the elasticity for the CO_2 levy is -1.264, demonstrating that consumers respond more strongly to policy-induced price changes than to market-driven price changes. In the long run, these elasticities increase to -0.064 (retail price) and -1.471 (levy), highlighting that over time, households adjust their demand more significantly in response to sustained price changes. A similar pattern is observed for natural gas, with short-run elasticities of -0.261 (retail) and -0.623 (levy), increasing to -0.521 and -1.241, respectively, in the long run. These findings provide robust evidence that the Swiss CO_2 levy is an effective instrument for reducing emissions in the residential heating sector. The results underline the importance of policy-induced price instruments and highlight the necessity of high levy rates to ensure a measurable impact on consumption behavior.

Keywords: Carbon tax, Tax elasticity, Synthetic control method
JEL classification: H23, Q,41, Q58

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1. Introduction

Climate change is one of the most pressing challenges of our time, with far-reaching consequences for the environment, human health, and the economy. A key political instrument for reducing greenhouse gas emissions is CO_2 pricing, which incentivizes companies and individuals to reduce their carbon footprint. This, in turn, contributes to global efforts aimed at achieving emission reduction targets and mitigating climate change. Many countries have already adopted such policies or are planning to introduce them. However, the design of pricing instruments and the energy sources they affect vary across countries (World Bank 2025).

To evaluate the effectiveness of carbon pricing, policymakers and researchers commonly use estimated price elasticities. A large number of studies have estimated the price elasticity of demand for various energy sources. For instance, Labandeira et al. (2017) report average natural gas demand elasticities of -0.184 in the short run and -0.568 in the long run. Similar values are found for heating oil, with -0.188 and -0.535, respectively. Gechert et al. (2025b) focus on heating and cooling energy and find unweighted average elasticities of -0.3 (short run) and -0.45 (long run). However, this study is among the few that account for publication bias, which often leads to an overestimation of elasticities. After correcting for this bias, the estimated price elasticities are significantly lower, ranging from -0.05 to -0.2 in the short run and from -0.1 to -0.3 in the long run. In particular, these low reported elasticities raise the question of whether consumers respond differently depending on the source of the price change, namely whether it is market-driven or policy-induced, suggesting that carbon pricing instruments can still have a steering effect.

The aim of this paper is to assess the impact of carbon pricing on fossil fuel demand by analyzing the Swiss CO_2 levy. Since Switzerland's heating sector largely relies on fossil energy sources, the country introduced a CO_2 levy in 2008 under the Federal Act on the Reduction of CO_2 Emissions (The Federal Council 1999a). The levy applies to heating oil, natural gas, coal, petroleum coke, and other fossil fuels used for heating purposes (Federal Office for the Environment (FOEN) 2024b). As heating oil and natural gas account for the largest share of energy consumption in this sector, the analysis focuses on these two fuels. We estimate how Switzerland's CO_2 emissions would have evolved in the absence of the levy by constructing a counterfactual comparison, and we examine the steering effect of the CO_2 levy on residential demand for heating oil and natural gas by following the approach of Andersson (2019).

For the first part of the analysis, we use OECD panel data from 1990 to 2021 to construct a synthetic Switzerland using the synthetic control method (e.g. Abadie et al. 2010; Abadie et al. 2015). By comparing Switzerland with its synthetic counterpart, we examine the impact of the CO_2 levy on emissions from the Swiss heating sector. The results indicate that the Swiss CO_2 levy led to an average annual reduction in CO_2 emissions of 6.5% during the post-treatment period (2008–2021), corresponding to a decrease of 0.1 metric tons of CO_2 per capita per year. The reduction in CO_2 emissions in the building sector became particularly evident following a further increase in the CO_2 levy in 2014.

Furthermore, our empirical estimates of price elasticities highlight that consumers react more strongly to policy-induced price changes than to market-driven price fluctuations. For heating oil, the short-run elasticity for the retail price is -0.055, while the elasticity for the CO_2 levy is -1.264. In the long run, these elasticities increase to -0.064 (retail price) and -1.471 (levy), emphasizing that households adjust their demand more significantly over time in response to sustained price changes. A similar pattern is observed for natural gas, with short-run elasticities of -0.261 (retail) and -0.623 (levy), increasing to -0.521 and -1.241, respectively, in the long run. These findings provide robust evidence that the CO_2 levy in Switzerland has a stronger steering effect on demand than market-price changes, both in the short and long run. They underline the importance of policy-induced price instruments and highlight the necessity of sufficiently high levy rates to ensure a measurable impact on consumption behavior.

Related literature. We contribute to a growing literature on carbon taxes and their impact on consumption and emissions by estimating and comparing both the price elasticity of demand and the tax elasticity. Many existing studies mainly focus on the transport sector.

Li et al. (2014), for example, show that consumers respond more to the gasoline carbon tax than to increases in (tax-inclusive) retail prices in the United States. Similar results are also reported by Rivers and Schaufele (2015) for British Columbia. Their findings suggest that demand in this region is more elastic with respect to gasoline prices than in the rest of the country, with the carbon tax having a greater impact than market-driven increases. Yu (2024) estimates a tax semi-elasticity of -0.289 for Norway, while the semi-elasticity for market price increase is -0.019. The tax effect is therefore 15 times greater than a market-driven price increase of the same amount. Andersson (2019) estimates a price elasticity of -0.51 and a carbon tax elasticity of -1.57 for the Swedish transport sector, indicating a threefold stronger effect of taxes compared to market price fluctuations.

While a large part of the literature has concentrated on transportation, studies focusing on the heating sector remain relatively scarce. An exception is Xiang and Lawley (2019), who examine natural gas consumption in British Columbia. They report a tax semi-elasticity ranging from -0.030 to -0.042 and a market price elasticity between -0.004 and 0.002, again highlighting stronger consumer responses to taxes. Likewise, Ghalwash (2007) provides one of the few contributions that directly compares tax and price elasticities across several energy types in Sweden, including electricity, district heating, and heating oil. For the heating sector, he finds a price elasticity of -0.07 and a tax elasticity of -0.36, which is broadly consistent with previous findings.

To estimate the direct effect of carbon pricing on CO_2 emissions, various econometric methods have been applied, such as the differences-in-differences approach (DiD) by Pretis (2022) and Lin and Li (2011), or the synthetic difference-in-differences method (SDID) as used in Basaglia et al. (2023). Another widely used approach is the synthetic control method (SCM), which has been applied in several policy evaluations, including studies by Bayer and Aklin (2020), Mideksa (2024), Elbaum (2021), and Andersson (2019). We follow this approach and apply the SCM to estimate the effect of the Swiss CO_2 levy on emissions in the building sector.

Existing studies using SCM to evaluate carbon pricing policies report heterogeneous effects across countries and policy designs. Our estimated effect of 6.5% for Switzerland is broadly consistent with these findings. For instance, Yu (2024) estimates an average reduction of 2.4% for Norway, whereas Basaglia et al. (2023) report an annual reduction of about 10% for Germany. Our results are more closely aligned with those of Pretis (2022) and Andersson (2019), who estimate average annual reductions of 5% for British Columbia and 6.3% for Sweden, respectively. Additionally, the recent meta-analysis by Döbbeling-Hildebrandt et al. (2024) estimates an average reduction of –10.4% across 21 carbon pricing schemes, indicating that overall, our results are consistent with global evidence.

The remainder of the paper is structured as follows: Section 2 presents the Swiss CO_2 levy and provides an empirical analysis of its tax pass-through. Section 3 describes the methodology and data collection and presents the results of the SCM analysis, including several robustness checks. Section 4 estimates the different elasticities, and finally, Section 5 discusses our results and concludes.

2. Swiss CO_2 levy and tax incidence

The energy mix in the Swiss heating sector mainly consists of fossil resources. Heating oil was the most important energy source in 1990 with a share of 58%, followed by wood at 17%, electricity at 12% and natural gas at 9%. The dominance of heating oil hardly changed in the following years, so that in 2000 it still had the largest share at 56%. The total share of heating oil and natural gas are accounted for 67% in 1990, 70% in 2000 and 54% in 2023, while the share of heating oil has fallen to 37% and the share of natural gas has risen to 17% in 2023. The building sector's share of total CO_2 emissions increased slightly from around 30% in 1990 to approximately 31% in 1999 (Federal Office for the Environment (FOEN) 2024b).

As a result, the Federal Act on the Reduction of CO_2 Emissions, commonly known as the CO_2 Act, was introduced in 1999 as an important legislative measure to mitigate climate change. This law was part of Switzerland's growing commitment to reducing greenhouse gas emissions, which was strongly influenced by the country's ratification of the Kyoto Protocol in 1997 (The Federal Council 1999b).

As part of this Act, Switzerland introduced a CO_2 levy on heating oil, natural gas, coal, petroleum coke, and other fossil fuels when used for heating.[1] The CO_2 levy is paid at the time of production, extraction or import (The Federal Council 2023b). As can be seen in Table A.1, the Swiss CO_2 levy stands out as a special adaptive system, linking levy rates directly to the achievement of predefined emission reduction targets in the heating sector. Fixed reduction targets were established to continuously reduce CO_2 emissions in the heating sector. If the reduction in the reference year did not reach the set target, the previously defined tax rates came into force. For example, since CO_2 emissions in 2006 had not fallen below the target of 94% compared to the 1990 level, a CO_2 levy of CHF 12 per ton of CO_2 was introduced on heating oil and natural gas in 2008. In 2022, the tax increased to the current rate of CHF 120 per ton of CO_2.[2]

In addition to the CO_2 levy, heating oil and natural gas are subject to value added tax (VAT), introduced in 1995 and adjusted over time, as well as to an energy tax (mineral oil tax), implemented in 1997 (see Table A.2). Thus, the retail price of heating oil and natural gas for private households (p_{it}^{retail}) consists of four components: value-added tax (VAT_t), the energy tax on mineral oil (X_{it}^{energy}), the CO_2 levy (X_{it}^{levy}), and the oil or gas price excluding taxes (p_{it}):

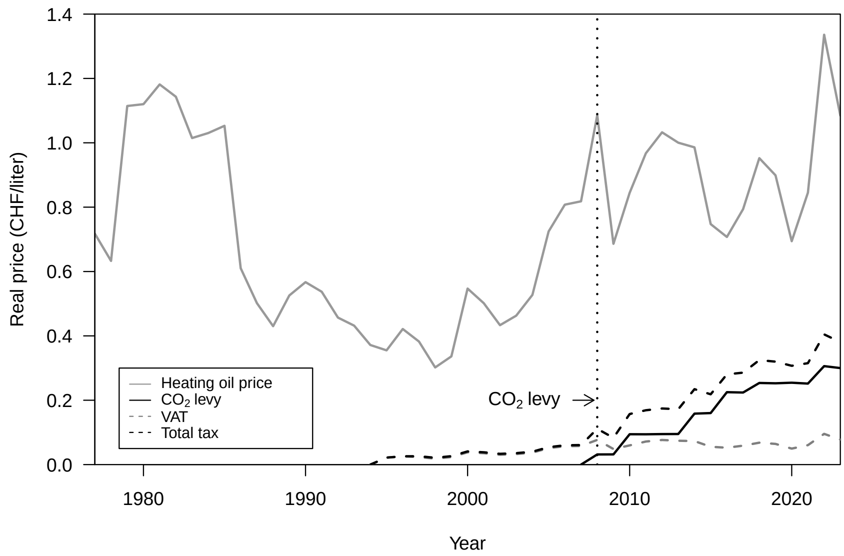
$$p_{it}^{retail} = (p_{it} + X_{it}^{levy} + X_{it}^{energy})(1 + VAT_t), \tag{1}$$

where i stands for oil or gas. Figure 1a illustrates the development of these components in real oil prices from 1977 to 2023. Following a sharp increase in the retail price in 1979, primarily driven by high crude oil prices due to the second global oil crisis, a downward trend in oil prices can be observed from 1985 until 1998.

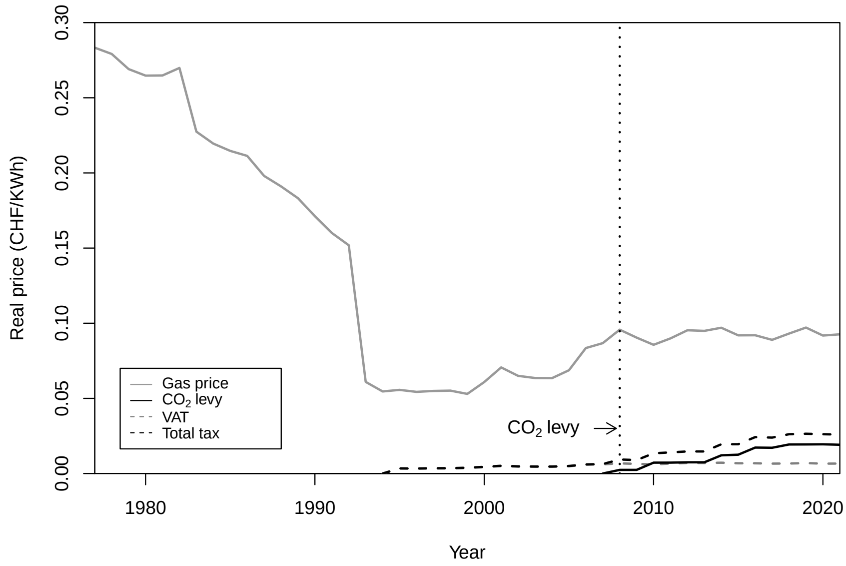
[1] Only heating oil and natural gas are analyzed in this paper, as these energy sources account for the largest share in the heating sector.

[2] Table A.1 provides an overview of the emission targets set and the respective levy rates.

Figure 1: Heating oil and natural gas price components in Switzerland



(a) Heating oil: Tax components

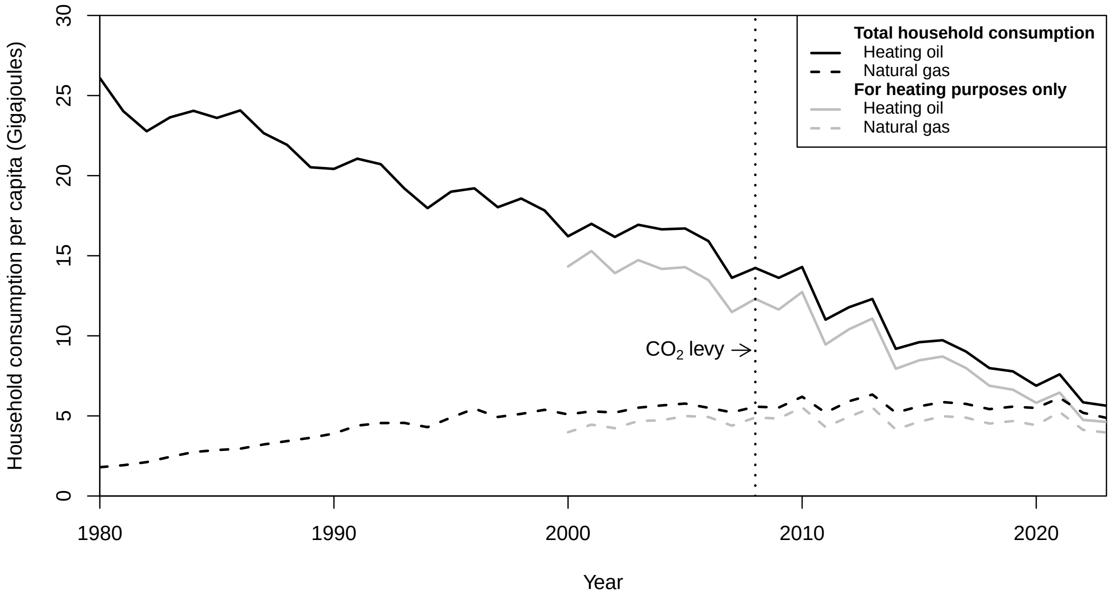


(b) Natural gas: Tax components

Notes: As its share of the total price is marginal, the mineral oil tax as a price component is not shown separately in Figure (a) and (b). However, it is included in the total tax. *Source:* Federal Statistical Office (2024), Federal Office for the Environment (FOEN) (2024a), Federal Tax Administration FTA (2024), The Federal Council (1996), The Federal Council (2023a).

This was followed by a steady increase, which peaked in 2008; the same year the CO_2 levy was introduced. Figure 1b shows a sharp drop in real retail gas prices at the beginning of the period before stabilizing at a certain level between 1993 and 1999 and from 2000 onward a slight and steady increase is observable. Both figures indicate that while total taxes increased continuously over time, no clear pattern linking tax changes to real retail energy prices emerges, particularly after 2008.

Figure 2: Household fuel consumption per capita in Switzerland 1980–2023



Notes: The black lines represent fuel consumption in the household sector, while the gray lines show household consumption for heating purposes only. *Source:* Swiss Federal Office of Energy (2024), Prognos (2024).

Figure 2 presents the consumption of heating oil and natural gas. Data on heating oil and gas used for heating only (gray lines) are not available before 2000. Consequently, we decide to use total household-sector consumption for both energy sources (black lines) in our empirical analysis. While this means that small proportions of heating oil and natural gas may have been used for non-heating purposes, the overall trajectory of these data aligns well with the other data.

The consumption of heating oil exhibits a steady decline but a levy effect after 2008 is not clearly visible in this figure. In contrast, natural gas consumption rises continuously until 1999, before stabilizing at a nearly constant level. This pattern is largely explained by a substitution effect: heating oil was gradually replaced by alternative energy sources, while natural gas increasingly served as a substitute for other fossil heating fuels (Prognos 2024).

To evaluate the effectiveness of steering instruments such as the CO_2 levy, it is essential to estimate the tax pass-through and so we empirically analyze the tax incidence of the Swiss CO_2 levy. To address the upward trends in prices and taxes over time, we apply the first-differences method to detrend the data and regress the nominal retail prices of heating oil and natural gas at time t on the crude oil price or natural gas price and the CO_2 levy:

$$\Delta p_{it}^{retail} = \beta_{i0} + \beta_{i1}\Delta\varphi_{it} + \beta_{i2}\Delta\gamma_{it} + u_{it}, \tag{2}$$

where p_{it}^{retail} represents the retail price for oil or gas ($i = oil, gas$), $\varphi_i =$ is the crude oil or natural gas price, and $\gamma_i =$ is the respective CO_2 levy and energy tax[3].

Based on annual data from 1977 to 2021, we estimate a significant total tax coefficient of 0.93 (see Table A.3) for oil which indicates that the CO_2 levy and the energy tax were almost entirely passed through to the final consumers. If the CO_2 levy is estimated separately, the significant coefficient is 0.91, which also indicates that consumers bear most of the tax burden. The mineral oil tax (energy tax) introduced in 1997 is not analyzed separately for two reasons. First, its contribution to the total retail price is negligible, making it less relevant for the overall price dynamics. Second, the tax rate has remained constant since its introduction, resulting in no variation in the data. This lack of variation makes it impossible to estimate or interpret the effect using regression analysis.

We conducted the same analysis for natural gas, but the results differ from those for heating oil. The significant coefficient for the natural gas price is only 0.31, suggesting

[3]For this analysis, all relevant price components for heating oil are converted to Swiss franc per liter. The relevant price components for gas are converted to Swiss francs per kilowatt hour (kWh) using the average annual standard density and the calorific value (kWh/m^3). The retail prices of heating oil are determined based on purchase quantities and we employ the prices for the purchase quantity category of 3001–6000 liters per year. The retail prices of gas are set according to consumption types (I–V) and we use the prices for consumption type III (20,001 kWh to 50,000 kWh per year). These categories reflect typical household consumption levels and are commonly used in official energy statistics.

that the global market price has significantly less influence on the retail price. Examining the data reveals substantial differences in the retail price, particularly during the period from 1977 to 1992. Several factors may explain this: on the one hand, consumption-type definitions were changed in May 1993 and, on the other hand, the pass-through of the global market price may be restricted by fixed and long-term consumer contracts. However, the total tax coefficient of 0.90 still indicates an almost complete pass-through of the levy, even if it is not statistically significant (see Table A.4). The extent to which these noticeable price increases have led to changes in the consumption of heating oil and natural gas, and the resulting reductions in CO_2 emissions, is examined in the following chapters.

3. Synthetic control method

3.1. Methodology and preliminaries

To assess the impact of the Swiss CO_2 levy on emissions, it is crucial to employ a methodological approach that enables a reliable counterfactual comparison. The primary objective of this analysis is to estimate the causal effect of the tax introduction on CO_2 emissions in the building sector. Various empirical approaches can be applied for this purpose. One commonly used method is the difference-in-differences (DiD) estimation. This method compares the average CO_2 emissions of Switzerland with the aggregated and averaged emissions of the selected control countries. In the present context, however, several challenges limit its applicability. In particular, DiD assigns equal weight to all control countries. Given that Switzerland differs significantly from other countries, particularly in terms of GDP per capita, a more appropriate approach would be to assign differential weights to the control countries. This is precisely the advantage of the synthetic control method (SCM), which constructs a synthetic counterpart that better replicates the characteristics of Switzerland.

Furthermore, SCM offers several advantages over DiD. While DiD assumes that unobserved confounding factors remain constant over time, SCM allows for their variation. This is particularly important in our context, as unobserved influences, such as economic shocks, technological advancements, or changes in energy policies, fluctuate over time and can affect

CO_2 emissions. While DiD treats these factors as fixed, SCM accounts for them through optimized weighting of control countries (Abadie et al. 2010). Additionally, the number of available control units is an important consideration. Abadie et al. (2015) emphasize that SCM is particularly effective when the number of control units is limited, as is the case in this study.[4] Given these methodological considerations, SCM is the preferred approach for our paper.[5]

To formally define the synthetic control framework, consider a sample of $J+1$ OECD countries, indexed by j where $(j = 1, 2, ..., J+1)$. We define Switzerland as the treated unit $(j = 1)$, while all other selected OECD countries serve as potential control units, which is termed the donor pool. Switzerland and the control countries are observed over the same time periods $t = 1, 2, ..., T$. Furthermore, we define T_0 as the number of periods preceding the intervention (the introduction of the Swiss CO_2 levy), and T_1 as the number of post-intervention periods, so that $T = T_0 + T_1$. As described before, synthetic Switzerland is constructed from the different weights W of the control units $(j = 2, ..., J + 1)$. For this purpose, a weight vector $W = (w_2, ..., w_{J+1})'$ is defined, where W is a $(J \times 1)$ vector of non-negative weights $(w_j > 0)$. Each weight w_j represents the relative contribution of a given control country to the synthetic Switzerland, such that $w_2 + ... + w_{J+1} = 1$.[6]

3.2. Data and sample

Gechert et al. (2025a) empirically find that OECD countries respond differently to price changes in the heating and cooling sector compared to non-OECD countries. For this reason, we use annual panel data for 38 OECD countries in our analysis. Since Switzerland is itself an OECD member, this choice also increases the comparability between the treatment unit and the pool of control countries. As data on CO_2 emissions in the building sector are only

[4] Abadie (2021) shows further advantages of synthetic control estimators compared to other methods.

[5] Nevertheless, as a robustness check, we also performed a difference-in-differences (DiD) analysis, with the results reported in Table A.6. The estimated treatment effects are larger than those obtained from the synthetic control method, highlighting some variation in effect sizes across methods.

[6] A detailed description of SCM using R can be found in Abadie et al. (2010).

available for the years 1990–2021, we limit the analysis to this period, which covers 32 years, 18 years before and 14 years after the introduction of the CO_2 levy.

Given that our study focuses on the heating sector, we use heating degree days (HDD) as a key criterion for selecting comparable countries. HDD are calculated by summing the differences between the heating threshold temperature (65° Fahrenheit[7]) and the average outdoor temperature on all heating days. To construct an appropriate synthetic control group, we first calculate each country's mean HDD over the entire period. Based on this, we initially select all countries whose HDD is within 30% above or below the mean HDD of Switzerland, resulting in a preliminary pool of 17 countries. Using this approach, we identify countries with climatic conditions comparable to those of Switzerland.

Switzerland's high GDP per capita makes it particularly challenging to find comparable OECD countries. To address this, we calculate the average GDP per capita for each country over the entire period. Applying the same threshold as used for HDD (±30%) would reduce the control group to only two countries. To ensure a sufficiently large control group, we rank all countries by their average GDP per capita and select the top 17, matching the number of countries in the HDD-based selection. In this ranking, Switzerland has the second-highest GDP per capita, following Luxembourg. Finally, we restrict our sample to countries that appear in both pools to ensure that the final control group consists only of countries with similar characteristics. Following this procedure, we obtain our final donor pool, which comprises nine OECD countries: Austria, Denmark, Finland, Germany, Iceland, Luxembourg, Norway, Sweden and the United States.[8]

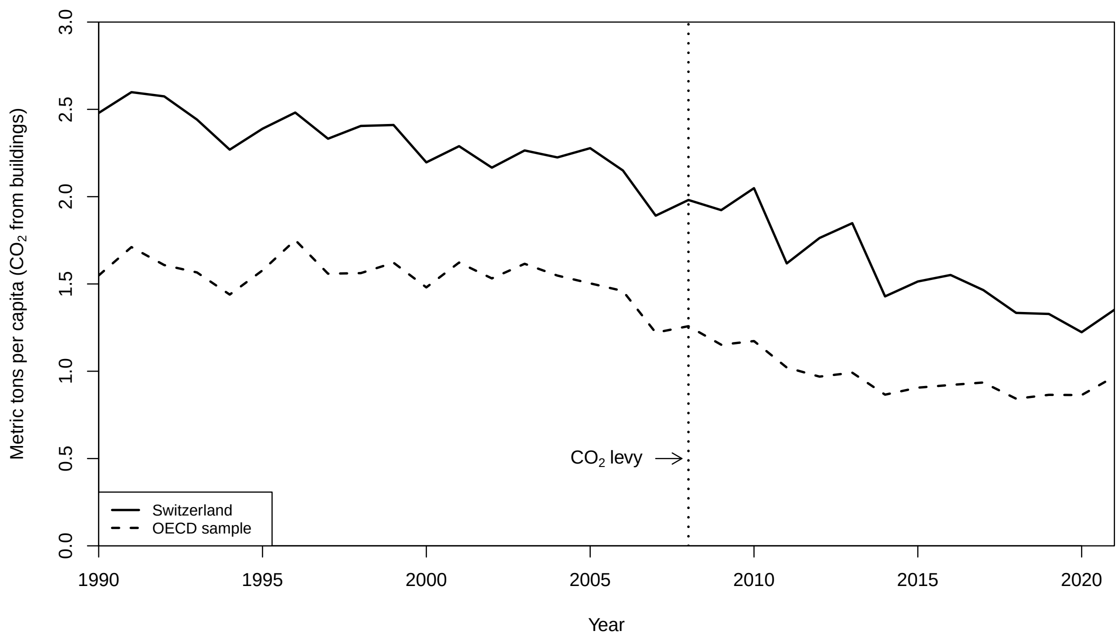
To construct an appropriate synthetic control group, it is necessary to identify variables that influence our dependent variable: CO_2 emissions in the building sector. This sub-sector includes CO_2 emissions from activities in the residential, commercial and public services sectors, whereby only emissions from fuel combustion are taken into account (Climate Watch

[7]Equivalent to approximately 18° Celsius.

[8]Table A.5 reports the control country pools based on climatic conditions (HDD) and GDP per capita. Countries excluded due to low GDP per capita include Chile, Poland, the Slovak Republic, Czechia, Lithuania, Latvia, and Estonia, while France, Belgium, Canada, Ireland, the United Kingdom, the Netherlands, and Australia are excluded due to climatic conditions.

2024). As these emissions are mainly caused by the consumption of fossil fuels such as heating oil and natural gas, we use both as key predictors. Additionally, GDP per capita is considered an important driver of CO_2 emissions, as shown by Zarco-Periñán et al. (2021). Moreover, studies such as Gierałtowska et al. (2022), Fan et al. (2017), and Sheng et al. (2017) show that the urbanization rate also affects CO_2 emissions. Finally, the concept of heating degree days further illustrates its impact, making it the fifth key predictor in our SCM analysis.[9]

Figure 3: Per capita CO_2 emissions from buildings (1990–2021): Switzerland vs. selected nine OECD donor countries



In Figure 3, we plot CO_2 emissions from the building sector for Switzerland and the average of our nine OECD countries. The trends until the introduction of the CO_2 levy are similar, but the absolute levels differ significantly. To address this discrepancy, we plotted the annual growth rates of CO_2 emissions in Figure A.1. The growth rates not only

[9]Various combinations of variables were tested by excluding individual predictors or adding unemployment (as a percentage). The final set of variables provided the best fit between Switzerland and the synthetic Switzerland.

exhibit similar trends but also align more closely in terms of levels. Notable deviations in growth rates can be observed at the beginning of the period (1990–1999) and shortly before the treatment (2004–2006). Based on these observations, we decided to average the key predictors over the period 1990–2000. In addition, we included lagged outcome variables in 1990, 1994, and 2007 as additional predictors, following Abadie et al. (2010) and Andersson (2019).

3.3. Estimation

The synthetic control method constructs a counterfactual Switzerland by combining the nine selected donor countries based on the previously identified predictor variables. To create a credible counterfactual, it is important that synthetic Switzerland closely resembles actual Switzerland prior to the levy's introduction. Table 1 shows the predictor mean for Switzerland, the mean of the donor pool, and the weighted average of synthetic Switzerland in the pre-treatment period (1990–2007). The table highlights that the average values between Switzerland and the nine OECD donor countries differ significantly in some cases, making the construction of a synthetic country challenging. However, there are strong matches for GDP per capita, urban population, and the three lagged years.

Table 1: CO_2 emissions predictor means before levy introduction

Variables	Switzerland	Synth. Switzerland	9 OECD countries
GDP per capita	63663.884	62282.732	53302.070
Oil consumption per capita	78.572	118.143	103.974
Gas consumption per capita	11.746	39.366	31.064
Urban population	73.654	76.013	78.919
Heating degree days	8760.436	7236.011	8415.794
CO_2 from buildings per capita 1990	2.479	2.437	1.556
CO_2 from buildings per capita 1994	2.269	2.289	1.453
CO_2 from buildings per capita 2007	1.891	1.871	1.077

Notes: GDP per capita, oil and gas consumption per capita, urban population and heating degree days are averaged for the period 1990–2000. GDP per capita is adjusted for purchasing power parity (PPP) and measured in 2021 US dollars. Oil and gas consumption are converted into gigajoules. Urban population is measured as a percentage of the total population, and CO_2 emissions are reported in metric tons.

Oil and gas consumption shows greater discrepancies, as donor countries rely on different shares of energy sources in their building sectors. In contrast, analyzing the transport sector is less complicated, as CO_2 emissions in this sector are almost entirely driven by gasoline and diesel consumption. Consequently, these discrepancies in the predictors for oil and gas consumption must be accepted. The predictors weights also reflect the challenge posed by Switzerland's high GDP per capita in constructing a synthetic Switzerland. This can be seen both in the average predictors, where the differences between Switzerland and the nine OECD donor countries differ considerably in some cases, and in the weights of the predictors (V Matrix). GDP per capita is assigned a weight of only 0.00001. Similarly, the large difference in gas consumption is also emphasized by the low weighting of 0.0002. All other predictors receive weights ranging between 0.002 (oil consumption and urban population) and 0.47 for the lagged year 1994.[10]

Table 2: Country weights in synthetic Switzerland

Country	Weight	Country	Weight	Country	Weight
Austria	0.162	Germany	0.329	Norway	0
Denmark	0	Iceland	0	Sweden	0
Finland	0.169	Luxembourg	0.340	United States	0

Notes: The weights determined by the synthetic control method and receive values between 0 and 1 ($\sum w_j = 1$). Countries with weights below 0.001 are represented as 0.

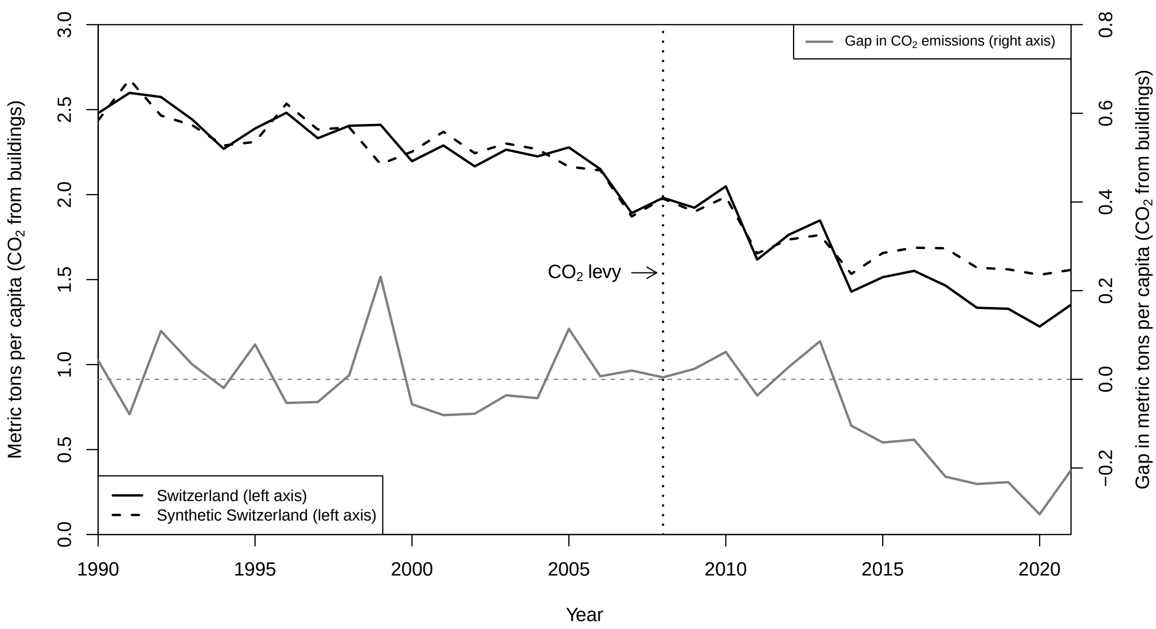
Table 2 displays the respective weights of the countries contributing to the construction of the synthetic Switzerland. It is evident that, out of the nine preselected control countries, four countries best replicate Switzerland. Consequently, the synthetic Switzerland is constructed based on two neighboring countries, Germany and Austria, which receive a weight of 0.329 and 0.162 respectively, as well as Luxembourg with a weight of 0.34 and Finland with a weight of 0.17.

[10] To find the V matrix and the weights we use the *Synth* package in **R** which is described in Abadie et al. (2011).

3.4. Results

Figure 4 presents a visual depiction of our analysis, showing the trends in per capita CO_2 emissions in the building sector for Switzerland and its synthetic counterpart (left axis), as well as the resulting emission gap (right axis). Focusing first on the trajectories displayed on the left axis, both curves follow a very similar path during the pre-treatment period. While a closer alignment of the two curves would have been preferable, the discrepancies can be explained by the substantial differences between Switzerland's predictors and those of its control countries.

Figure 4: Trends in per capita CO_2 emissions from buildings (1990–2021): Switzerland versus synthetic Switzerland



Notes: This figure displays the per capita CO_2 emissions in the building sector for Switzerland and its synthetic control (left axis), and the estimated emission gap between the two (right axis). The emission gap represents the difference between observed emissions in Switzerland and the counterfactual scenario in which no CO_2 levy was introduced. Positive values indicate higher emissions in Switzerland compared to the synthetic Switzerland.

Furthermore, the expected spread between Switzerland and the synthetic Switzerland after the treatment is also not visible. This is a first indicator that the introduction of the Swiss CO_2 levy did not immediately achieve the desired reduction effect, which is in line with Francescutto and Mathys (2022), who empirically analyzed that the desired demand effect did not occur until 2014. A clear divergence can be seen from 2014 onwards, with synthetic Switzerland, representing the counterfactual without the CO_2 levy, emitting more CO_2 than Switzerland. Moreover, after 2020, a renewed increase in CO_2 emissions can be observed in Switzerland. Not visible in this figure, but in the following year, 2022, CO_2 emissions in the building sector declined again, partly due to a milder winter (Federal Office for the Environment (FOEN) 2024c). Overall, the trajectory of the two curves exhibits annual fluctuations, which are mainly affected by the different respective heating periods.

In addition to the emission trends, Figure 4 also presents the CO_2 emission gap between Switzerland and its synthetic counterpart, defined as the estimated difference between observed emissions in Switzerland and the counterfactual scenario without the CO_2 levy (right axis). All reported emission changes in this section refer to this gap. Between 2008 and 2010, Switzerland's emissions were, on average, 1.53% higher than those of the synthetic counterpart. After a reduction of 2.2% from 2010 to 2011, Switzerland's emissions again exceeded those of synthetic Switzerland for the following two years. A sustained reduction only emerges from 2014 onward. Over the period 2014–2021, emissions in Switzerland were on average 12.4% lower per year than those of the synthetic counterpart, corresponding to a difference of approximately 0.2 metric tons of CO_2 per capita per year.

These results may indicate that the levy increase from CHF 36 to CHF 60 per ton in 2014 contributed to the sustained reduction in CO_2 emissions. On average, Switzerland reduced its CO_2 emissions from buildings by 6.5% per year during the post-treatment period (2008–2021), equivalent to an annual reduction of 0.1 metric tons of CO_2 per capita. The most pronounced gap occurred in 2020, when Switzerland emitted approximately 20% less CO_2 than its synthetic counterpart, corresponding to a difference of 0.3 metric tons. Over the entire post-treatment period (2008–2021), Switzerland emitted a total of 12.1 million metric tons of CO_2 less than its synthetic counterpart.

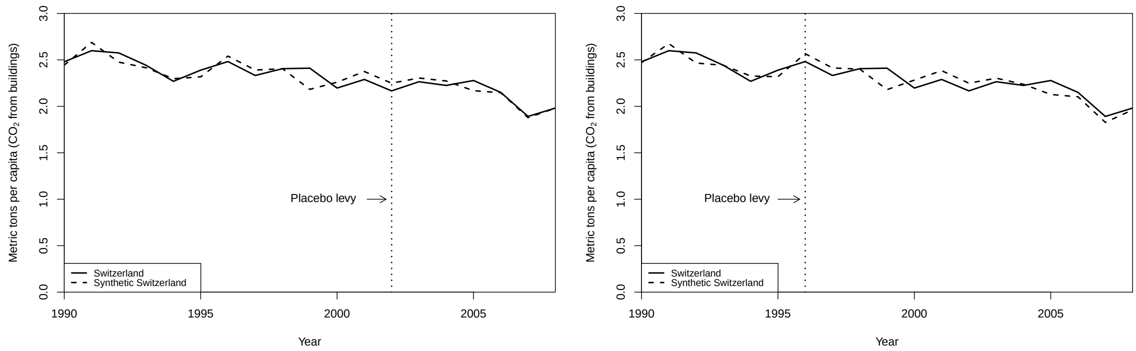
Overall, the SCM results indicate that Switzerland's CO_2 emissions did not immediately decline following the introduction of the CO_2 levy in 2008. However, as the levy increased over time, CO_2 emissions decreased more significantly compared to synthetic Switzerland. Furthermore, a comparison of our estimated effect with the existing literature suggests that Switzerland's emission reductions are within a moderate range. For example, Yu (2024) estimates an average reduction of 2.4% for Norway, whereas Basaglia et al. (2023) report an annual reduction of about 10% for Germany. Our findings are more in line with those of Pretis (2022) and Andersson (2019), who estimate average annual reductions of 5% for British Columbia and 6.3% for Sweden, respectively. Additionally, the recent meta-analysis by Döbbeling-Hildebrandt et al. (2024) estimates an average reduction of 10.4% across 21 carbon pricing schemes, indicating that overall, our results are consistent with global evidence. In the following section, we assess the robustness of these results by applying alternative estimation approaches and placebo tests.

3.5. Robustness checks

To evaluate the robustness of our results, we conduct several placebo tests, including an in-time placebo test as recommended by Abadie et al. (2015). In this approach, we use the same data and methodology but artificially reassign the introduction of the CO_2 levy to 2002 in the first test and to 1996 in the second test. After adjusting the predictors to the new pre-treatment and post-treatment periods, we run the synthetic control method again for each scenario. These placebo interventions are expected to show no significant differences between Switzerland and its synthetic counterpart, as the effect of the CO_2 levy is specific to the actual intervention and not influenced by random or other factors during the pre-treatment period.

In both in-time placebo tests, the trajectories do not align perfectly throughout all periods. However, as shown in Figure 5, shifting the intervention year does not fundamentally alter the estimated treatment effect. Moreover, a comparison with Figure 4 reveals no structural changes in trends. Instead, the observed deviations between Switzerland and its synthetic counterpart remain consistent, indicating that the post-treatment trends were not driven by external shocks.

Figure 5: Placebo in-time tests



(a) Placebo levy in 2002

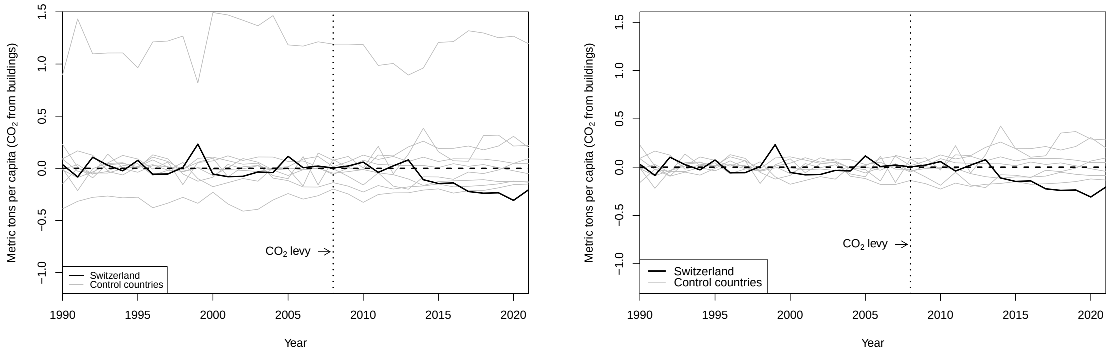
(b) Placebo levy in 1996

As an additional robustness check, we follow Abadie et al. (2015) and conduct an in-space placebo test. In this approach, the treatment (CO_2 levy) is iteratively assigned to each country in the donor pool, rather than only to the treated unit. For each of our nine control countries, a unique synthetic control group is constructed, and the gaps between the actual and synthetic values for the respective country are calculated. Figure 6a shows that Luxembourg's trajectory lies consistently above those of the other control countries, indicating that it is difficult to construct a suitable synthetic counterpart for Luxembourg. This is likely due to its high CO_2 emissions, which are, on average, 60% higher than those of Switzerland.

In contrast, Iceland's trajectory lies noticeably below the others, which reflects its significantly lower CO_2 emissions compared to Switzerland. The test relies on the mean squared prediction error (MSPE) to assess the quality of the synthetic fit during the pre-treatment period[11]. According to Abadie et al. (2010), countries with an MSPE 20 times higher than that of Switzerland are excluded from the analysis, as shown in the second graph in Figure 6b. As a result, Luxembourg and Iceland are removed, even though Luxembourg contributes as a donor country in the construction of synthetic Switzerland. However, Andersson (2019) criticizes the exclusion of countries based on seemingly arbitrary thresholds.

[11]The mean squared prediction error (MSPE) measures the average squared difference between Switzerland and the synthetic Switzerland. A low MSPE implies that the synthetic control closely follows the actual data during the pre-treatment period, while a high MSPE indicates a poor replication of its trends.

Figure 6: Per capita CO_2 emissions gap in Switzerland and placebo gaps in all nine control countries



(a) All control countries

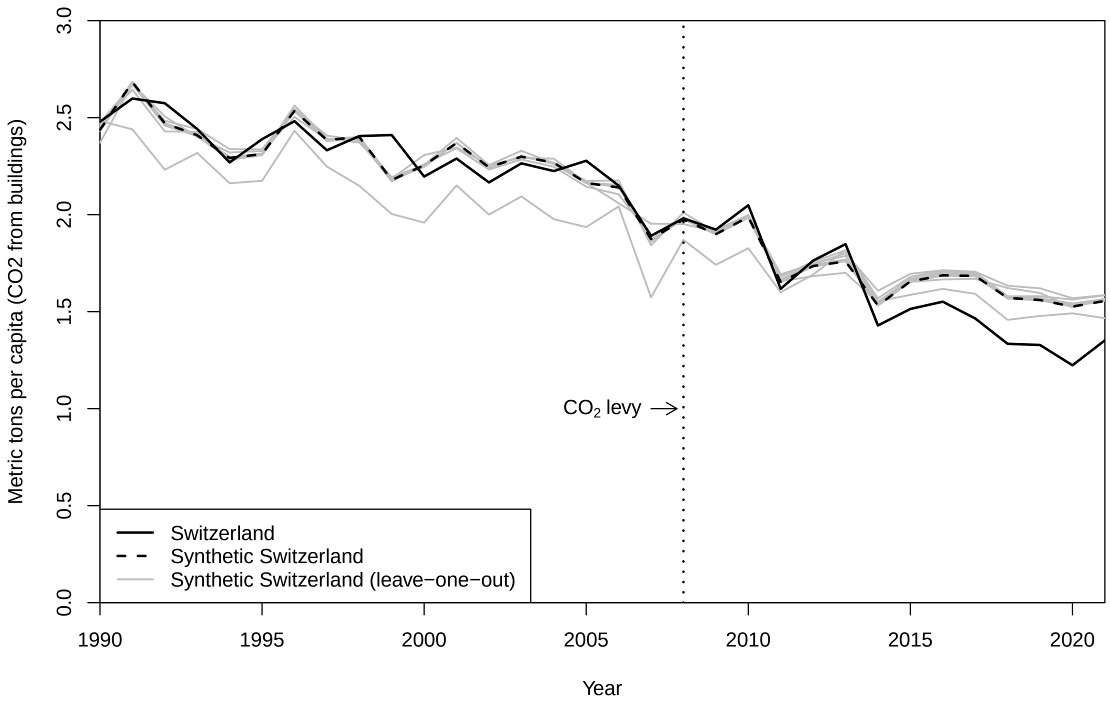
(b) After MSPE-exclusion

For example, Abadie et al. (2011) exclude all control units with an MSPE five times higher than the treated unit, without providing a detailed explanation for this threshold.

Given these results, it is important to further examine the robustness. To address this, we conduct a leave-one-out test, which systematically assesses how sensitive the results are to the inclusion of specific donor countries. At each iteration, synthetic Switzerland was reconstructed based on the remaining control countries, using the same predictors, period and lagged years. The purpose of this analysis is to identify whether the results are disproportionately influenced by any specific control country. If the synthetic Switzerland remains stable after the exclusion of individual countries, this would indicate that the results are robust. In contrast, significant deviations in the synthetic Switzerland after the exclusion of certain countries would suggest that these countries play a significant role in constructing the synthetic counterpart.

The visual representation of the leave-one-out test is provided in Figure 7, where the dashed gray lines represent the trajectories of the synthetic Switzerland after the exclusion of individual control countries. The solid black line represents the actual CO_2 emissions of Switzerland, and the dashed black line represents the original synthetic Switzerland. The results indicate that the exclusion of Luxembourg leads to noticeable deviations in the trajectory of the synthetic Switzerland. This suggests that Luxembourg plays a significant

Figure 7: Leave-One-Out Placebo Test

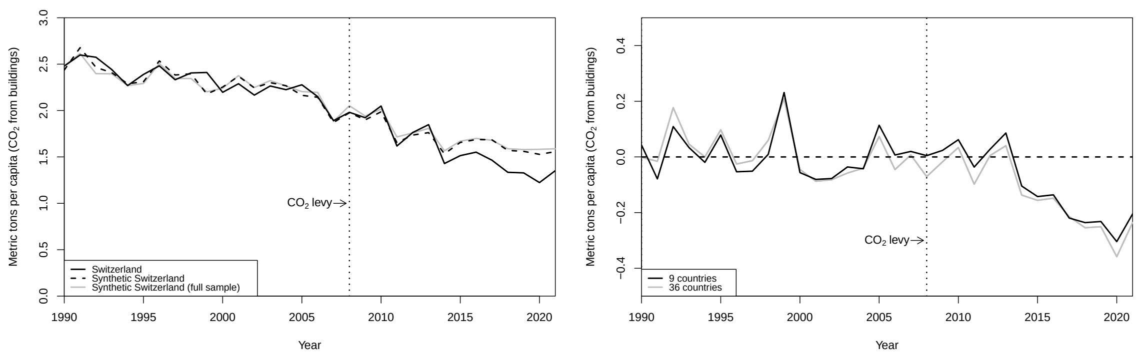


*Notes:*Each gray line represents a synthetic Switzerland constructed by excluding one donor country from the donor pool. The plot illustrates the range of resulting trajectories and highlights whether the synthetic control is disproportionately affected by the exclusion of any specific country.

role in approximating Switzerland's CO_2 emissions, as shown in Table 2. In contrast, the exclusion of other countries results in only minor deviations, demonstrating that the model is not overly reliant on these countries.

In the case of small control countries samples, it is essential to question whether our exclusion criteria were appropriate or whether using a larger sample could have produced better results. To address this, we use the synthetic control method to the full sample of 36 OECD countries, as shown in Figure 8a.[12] The trajectory of the synthetic Switzerland generated from this larger sample is consistent with the original synthetic Switzerland. Only in 2008, 2011, and 2019 are minor gaps observable between the original synthetic Switzerland and the synthetic Switzerland created from the 36 countries.[13] The new analysis also does not affect the composition of countries contributing to the synthetic Switzerland. The model still includes Austria, Germany, and Luxembourg, but Finland is replaced by Ireland. However, the weight for Germany increases to 0.420, which may be considered critically, as this country receives a large weight in this sample, despite being only one of four countries in the donor pool.[14]

Figure 8: Robustnes checks with different samples



(a) CO_2 paths (b) CO_2 gaps

Notes: The main results use the smaller sample of nine OECD countries to construct synthetic Switzerland. The full sample result use all 36 OECD countries in the donor pool to construct the synthetic Switzerland.

[12] All results from this SCM analysis are presented in Table A.7 and Table A.8.

[13] From the current 38 OECD countries, Costa Rica is excluded due to missing data, and Switzerland, as the treated country, is not part of the donor pool.

[14] Austria has a weight of 0.225, Ireland 0.157, and Luxembourg 0.197.

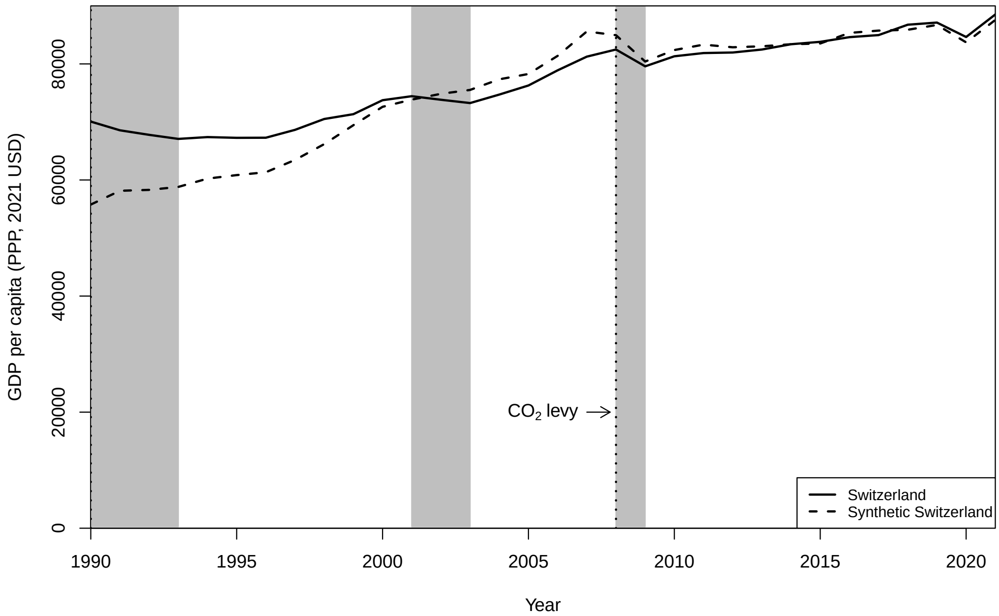
In Figure 8b, we plot the CO_2 emission gaps between Switzerland and the synthetic Switzerland based on our nine control countries, and the gap using the synthetic Switzerland generated from 36 control countries. The two lines are broadly similar, but deviations are particularly noticeable between 2005 and 2010, spanning the pre- and post-period of Switzerland's CO_2 levy. This can be explained by changes in the weights of the control countries. Germany's weight is significantly higher in the new synthetic Switzerland based on 36 countries, while Luxembourg's weight decreases. Since Germany has been part of the EU ETS since 2005, while Luxembourg has not, this shift in weights also affects the synthetic Switzerland. Given that Switzerland only joined the EU ETS in 2020 and therefore does not exhibit this effect, this supports the choice of the smaller sample over the one including all 36 OECD countries.

3.6. Economic effects

Carbon taxes are introduced with the objective of reducing CO_2 emissions by increasing the cost of fossil fuels. However, concerns about potential negative economic effects are a common argument against their implementation. To assess this, Figure 9 compares per capita GDP between Switzerland and its synthetic counterpart. Between 1990 and 1993, Switzerland's GDP per capita declined by a total of 4.3%, marking a stronger contraction compared to the other nine OECD donor countries. Similarly, Finland (−11.1%), Sweden (−5.6%), and Iceland (−6.1%) experienced overall negative growth during this period. However, due to their low weights in the synthetic control, these effects remain negligible.

After Switzerland's GDP reached the same level as its synthetic counterpart in 2001, it recorded an overall growth rate of −0.1% over the next two years, whereas all other nine OECD countries (except Germany with −1.0%) showed a positive growth rate. The impact of the financial crisis in 2008–2009 is visible in the decline of both lines. Switzerland's GDP per capita declined by a total of 3.5% during this period, compared to an average decrease of 5.4% across the nine OECD control countries. However, from 2009 onward,

Figure 9: Path of GDP per capita: Switzerland versus synthetic Switzerland

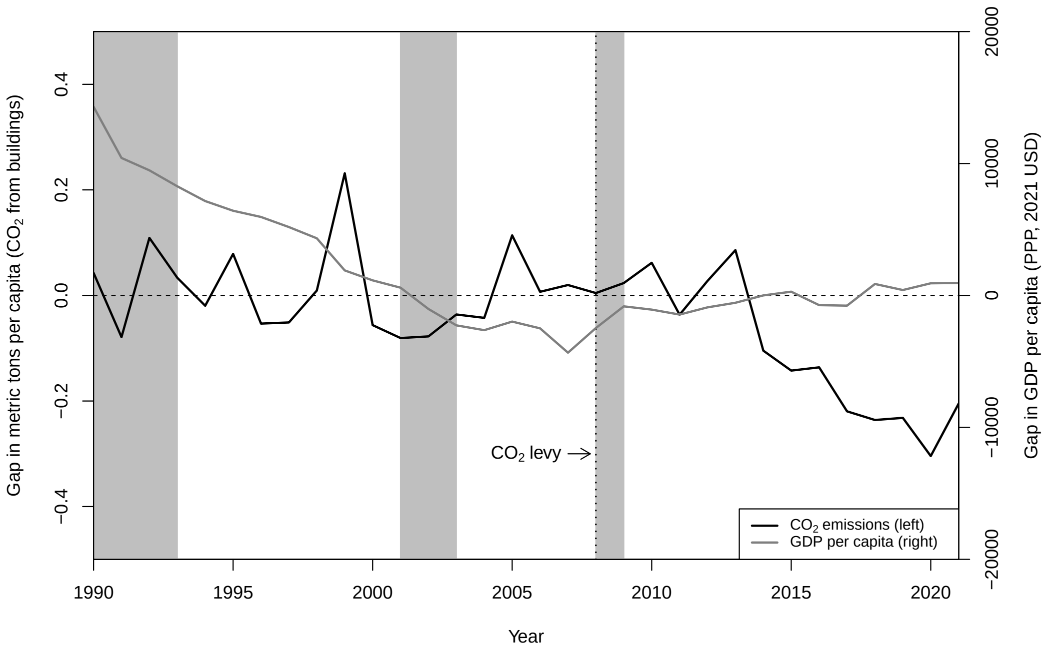


Notes: The gray-shaded areas represent periods (1990–1993, 2001–2003, 2008–2009) of negative GDP per capita growth in Switzerland.

the trajectories of both lines align almost perfectly, countering the argument that economic growth is negatively affected by carbon taxes.

In addition to the previously examined effects of carbon taxes on economic growth, this section examines the relationship between CO_2 emissions and GDP growth in Switzerland. As highlighted by studies such as Tucker (1995), Mitić et al. (2017), and Uçak et al. (2015), an increase in GDP is generally associated with higher CO_2 emissions. Figure 10 shows both the gap in per capita CO_2 emissions from buildings between Switzerland and its synthetic counterpart, as well as the gap in GDP per capita. The gray-shaded areas are the same as in Figure 9 and represent periods of negative growth rates of GDP per capita in Switzerland. During the first two recession phases, Switzerland's GDP per capita dropped by approximately $6,000 and $2,800 in comparison to the synthetic Switzerland, highlighting the varying economic impacts between Switzerland and the control countries. As shown

Figure 10: Gaps between Switzerland and synthetic Switzerland



Notes: The black line shows the gap in GDP per Capita and the grey line shows the gap in CO_2 emissions per capita between Sweden and synthetic Sweden. The gray-shaded areas represent periods (1990–1993, 2001–2003, 2008–2009) of negative GDP per capita growth in Switzerland.

before, the decrease of GDP in the third recession phase (2008–2009) was less severe in Switzerland than in the synthetic control group.

However, the emissions gap does not correlate with the GDP gap. During the first recession, the emissions gap initially narrows and then briefly increases before returning to its 1990 level, resulting in a marginal reduction of only 0.009 tons per capita. In the second recession phase (2001–2003), per capita CO_2 emissions increased by 0.045 tons compared to the synthetic Switzerland and by 0.019 tons in 2008–2009. This indicates that there is no clear link between GDP growth and CO_2 emissions. From 2008 to 2021 (post-treatment period), the gap between Switzerland's GDP per capita and that of its synthetic counterpart was marginal. At the same time, CO_2 emissions decreased in the post-treatment period, as explained in more detail in Figure 4.

Taken together, the SCM results suggest that Switzerland has achieved a sustained reduction in CO_2 emissions, particularly from 2014 onward, coinciding with the increase of the levy from 36 to 60 CHF per ton of CO_2. At the same time, GDP per capita remained largely unaffected during the post-treatment period. One possible explanation for the absence of negative economic effects may relate to the specific design of the Swiss CO_2 levy. Revenues from the levy are fully recycled through lump-sum climate bonuses and allocations via the national climate fund. This fund supports the replacement of fossil heating systems, energy-efficient building renovations, renewable energy deployment, and innovative low-carbon technologies (Federal Office for the Environment (FOEN) 2025; Federal Assembly of the Swiss Confederation 2011, Art. 38). This revenue recycling mechanism may have mitigated potential adverse effects on economic activity, thereby decoupling emission reductions from GDP losses.

4. CO_2 levy elasticity

Understanding how consumers respond to energy price changes is essential for evaluating the effectiveness of climate policy instruments. In this final section of our paper, we examine the responsiveness of fossil fuel demand in the residential heating sector to price signals. In particular, we empirically examine whether price elasticities differ depending on whether price changes are driven by market forces or by the CO_2 levy.

To disentangle these effects, we decompose the retail price into its components: the retail price including the value added tax, $p_{it}^{VAT_t} = (p_{it})(1 + VAT_t)$, and the CO_2 levy including VAT, $X_{it}^{VAT_t,levy} = (X_{it}^{levy})(1 + VAT_t)$, and run the following model separately for heating oil and natural gas consumption:

$$lnC_{it} = \alpha + \beta_{i1} lnC_{it-1} + \beta_{i2} p_{it}^{VAT_t} + \beta_{i3} X_{it}^{VAT_t,levy} + \beta_{i4} D_t + \beta_{i5} Trend + \beta_{i6} GDP_t + u_{it}, \quad (3)$$

where lnC_{it} is the natural logarithm of the consumption per capita of oil or gas ($i = oil, gas$). Given that both dependent variables are non-stationary, we detrend them by including the first lag of logarithmic consumption, $\ln C_{it-1}$, to account for a stochastic trend in the regressions.[15] The dummy variable D_t takes a value of 1 for the period 2008–2023 and 0 for the pre-treatment period, GDP_t is the control variable GDP per capita, $Trend$ is a deterministic time trend, and u_{it} represents the error term. The heating oil and crude oil prices, as well as the CO_2 levy and the energy tax, were converted into CHF per liter. The prices for natural gas[16], the CO_2 levy, and the energy tax for natural gas were converted into CHF per kWh. Using the Consumer Price Index (CPI), all prices and taxes as well as GDP per capita were adjusted to real terms (2020 = 100). Due to the low share of energy tax in total retail price components and the fact that it has remained unchanged since its introduction, we have excluded this price component from our regression analysis.

Table 3 presents the results for heating oil, with column (1) reporting the baseline specification without GDP per capita and column (2) including GDP per capita as an additional control variable. The estimates are obtained from a log-linear specification and therefore represent semi-elasticities, which are converted into own-price elasticities following the transformation described in the note to the table.[17] Due to the inclusion of a lagged consumption variable, the estimated coefficients should be interpreted as short-run elasticities. The OLS regression result in column (2) shows no statistically significant price elasticity for the retail price of heating oil. Moreover, the estimated price elasticity of −0.055 suggests that a 1% increase in the retail price of heating oil leads to only a 0.055% reduction in short-run demand, indicating that elasticity is near inelastic.

In contrast, the significant estimate in column (2) indicate that a 1% increase in the CO_2 levy results in a short-run reduction in heating oil demand of −1.264%. This implies that policy-induced price increases have a much stronger impact on demand than market-driven price changes. As expected, the long-run elasticities are slightly higher, with values

[15] To test for potential non-stationarity, we conducted an Augmented Dickey-Fuller (ADF) test on the logarithm of oil and gas consumption. The test results indicate that both variables exhibit a unit root, confirming their non-stationarity.

[16] Since the retail price of natural gas (consumption type III) was highly decoupled from the natural gas price before 1994, we extrapolated the retail prices for the years 1980 to 1993 based on the market price.

[17] All calculated short- and long-run elasticities are reported in Table A.10.

Table 3: Regression results for heating oil consumption

	(1) OLS	(2) OLS	(3) IV(OilPrice)
Log oil consumption $(t-1)$	0.135	0.141	0.141*
	(0.154)	(0.160)	(0.071)
Oil retail price with VAT	-0.0754	-0.0750	-0.0723*
	(0.039)	(0.039)	(0.031)
CO_2 levy with VAT	-1.730***	-1.724***	-1.724***
	(0.323)	(0.328)	(0.123)
Dummy CO_2 levy	0.0944*	0.101*	0.100***
	(0.042)	(0.041)	(0.027)
Trend	-0.0178***	-0.0166***	-0.0166***
	(0.003)	(0.004)	(0.002)
GDP per capita		-0.00000207	-0.00000208
		(0.000)	(0.000)
Constant	5.807***	5.887***	5.886***
	(1.018)	(1.013)	(0.493)
Observations	43	43	43
R^2			0.981

Notes: Based on annual data from 1980 to 2023. All real prices are calculated in Swiss franc. The CO_2 levy and energy tax is converted in Swiss francs per liter. Newey-West standard errors in parentheses are heteroskedasticity and autocorrelation robust. The standard errors are calculated using lags following Newey and West (1994). Column (1) presents the baseline specification without GDP per capita, while column (2) includes GDP per capita as an additional control variable. Column (3) reports results from an instrumental variable (IV) estimation, using the crude oil price in CHF as an instrument for the retail price of heating oil. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The short-run elasticity is given by $\epsilon = \frac{dY}{dP} \times \frac{P}{Y}$. Since the model is log-linear, $ln(Y) = a + bP$, the elasticity simplifies to $\epsilon_{SR} = bP$. Here, P denotes the real retail price of heating oil, evaluated at its sample mean of 0.7331 CHF. Accordingly, the price elasticity of demand is $\epsilon_{SR} = -0.0750 \times 0.7331 = -0.055$, while the levy elasticity is $\epsilon_{SR} = -1.724 \times 0.7331 = -1.264$. The long-run elasticities are calculated as $\epsilon_{LR} = \frac{\epsilon_{SR}}{1-\beta_{i1}}$.

of -0.064 for the retail price and -1.471 for the CO_2 levy, reflecting greater consumer adaptation over time.[18]

Our estimated retail price elasticities fall within the lower range of those reported by Gechert et al. (2025b), who find short-run elasticities between -0.05 and -0.2 and long-run

[18]The long run elasticities are calculated as: $\epsilon_{LR} = \frac{\epsilon_{SR}}{1-\beta_{i1}}$.

elasticities between −0.1 and −0.3 for heating and cooling energy demand after correcting for publication bias. While this suggests that our estimated short-term elasticities are broadly consistent with existing evidence, our long-run estimates are smaller in magnitude. In contrast, the elasticities associated with the CO_2 levy are consistently larger, indicating a stronger behavioral response to policy-induced price changes. In column (3), we conduct an IV estimation, instrumenting the retail price of heating oil with the crude oil price in CHF to account for potential endogeneity. However, the Durbin-Wu-Hausman test does not reject the null hypothesis that the retail price is exogenous. This suggests that IV estimation is not necessary, as OLS provides an efficient and unbiased estimator in this case.

Table 4 presents the regression results for natural gas, again based on a log-linear specification and therefore representing semi-elasticities. These estimates are converted into own-price elasticities following the transformation described in the note to the table.[19] As before, column (1) reports the baseline specification without GDP per capita, while column (2) includes GDP per capita as an additional control variable. The price elasticities for the retail price in both columns are statistically significant, with a short-run elasticity of −0.261, indicating a higher price elasticity compared to heating oil. In contrast, the short-run CO_2 levy elasticity is −0.623, which is nearly two and a half times larger than the price elasticity. Here as well, the results show that politically induced price increases due to the CO_2 levy have a greater influence on demand than market-driven price fluctuations. A similar pattern is evident in the long-run elasticities, estimated at −0.521 for the retail price and −1.241 for the CO_2 levy. As expected, both elasticities increase over time, indicating greater consumer responsiveness in the long run. Moreover, the long-run effect of the CO_2 levy remains nearly twice as strong as the price elasticity of the retail price, reinforcing the dominant role of policy measures in reducing natural gas consumption. Compared to the corrected elasticities reported in the meta-analysis by Gechert et al. (2025b), our estimated retail elasticities for natural gas are only slightly above the upper bound of their reported range. In column (3), we also conduct an IV estimation, using the market price of natural gas as an instrument

[19] All calculated short- and long-run elasticities are reported in Table A.10.

for the retail price. However, as with heating oil, the Durbin-Wu-Hausman test does not indicate any endogeneity issues.

Table 4: Regression results for natural gas consumption

	(1) OLS	(2) OLS	(3) IV(GasPrice)
Log gas consumption $(t-1)$	0.537***	0.498***	0.424***
	(0.143)	(0.129)	(0.103)
Gas retail price with VAT	-2.959***	-3.471***	-4.498***
	(0.618)	(0.693)	(0.508)
CO_2 levy with VAT	-7.789	-8.273*	-9.076***
	(4.849)	(4.777)	(3.441)
Dummy CO_2 levy	-0.0402	-0.0529	-0.0607**
	(0.055)	(0.051)	(0.025)
Trend	0.0141**	0.0117**	0.0133***
	(0.006)	(0.005)	(0.003)
GDP per capita		0.00000667*	0.00000847***
		(0.000)	(0.000)
Constant	3.278***	3.170***	3.617***
	(0.954)	(0.841)	(0.644)
Observations	43	43	43
R^2			0.961

Notes: Based on annual data from 1980 to 2023. The CO_2 levy and energy tax is converted in Swiss francs per liter. Newey-West standard errors in parentheses are heteroskedasticity and autocorrelation robust. The standard errors are calculated using lags following Newey and West (1994). Column (1) presents the baseline specification without GDP per capita, while column (2) includes GDP per capita as an additional control variable. Column (3) reports results from an instrumental variable (IV) estimation, using the crude oil price in CHF as an instrument for the retail price of natural gas. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The short-run elasticity is given by $\epsilon = \frac{dY}{dP} \times \frac{P}{Y}$. Since the model is log-linear, $ln(Y) = a + bP$, the elasticity simplifies to $\epsilon_{SR} = bP$. Here, P denotes the real retail price of natural gas, evaluated at its sample mean of 0.0753 CHF. Accordingly, the price elasticity of demand is $\epsilon_{SR} = -3.471 \times 0.0753 = -0.261$, while the levy elasticity is $\epsilon_{SR} = -8.273 \times 0.0753 = -0.623$. The long-run elasticities are calculated as $\epsilon_{LR} = \frac{\epsilon_{SR}}{1-\beta_{i1}}$.

As the results in Section 2 show that a significant part of the CO_2 levy on heating oil and natural gas is passed on to consumers, the estimated CO_2 levy elasticities confirm the expected effect of a stronger decline in demand. The significant negative trend coefficients for heating oil and the significant positive trend coefficients for natural gas are consistent with Figure 2 and reflect the long-run consumption trends in Switzerland. These trends can primarily be attributed to substitution effects between natural gas and heating oil (Prognos 2024).

Overall, the elasticity analysis highlights the importance of distinguishing not only between different energy sources, but also between different sources of price changes when assessing consumer responsiveness in the heating sector. While households show only limited sensitivity to market-driven price fluctuations, policy-induced price signals elicit significantly stronger behavioral responses. These findings underscore the importance of fiscal instruments in steering energy demand and suggest that carbon pricing can be an effective component of climate policy. We discuss the broader implications of these findings in the final section.

5. Conclusion

This study assesses the effectiveness of the Swiss CO_2 levy, which was introduced in 2008, in reducing residential heating energy demand and associated CO_2 emissions. By employing the synthetic control method, the analysis shows that the levy resulted in an average annual reduction of 6.5% in residential CO_2 emissions during the post-treatment period (2008–2021), equivalent to a yearly decrease of approximately 0.1 metric tons of CO_2 per capita. This effect became particularly evident following the 2014 increase in the CO_2 levy, resulting in greater emission reductions in the building sector.

Additionally, the empirically estimated price elasticities for heating oil indicate that the short-run elasticity for the retail price is -0.055, while the elasticity for the CO_2 levy is -1.264, demonstrating that consumers respond more strongly to policy-induced price changes than to market-driven price changes. In the long run, these elasticities increase to -0.064 (retail price) and -1.471 (levy), highlighting that over time, households adjust their demand more significantly in response to sustained price changes. A similar pattern is observed for natural gas, with short-run elasticities of −0.261 (retail) and −0.623 (levy), increasing to −0.521 and −1.241 , respectively, in the long run.

The results indicate that the CO_2 levy contributed to reducing emissions in the building sector, particularly through stronger responsiveness to policy-induced price signals. At the same time, the relatively high CO_2 levy elasticities should be interpreted with caution. Although emissions decline, the overall magnitude of the reduction remains moderate, suggesting that the estimated elasticities may overstate the underlying behavioral response.

Despite its measurable estimated impact, the levy on its own has not ensured that Switzerland consistently meets its reduction targets (see Table A.1). This may be partly attributed to sector-specific challenges. Unlike fuel price increases, which are immediately visible to end consumers at the pump, changes in heating costs often become apparent only with a delay due to billing cycles. Moreover, the ability to switch to alternative energy sources in response to price increases is limited; particularly for tenants. As a result, price signals often only lead to small short-run behavioral adjustments rather than an immediate shift to alternative technologies or a substitution of heating oil or natural gas.

Overall, the findings provide robust evidence supporting the effectiveness of the Swiss CO_2 levy as a climate policy instrument in the residential heating sector, even though the construction of a synthetic control was challenging due to heterogeneity in key predictors across countries. This study highlights the importance of strong, policy-driven price signals for achieving substantial emission reductions, particularly as Subsection 3.6 shows that the introduction of the Swiss CO_2 levy does not negatively impact GDP per capita. Moreover, the results emphasize the necessity of setting sufficiently high levy rates to ensure significant behavioral changes, especially given the relative price inelasticity of heating energy demand in the short run.

References

Abadie, A., A. Diamond, and J. Hainmueller (2010). "Synthetic control methods for comparative case studies: Estimating the effect of California's tobacco control program". In: *Journal of the American Statistical Association* 105.490, pp. 493–505.

– (2011). "Synth: An R package for synthetic control methods in comparative case studies". In: *Journal of Statistical Software* 42.13.

– (2015). "Comparative politics and the synthetic control method". In: *American Journal of Political Science* 59.2, pp. 495–510.

Abadie, Alberto (2021). "Using synthetic controls: Feasibility, data requirements, and methodological aspects". In: *Journal of Economic Literature* 59.2, pp. 391–425.

Andersson, J. J. (2019). "Carbon Taxes and CO2 Emissions: Sweden as a Case Study". In: *American Economic Journal: Economic Policy* 11.4, pp. 1–30.

Basaglia, Pier, Sophie M. Behr, and Moritz A. Drupp (2023). "De-Fueling Externalities: Causal Effects of Fuel Taxation and Mediating Mechanisms for Delivering Climate and Health Benefits". In: *CESifo Working Paper* 10508.

Bayer, Patrick and Michaël Aklin (2020). "The European Union Emissions Trading System Reduced CO2 Emissions Despite Low Prices". In: *Proceedings of the National Academy of Sciences* 117.16, pp. 8804–8811.

Climate Watch (Feb. 2024). *Data Explorer*. URL: https://www.climatewatchdata.org/data-explorer/historical-emissions (visited on 02/05/2025).

Döbbeling-Hildebrandt, Niklas et al. (2024). "Systematic review and meta-analysis of ex-post evaluations on the effectiveness of carbon pricing". In: *Nature communications* 15.1, p. 4147.

Elbaum, J. D. (2021). "The Effect of a Carbon Tax on Per Capita Carbon Dioxide Emissions: Evidence from Finland". In: *IRENE Working Paper* 21.05.

Energy Institute (Feb. 2024). *Statistical Review of World Energy*. URL: https://www.energyinst.org/statistical-review/home (visited on 02/05/2025).

Fan, J. L., Y. J. Zhang, and B. Wang (2017). “The impact of urbanization on residential energy consumption in China: An aggregated and disaggregated analysis”. In: *Renewable and Sustainable Energy Reviews* 75.

Federal Assembly of the Swiss Confederation (2011). *Federal Act on the Reduction of CO_2 Emissions (CO_2 Act)*. Swiss federal law, Fedlex. Status as of 1 January 2025, Art. 38.

Federal Office for the Environment (FOEN) (Oct. 2024a). *CO extsubscript2-Emissionsfaktoren des Treibhausgasinventars der Schweiz*. Technical Report.

– (July 2024b). *Emissionsübersicht: Tabellen zum Bericht (Version Juli 2024)*. Online Data Table.

– (Mar. 2024c). *Greenhouse gas emissions from buildings*. URL: https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/greenhouse-gas-inventory/buildings.html.

– (Sept. 2025). *Faktenblatt CO2-Abgabe und Verwendung der Einnahmen*. Faktenblatt, Bundesamt für Umwelt BAFU. Available at: https://www.bafu.admin.ch/co2-levy-private-individuals.

Federal Statistical Office (2024). *LIK, Durchschnittspreise für Energie und Treibstoffe: Monatswerte (ab 1993) und Jahresdurchschnitte (ab 1966)*.

Federal Tax Administration FTA (2024). *Development of the Swiss VAT rates*. Online Resource.

Francescutto, N. and N. A. Mathys (2022). “The effect of the Swiss CO2 levy on heating fuel demand of private real estate owners”. In: *Energies* 15.9, p. 3019.

Gechert, Sebastian, Bianka Mey, Franz Prante, and Teresa Schäfer (2025a). *State vs Market: Do Energy Price Elasticities Differ?* Mimeo.

– (Sept. 2025b). *The Price Elasticity of Heating and Cooling Energy Demand*. Tech. rep. 265. I4R Discussion Paper Series.

Ghalwash, T. (2007). “Energy Taxes as a Signaling Device: An Empirical Analysis of Consumer Preferences”. In: *Energy Policy* 38.1, pp. 29–38.

Gierałtowska, U., R. Asyngier, J. Nakonieczny, and R. Salahodjaev (2022). “Renewable energy, urbanization, and CO2 emissions: a global test”. In: *Energies* 15.9.

Labandeira, X., J. M. Labeaga, and X. López-Otero (2017). *A meta-analysis on the price elasticity of energy demand.*

Li, Shanjun, Joshua Linn, and Erich Muehlegger (2014). "Gasoline Taxes and Consumer Behavior". In: *American Economic Journal: Economic Policy* 6.4, pp. 302–342.

Lin, Boqiang and Xuehui Li (2011). "The Effect of Carbon Tax on Per Capita CO2 Emissions". In: *Energy Policy* 39.9, pp. 5137–5146.

Mideksa, T. K. (2024). "Pricing for a Cooler Planet: An Empirical Analysis of the Effect of Taxing Carbon". In: *Journal of Environmental Economics and Management* 103034.

Mitić, P., O. Munitlak Ivanović, and A. Zdravković (2017). "A cointegration analysis of real GDP and CO2 emissions in transitional countries". In: *Sustainability* 9.4, p. 568.

Newey, Whitney K. and Kenneth D. West (1994). "Automatic lag selection in covariance matrix estimation". In: *Review of Economic Studies* 61.4, pp. 631–653.

Pretis, F. (2022). "Does a Carbon Tax Reduce CO2 Emissions? Evidence from British Columbia". In: *Environmental and Resource Economics* 83.1, pp. 115–144.

Prognos (Nov. 2024). *Energieverbrauch der privaten Haushalte 2000–2023: Auswertung nach Verwendungszwecken und Ursachen der Veränderungen.* Prognos AG.

Rivers, Nicholas and Brandon Schaufele (2015). "Salience of Carbon Taxes in the Gasoline Market". In: *Journal of Environmental Economics and Management* 74, pp. 23–36.

Sheng, P., Y. He, and X. Guo (2017). "The impact of urbanization on energy consumption and efficiency". In: *Energy & Environment* 28.7, pp. 673–686.

Swiss Federal Office of Energy (2024). *Schweizerische Gesamtenergiestatistik 2023.* Swiss Federal Office of Energy.

Swiss Federal Statistical Office (Aug. 2024a). *Gross Domestic Product – Long Time Series.* URL: https://www.bfs.admin.ch/bfs/en/home/statistics/national-economy/national-accounts/gross-domestic-product.assetdetail.32257509.html (visited on 02/05/2025).

– (Apr. 2024b). *Landesindex der Konsumentenpreise (LIK).* URL: https://www.bfs.admin.ch/asset/de/32267424 (visited on 02/05/2025).

The Federal Council (1996). *Mineralölsteuergesetz (MinöStG) vom 21. Juni 1996*. Official Document.

– (Nov. 1999a). *Federal Act of 08 October 1999 on the Reduction of CO2 Emissions (CO2 Act)*. Official Publication.

– (Oct. 1999b). *Switzerland approves law to implement the Kyoto Protocol*. Press release.

– (2007). *Ordinance on the Reduction of Carbon Emissions (CO2 Ordinance) of 8th June 2007*. Official Publication.

– (2012). *Ordinance of 30th November 2012 on the reduction of CO extsubscript2 Emissions (CO extsubscript2 Ordinance) - AS 2012 7005*. Official Compilation (AS).

– (2020). *Ordinance 25th November 2020 on the reduction of CO extsubscript2 Emissions (CO extsubscript2 Ordinance) - AS 2020 6081*. Official Compilation (AS).

– (2023a). *Federal Act on Value Added Tax of 12 June 2009 (Status as of 1 September 2023)*. Official Publication.

– (2023b). *Ordinance of 30 November 2012 for the Reduction of CO2 Emissions (CO2 Ordinance) of 30 November 2012 (Status as of 10 November 2023)*. Official Publication.

Tucker, M. (1995). "Carbon dioxide emissions and global GDP". In: *Ecological Economics* 15.3, pp. 215–223.

Uçak, H., A. Aslan, F. Yucel, and A. Turgut (2015). "A dynamic analysis of CO2 emissions and the GDP relationship: empirical evidence from high-income OECD countries". In: *Energy Sources, Part B: Economics, Planning, and Policy* 10.1, pp. 38–50.

World Bank (Mar. 2024a). *Climate Change Knowledge Portal – Data Download*. URL: https://climateknowledgeportal.worldbank.org/download-data (visited on 02/05/2025).

– (Apr. 2024b). *World Bank Commodity Price Data (The Pink Sheet)*. URL: https://www.worldbank.org/en/research/commodity-markets (visited on 02/05/2025).

– (Feb. 2024c). *World Bank Data: Indicators*. URL: https://data.worldbank.org/indicator (visited on 02/05/2025).

– (2025). *State and Trends of Carbon Pricing 2025*. License: Creative Commons Attribution CC BY 3.0 IGO. Washington, DC: World Bank.

Xiang, Di and Chad Lawley (2019). “The Impact of British Columbia’s Carbon Tax on Residential Natural Gas Consumption”. In: *Energy Economics* 80, pp. 206–218.

Yu, Y. (2024). “Carbon Taxes and CO2 Emissions: A Replication of Andersson (American Economic Journal: Economic Policy, 2019)”. In: *Economics* 18.1, p. 20220109.

Zarco-Periñán, P. J., I. M. Zarco-Soto, F. J. Zarco-Soto, and R. Sánchez-Durán (2021). “Influence of population income on energy consumption for heating and its CO2 emissions in cities”. In: *Energies* 14.15.

A. Appendix

Figure A.1: Annual changes in CO_2 emissions (Switzerland vs. OECD sample)

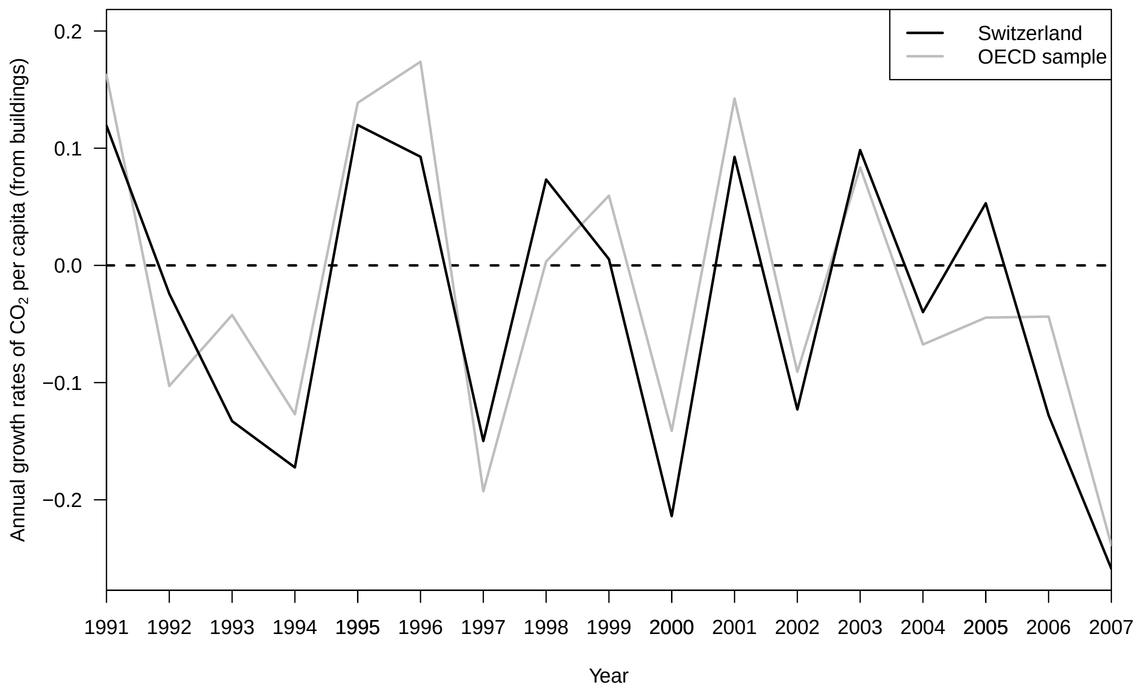


Table A.1: Legal framework of Swiss CO_2 levy

Reference year	Objective	Levy amount, in CHF per t/CO_2	Year of introduction
[SR 641.71] Federal Act of 7th October 1999 on the reduction of CO_2 Emissions (CO_2 Act) [SR 641.712] Ordinance of 7th June 2007 on the reduction of CO_2 Emissions (CO_2 Ordinance)			
2006	when CO_2 emissions from fossil heating fuels amounted to more than 94% of 1990 emissions	**12***	2008
2007	when CO_2 emissions from fossil heating fuels amounted to more than 90% of 1990 emissions	**24***	2009
2008	when CO_2 emissions from fossil heating fuels amounted to more than 86.5% of 1990 emissions	**36***	2010
2009–2011	when CO_2 emissions from fossil heating fuels amounted to more than 85.75% of 1990 emissions	36	2011–2013
[SR 641.711] Ordinance of 30th November 2012 on the reduction of CO_2 Emissions (CO_2 Ordinance) – AS 2012 7005			
2012	when CO_2 emissions from fossil heating fuels amounted to more than 79% of 1990 emissions	**60***	2014
2014	when CO_2 emissions from fossil heating fuels amounted to more than 76% of 1990 emissions	72	2016
	when CO_2 emissions from fossil heating fuels amounted to more than 78% of 1990 emissions	**84***	
	when CO_2 emissions from fossil heating fuels amounted to more than 73% of 1990 emissions	**96***	
2016	when CO_2 emissions from fossil heating fuels amounted to more than 76% of 1990 emissions	120	2018
[SR 641.711] Ordinance 25th November 2020 on the reduction of CO_2 Emissions (CO_2 Ordinance) – AS 2020 6081			
2020	when CO_2 emissions from fossil heating fuels amounted to more than 67% of 1990 emissions	**120***	2022

Notes: The CO_2 levies marked with an asterisk were levied on the basis of the emission reductions that were actually achieved. *Source:* The Federal Council (1999a), The Federal Council (2007), The Federal Council (2012), The Federal Council 2020.

Table A.2: Swiss taxes and levy rates for heating fuels

			Light heating oil		Natural gas	
Year	VAT (%)	CO_2 levy (CHF/tCO_2)	Mineral oil tax (CHF/1000 L)	CO_2 levy (CHF/1000 L)	Mineral oil tax (CHF/1000 kg)	CO_2 levy (CHF/1000 kg)
1995–1996	6.5	–	–	–	–	–
1997–1998	6.5	–	3.0	–	2.1	–
1999–2000	7.5	–	3.0	–	2.1	–
2001–2008	7.6	–	3.0	–	2.1	–
2008–2009	7.6	12	3.0	31.8	2.1	30.7
2010	7.6	36	3.0	95.4	2.1	92.1
2011–2013	8.0	36	3.0	95.4	2.1	92.1
2014–2015	8.0	60	3.0	159.0	2.1	153.6
2016–2017	8.0	84	3.0	222.6	2.1	216.7
2018–2021	7.7	96	3.0	254.4	2.1	255.4
2022–2023	7.7	120	3.0	318.0	2.1	321.6

Notes: The levy rates are calculated using fixed CO_2 emission factors indicating how many kilograms of CO_2 are emitted per liter of heating oil or per kilogram of natural gas. *Source:* Table A.1, Federal Office for the Environment (FOEN) (2024a), Federal Tax Administration FTA (2024), The Federal Council (1996), The Federal Council (2023a).

Table A.3: Regression results for heating oil

(a) Total energy tax

	Retail price
Crude oil price in CHF	1.306***
	(0.0959)
CO_2 levy + energy tax	0.927***
	(0.292)
Constant	-0.000619
	(0.00440)
Observations	44

(b) Only CO_2 levy

	Retail price
Crude oil price in CHF	1.307***
	(0.0965)
CO_2 levy	0.914***
	(0.297)
Constant	0.000694
	(0.00434)
Observations	44

Notes: Based on annual data from 1977 to 2021. The CO_2 levy and energy tax is converted in Swiss francs per liter. Newey-West standard errors in parentheses are heteroskedasticity and autocorrelation robust. The standard errors are calculated using lags following Newey and West (1994). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.4: Regression results for natural gas

(a) Total energy tax

	Retail price
Natural Gas price in CHF	0.313**
	(0.147)
CO_2 levy + energy tax	0.898
	(0.633)
Constant	-0.00177
	(0.00216)
Observations	44

(b) Only CO_2 levy

	Retail price
Natural gas price in CHF	0.312**
	(0.148)
CO_2 levy	0.909
	(0.649)
Constant	-0.00182
	(0.00223)
Observations	44

Notes: Based on annual data from 1977 to 2021. The CO_2 levy was converted into Swiss francs per kilowatt hour (kWh) using the annual emission factor (g/kWh). The energy tax was also converted into Swiss francs per kWh using the average annual standard density and the calorific value (kWh/m^3). Newey-West standard errors in parentheses are heteroskedasticity and autocorrelation robust. The standard errors are calculated using lags following Newey and West (1994). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.5: Selection of control group

Pool A		Pool B	
Country	Heating degree days	Country	GDP per capita
Luxembourg	6107.6	United Kingdom	42587.0
Germany	6189.8	**Finland**	44476.8
Denmark	6328.3	France	44921.4
Chile	6334.5	Canada	45113.0
Poland	6662.9	**Sweden**	45937.6
Slovak Republic	6783.3	**Iceland**	46230.9
Czechia	6795.2	Ireland	47025.5
United States	6823.3	**Germany**	48471.7
Lithuania	7492.1	Italy	48651.7
Latvia	7812.6	Belgium	49218.6
Austria	7915.8	**Austria**	51458.7
Estonia	8097.0	**United States**	52058.3
Switzerland	8675.6	Netherlands	52611.8
Sweden	9629.4	**Denmark**	54788.7
Finland	10290.7	Switzerland	66186.0
Norway	10419.8	**Norway**	73320.6
Iceland	10977.6	**Luxembourg**	107834.9

Notes: The countries highlighted in bold appear in both pools and are thus included in the final control group. Mean values are calculated by the authors based on data from World Bank (2024a) and World Bank (2024c).

Table A.6: Differences-in-differences

Dependent variable: CO_2 emissions from buildings	(1)	(2)
Treatment	-0.263***	-0.198*
	(0.0759)	(0.105)
Year fixed effects	Yes	Yes
Country fixed effects	Yes	Yes
Control variables	No	Yes
Observations	320	320
R^2 (within)	0.7933	0.8268

Notes: The Difference-in-Differences (DiD) analysis is based on annual panel data from 1990 to 2021 for the 9 OECD countries in our donor pool. Standard errors (clustered by country) are reported in parentheses. Column (1) replicates the approach used in Andersson (2019), estimating a fixed-effects panel data model with country and time fixed effects. Column (2) extends this specification by including the same control variables as our Synthetic Control Method analysis (GDP per capita, urbanization rate, oil consumption, gas consumption, and HDD). The estimated treatment effect in Column (1) is -0.263, while the more controlled specification in Column (2) yields -0.198. Both estimated treatment effects suggest a stronger reduction in CO_2 emissions compared to the synthetic control method (SCM) result of approximately 0.1 metric tons CO_2 per capita per year. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.7: CO_2 emissions predictor means before levy introduction

Variables	Switzerland	Synth. Switzerland	36 OECD countries
GDP per capita	63663.884	62282.732	53302.070
Oil consumption per capita	78.572	118.143	103.974
Gas consumption per capita	11.746	39.366	31.064
Urban population	73.654	76.013	78.919
Heating degree days	8760.436	7236.011	8415.794
CO_2 from buildings per capita 1990	2.479	2.437	1.556
CO_2 from buildings per capita 1994	2.269	2.289	1.453
CO_2 from buildings per capita 2007	1.891	1.871	1.077

Notes: GDP per capita, oil and gas consumption per capita, urban population and heating degree days are lagged for the period 1990–2000. GDP per capita is purchasing power parity (PPP), adjusted and measured in 2021 US dollars, oil and gas consumption are converted in gigajoules, urban population is measured as percentage of total population and CO_2 are measured in metric tons. The right column presents the average of the 36 OECD control countries.

Table A.8: Country weights in synthetic Switzerland (36 OECD countries)

Country	Weight	Country	Weight	Country	Weight
Australia	0.000	Greece	0.000	Netherlands	0.000
Austria	0.225	Hungary	0.000	New Zealand	0.000
Belgium	0.000	Iceland	0.000	Norway	0.000
Canada	0.000	Ireland	0.157	Poland	0.000
Chile	0.000	Israel	0.000	Portugal	0.000
Colombia	0.000	Italy	0.000	Slovak Republic	0.000
Czechia	0.000	Japan	0.000	Slovenia	0.000
Denmark	0.000	Korea, Rep.	0.000	Spain	0.000
Estonia	0.000	Latvia	0.000	Sweden	0.000
Finland	0.000	Lithuania	0.000	Turkey	0.000
France	0.000	Luxembourg	0.197	United Kingdom	0.000
Germany	0.420	Mexico	0.000	United States	0.000

Notes: The weights determined by the synthetic control method and receive values between 0 and 1 ($\sum w_j = 1$). Countries with weights below 0.001 are represented as 0.

Table A.9: Descriptive statistics

Heating oil	Mean	SD	Min	Max
Log oil consumption	6.0385	0.4171	5.0619	6.5899
Real retail price with VAT	0.6618	0.2507	0.2984	1.1814
CO_2 levy with VAT	0.0693	0.1099	0	0.3296
Dummy CO_2 levy	0.3636	0.4866	0	1
Trend	22.5	12.8452	1	44
GDP per capita	72189.01	8267.15	58432.40	86424.16
Real crude oil price	0.3945	0.1896	0.1279	0.7753
Natural gas	Mean	SD	Min	Max
Log gas consumption	7.1341	0.3275	6.21412	7.4726
Real retail price with VAT	0.0753	0.0154	0.0528	0.1350
CO_2 levy with VAT	0.0053	0.0084	0	0.02509
Dummy CO_2 levy	0.2954	0.4615	0	1
Trend	22.50	12.84	1	44
GDP per capita	72189.01	8267.15	58432.40	86424.16
Real gas price	0.0293	0.0196	0.0104	0.1265

Notes: The real retail price for natural gas was extrapolated based on the real natural gas price for the years 1980–1993. The heating oil and crude oil prices, as well as the CO_2 levy and the energy tax for oil, were converted into CHF per liter. The prices for natural gas, the CO_2 levy, and the energy tax for natural gas were converted into CHF per kWh. Using the Consumer Price Index (CPI), all prices and taxes, as well as GDP per capita, were adjusted to real terms (2020 = 100).

Table A.10: Short and long run elasticities for heating oil and natural gas

Heating Oil	OLS (base)		OLS (control)		IV (OilPrice)	
	SR	LR	SR	LR	SR	LR
Retail price with VAT	-0.055	-0.064	-0.055	-0.064	-0.053	-0.062
CO2 levy with VAT	-1.268	-1.466	-1.264	-1.471	-1.264	-1.471
Natural gas	OLS (base)		OLS (control)		IV (GasPrice)	
	SR	LR	SR	LR	SR	LR
Retail price with VAT	-0.223	-0.481	-0.261	-0.521	-0.339	-0.588
CO2 levy with VAT	-0.586	-1.265	-0.623	-1.241	-0.683	-1.186

Notes: The short- and long-run elasticities are based on the results reported in column (2) of Table 3 and Table 4.

Table A.11: Data sources

Variable	Data source	Data Characteristics and Remarks	Time period
Retail price for oil	Swiss Federal Statistical Office (2024b). Landesindex der Konsumentenpreise (LIK) - 2024. https://www.bfs.admin.ch/asset/de/32267424	Purchase quantity category of 3001–6000 is used.	1977–2023
Retail price for gas	Swiss Federal Statistical Office (2024b). Landesindex der Konsumentenpreise (LIK) - 2024. https://www.bfs.admin.ch/asset/de/32267424	Consumption type III (20,001 kWh to 50,000 kWh per year) is used.	1977–2023
Crude Oilprice	World Bank (2024b). World Bank Commodity Price Data (The Pink Sheet). https://www.worldbank.org/en/research/commodity-markets	Crude oil (Brent) in $/bbl converted to CHF/Liter.	1977–2023
Natural gas price	World Bank (2024b). World Bank Commodity Price Data (The Pink Sheet). https://www.worldbank.org/en/research/commodity-markets	Natural Gas Europe in ($/mmbtu) converted to (CHF/kWh).	1977–2023
Mineral oil tax	The Federal Council (1996). Mineralölsteuergesetz (MinöStG) vom 21. Juni 1996. https://www.fedlex.admin.ch/eli/cc/1996/3371_3371_3371/de; The Federal Council (2023a). Federal Act on Value Added Tax of 12 June 2009 (Status as of 1 January 2025). https://www.fedlex.admin.ch/eli/cc/2009/615/en	All amendments and versions of the Mineral Oil Tax Act between 1996 and 2023 have been considered.	1997–2023

CO_2 levy	The Federal Council (1999a). SR 641.71: Federal Act of 8 October 1999 on the Reduction of CO_2 Emissions (CO_2 Act). https://www.fedlex.admin.ch/eli/cc/2000/148/de The Federal Council 2023b. SR 641.711: Ordinance of 30 November 2012 for the Reduction of CO_2 Emissions (CO_2 Ordinance) of 30 November 2012 (Status as of 10 November 2023). https://www.fedlex.admin.ch/eli/cc/2012/856/en	All laws and ordinances between 1999 and 2023 have been considered.	2008–2023
Value added tax	Federal Tax Administration FTA (2024). Development of the Swiss VAT rates. https://www.estv.admin.ch/estv/en/home/value-added-tax/vat-rates-switzerland/development-of-the-swiss-vat-rates.html	Light heating oil and gas are subject to the standard VAT rate.	1995–2023
Crude oil consumption	Energy Institute (2024). Statistical Review of World Energy. https://www.energyinst.org/statistical-review/home	EJ converted to GJ per capita.	1990–2021
Natural gas consumption	Energy Institute (2024). Statistical Review of World Energy. https://www.energyinst.org/statistical-review/home	EJ converted to GJ per capita.	1990–2021
Population	World Bank (2024c). World Bank Data: Indicators. https://data.worldbank.org/indicator	Population, total.	1977–2023
Urban population	World Bank (2024c). World Bank Data: Indicators. https://data.worldbank.org/indicator	Urban population (% of total population).	1980–2023
GDP per capita (OECD countries)	World Bank (2024c). World Bank Data: Indicators. https://data.worldbank.org/indicator	Purchasing power parity (PPP), adjusted and measured in 2021 US dollars.	1990–2021

Heating degree days	World Bank (2024c). World Bank Data: Indicators. https://data.worldbank.org/indicator	Calculated by summing the differences between the heating threshold temperature (65°F) and the average outdoor temperature on all heating days.	1990–2021
CO_2 Emissions (building sector)	Climate Watch (2024). Data Explorer. https://www.climatewatchdata.org/data-explorer/historical-emissions?historical-emissions-data-sources=climate-watch	CO_2 emissions from buildings in $MtCO_2e$ converted to per capita values.	1990–2021
Household heating oil and gas consumption	Swiss Federal Office of Energy (2024). Schweizerische Gesamtenergiestatistik 2023. https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/overall-energy-statistics.html	TJ converted to GJ per capita and liter per capita.	1980–2023
GDP per capita (Switzerland)	Swiss Federal Statistical Office (2024a). Bruttoinlandsprodukt, lange Serie. https://www.bfs.admin.ch/bfs/en/home/statistics/national-economy/national-accounts/gross-domestic-product.assetdetail.32257509.html	Converted to per capita values.	1980–2023
Standard density, calorific value and emission factor for natural gas	Association for water, gas and district heating (2024). Eigenschaften des in der Schweiz verteilten Erdgases (G10001 Information); Swiss Gas and Water Industry Association (2004)-(2023). Eigenschaften des in der Schweiz verteilten Erdgases (G10001 Information).	Annual averages.	1997–2023
Consumer Price Index (CPI)	Swiss Federal Statistical Office (2024b). Landesindex der Konsumentenpreise (LIK) - 2024; https://www.bfs.admin.ch/asset/de/32267424	CPI-adjusted (2020 = 100)	1980–2023