Taxes versus Targets: An Empirical Analysis of two Policy Instruments on Greenhouse Gas Mitigation in the Industry and Service Sector

Building Competence. Crossing Borders.

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thomas.leu@zhaw.ch, 26. Januar 2023, Präsentation an den 8. Energieforschungsgesprächen – Disentis

Motivation

- **What is the effect of the Swiss climate policy mix on firms' energy consumption and CO_2 emissions in the industry and service sector?**

- **Is it possible to quantify a difference in the mitigation effect between a mandatory CO_2 levy and binding reduction target agreement.**

- **What are the challenges when facing such a research question?**

Outline of the Presentation

- **Introduction to the topic**
- **Descriptive overview of the energy consumption and GHG emissions in the industry and the service sector**
- **Switzerland's energy and climate policy instruments for the industry and the service sector**
- **The CO_2 levy and economic incentives**
- **Project and research question**
- **Description of the underlying two different databases**
- **Strategy for linking these two datasets**
- **Empirical strategy and descriptive overview**
- **Empirical Results taking into account only the CO_2 levy**
- **Conclusion and outlook**

Evolution of Switzerland's Greenhouse Gas Emissions by Sector, Aggregate Data 1990 – 2020
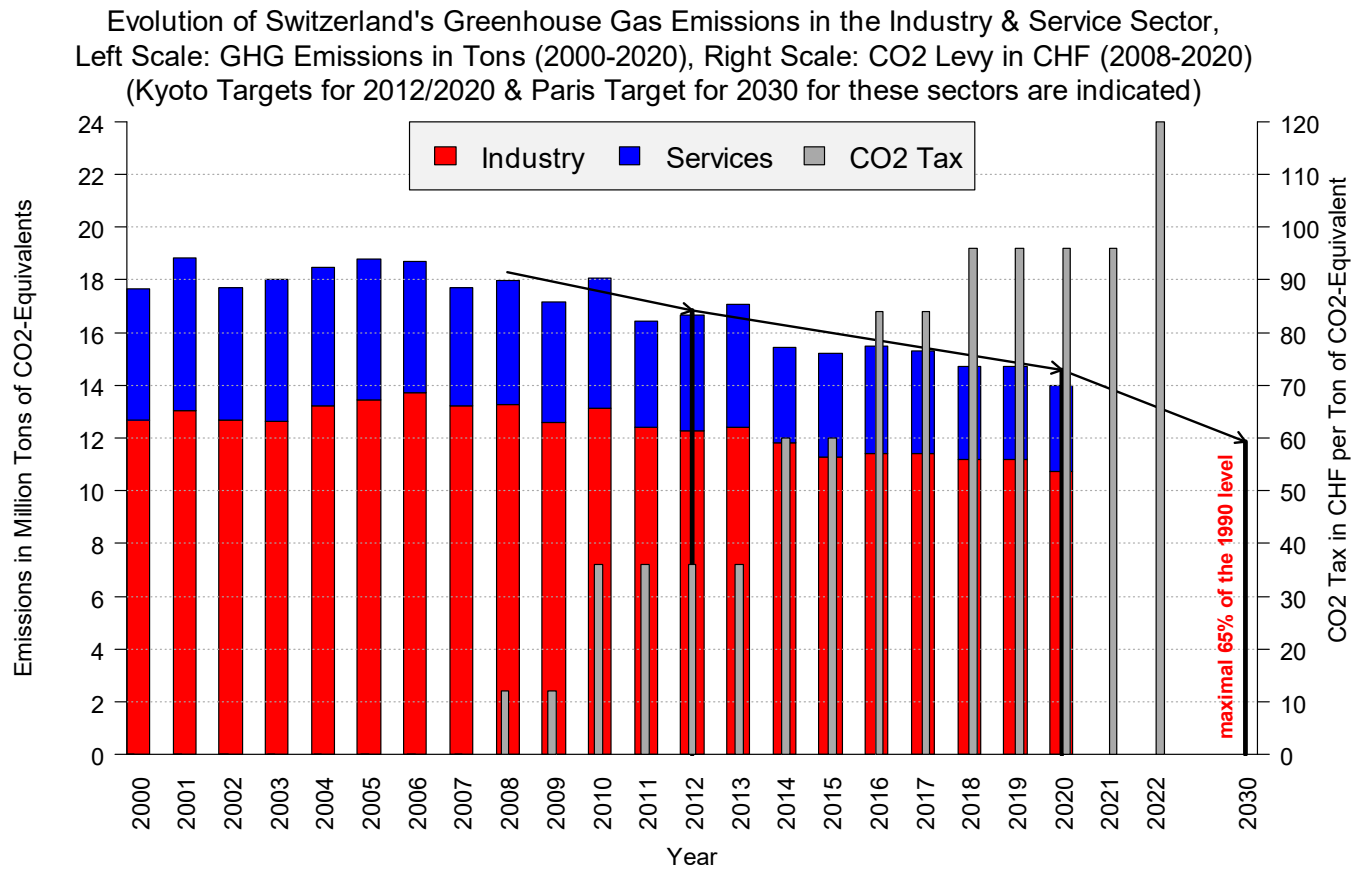
Evolution of Switzerland's Greenhouse Gas Emissions subdivided by Sectors, 1990-2020
(Kyoto Targets for 2012 and 2020, Paris Target for 2030, Federal Target for 2050)
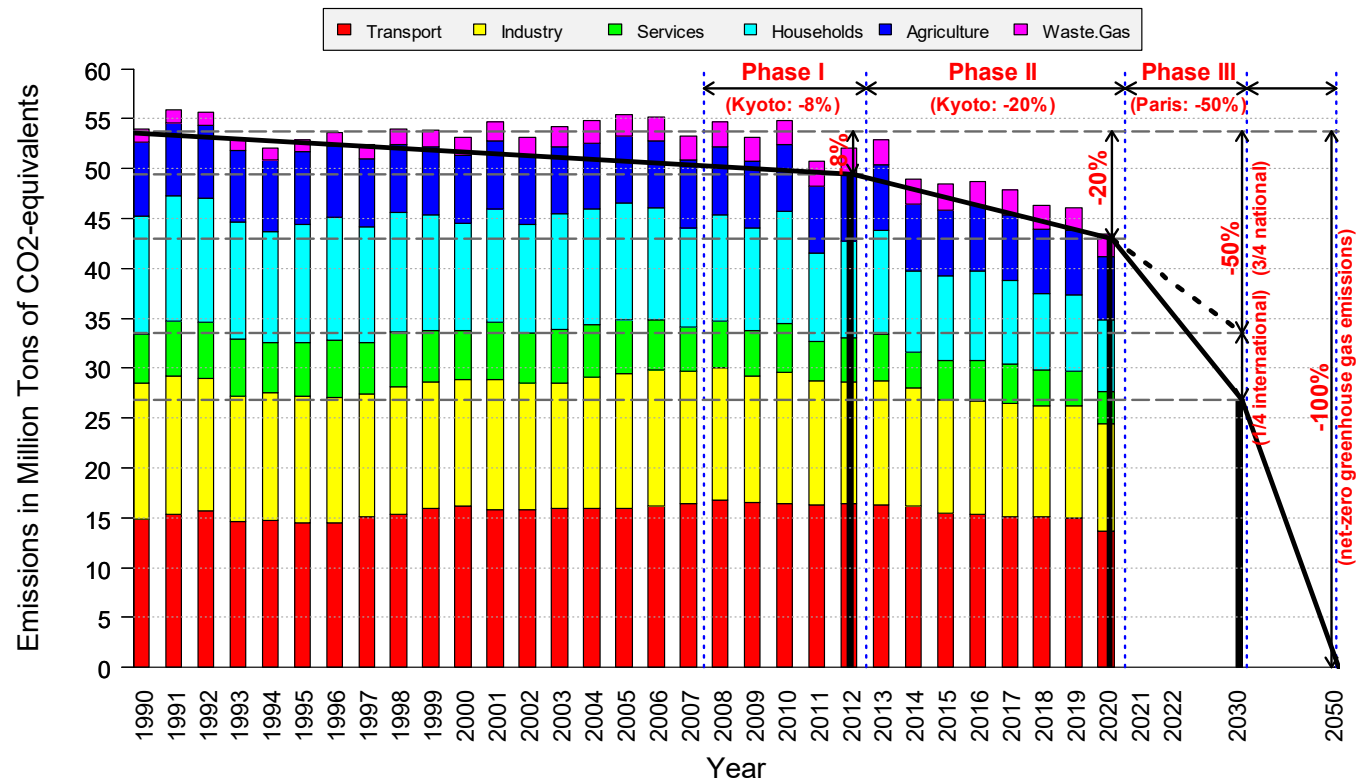
Data Source: Swiss Federal Office for the Environment FOEN, Own Calculations (2022)

- In 2020, the industry and service sector account for 32.3% (**yellow** and **green** bars) of the total greenhouse gas emissions of 43.4 million tons of CO_2eq.
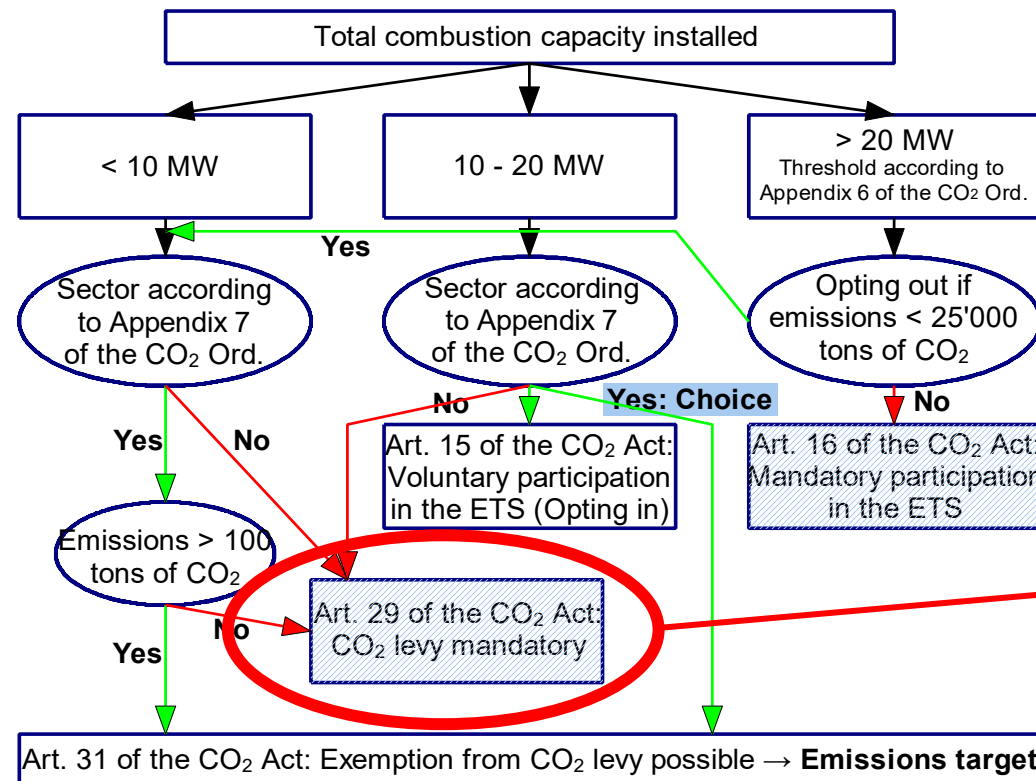
Evolution of Switzerland's Greenhouse Gas Emissions in the Industry & Service Sector, Aggregate Data 2000 – 2020

Evolution of Switzerland's Greenhouse Gas Emissions in the Industry & Service Sector,
Left Scale: GHG Emissions in Tons (2000-2020), Right Scale: CO_2 Levy in CHF (2008-2020)
(Kyoto Targets for 2012/2020 & Paris Target for 2030 for these sectors are indicated)

Data Source: Swiss Federal Office for the Environment FOEN, Own Calculations (2022)

- The sectoral interim target path towards a maximum of 65% of the 1990 level in 2030 is indicated.

- The sectoral target of the CO_2 Ordinance is likely to be achieved.

The three main Climate Policy Instruments available in the Swiss Industry & Service Sector

Total combustion capacity installed

< 10 MW

10 - 20 MW

> 20 MW
Threshold according to Appendix 6 of the CO_2 Ord.

Sector according to Appendix 7 of the CO_2 Ord.

Sector according to Appendix 7 of the CO_2 Ord.

Opting out if emissions < 25'000 tons of CO_2

Yes

Yes: Choice

No

No

Art. 15 of the CO_2 Act: Voluntary participation in the ETS (Opting in)

Art. 16 of the CO_2 Act: Mandatory participation in the ETS

Yes

No

Emissions > 100 tons of CO_2

Yes

No

Art. 29 of the CO_2 Act: CO_2 levy mandatory

The CO_2 levy is the instrument for the majority of the installations.

Art. 31 of the CO_2 Act: Exemption from CO_2 levy possible → **Emissions target**

- **CO_2 levy on fossil heating and process fuels:**
  Carbon tax imposed on fossil heating fuels (Default for the majority of the installations).

- **Emissions trading scheme (ETS):**
  Mandatory for 56 CO_2-intensive companies («cap-and-trade»-principle, linked to EU ETS).

- **Exemption from the CO_2 levy** possible for CO_2-intensive companies under certain conditions. In return, companies have to commit to an **emissions target.**

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Economic Incentives for applying for an Exemption from the CO_2 Levy
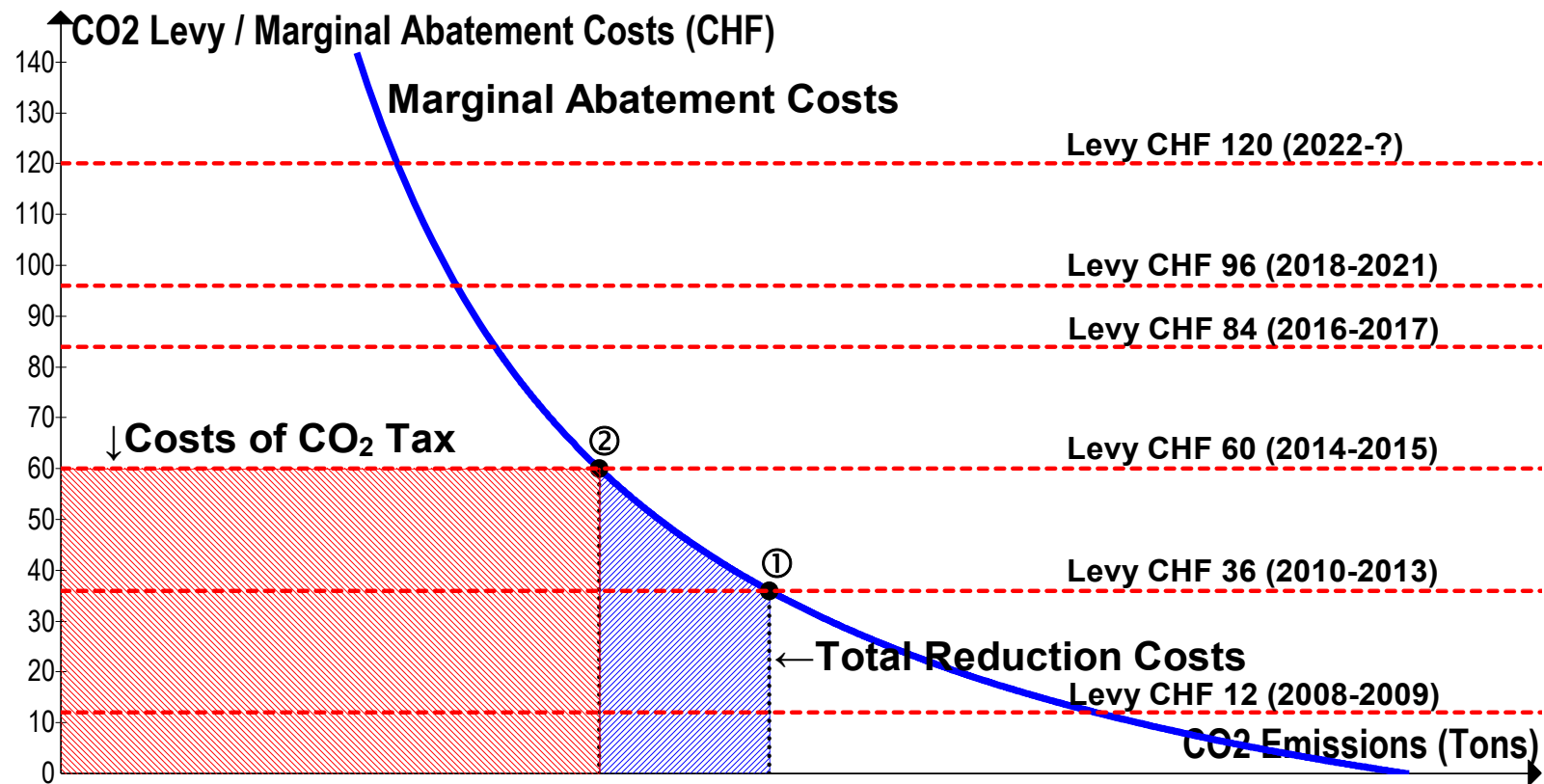
- The CO_2 Levy was increased 5 times after its introduction in 2008; last time in 2022.
- **Starting position:** CO_2 levy increases from CHF 36 to CHF 60 per ton of CO_2eq.
- A rational firm moves along the marginal abatement cost function from point ① to point ②.
- Total reduction costs: **blue area.** Tax costs: **red area.**
- The **tax costs** can be saved by committing to a target agreement.

Research Questions and Research Project

Research Questions

- What is the impact of the CO_2 levy versus the target agreements on greenhouse gas emissions mitigations in the industrial and services sector?

- Can the null-hypothesis, which states that the impact on greenhouse gas emissions mitigations does not differ between the two groups, econometrically be rejected, by applying microdata of firm behavior.

Challenges

- Two different datasets from two sources (Federal Office of Energy & Energy Agency of the Swiss Private Sector) must be linked.

- Finding an adequate econometric strategy to avoid self selection bias issues as well as the lack of a control group.

The Process of Data Collection

Actual Position

Goal

Step 1:
Data origin & linking key

Step 2:
Linking at the Federal Statistical Office

Step 3:
Preparation of a common data set

Data from the Energy Agency (private):
Key: UID-no. (Company level)
Data includes the choosen policy
(CO_2 levy, target agreement,
mandatory emissions trading)

Linking data through common key identifier (UID-no.)
Assignment of the corresponding policy

Anonymized research data set

Data from the Federal Office of Energy:
Key: BUR-no. (Plant level)
Each BUR-no. is assigned to an UID-no.
Data includes controls (area, employees, etc.)

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Empirical Strategy I

<u>Step I:</u> Data from the representative survey conducted by the Swiss Federal Office of Energy; plants exempted from the CO_2 levy are identified and eliminated from the dataset:

- The causal effect of the different levels of the CO_2 levy, paid by those plants not being exempted from the levy, is empirically analyzed.

- Standard firm fixed effects regression models which control for unobserved heterogeneity of time-invariant plant-specific characteristics, such as the management's attitude toward environmental aspects, are applied.

- Regressions of the form are estimated:

$$y_{it} = D_k \tau + x'_{it} \eta + A'_t \gamma + \theta_i + \lambda t + \varepsilon_{it}$$

  - y_{it}: dependent variable for the GGE of plant i in period t
  - D_k: policy vector indicating the different tax level periods
  - x_{it}: vector of time-variant firm specific factors (firm size, number of employees, etc.)
  - A_t: Vector of economy wide indicators (heating degree-days, oil price, economy-wide activity etc.)
  - λ: Time Trend to capture technological progress.

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Empirical Strategy II

Step II: Data from the representative survey conducted by Swiss Federal Office of Energy are linked with the data originating from the Energy Agency of the Swiss Private Sector:

- Plants of companies which committed themselves to a binding target agreement are identified by linking the SFOE sample with data from the Energy Agency.

- As firms self-select themselves into target agreement programs, differences-in-differences estimators or other quasi experimental methods are applied to best avoid self-selection issues.

- The null-hypothesis, which states that the impact on greenhouse gas emissions mitigations does not differ between the two groups, is being tested.

- The resulting empirical evidence might provide findings that allow to distinguish the impact of the CO_2 levy opposed to that of the target agreements.

Description of the two Datasets I: Number of Installations / Firms

SFOE: Representative sample of installations:

- Due to its representativeness, the SFOE sample more adequately represents the evolution of the economic sectors.

EnAW: Firms exempted from the CO_2 levy → target agreement:

- Self selection and the entry restriction led to an over-representation of the industry sector.

Number of Installations grouped by Sector (1999-2021)
SFOE Sample: Energy Consumption in the Industry and Service Sector
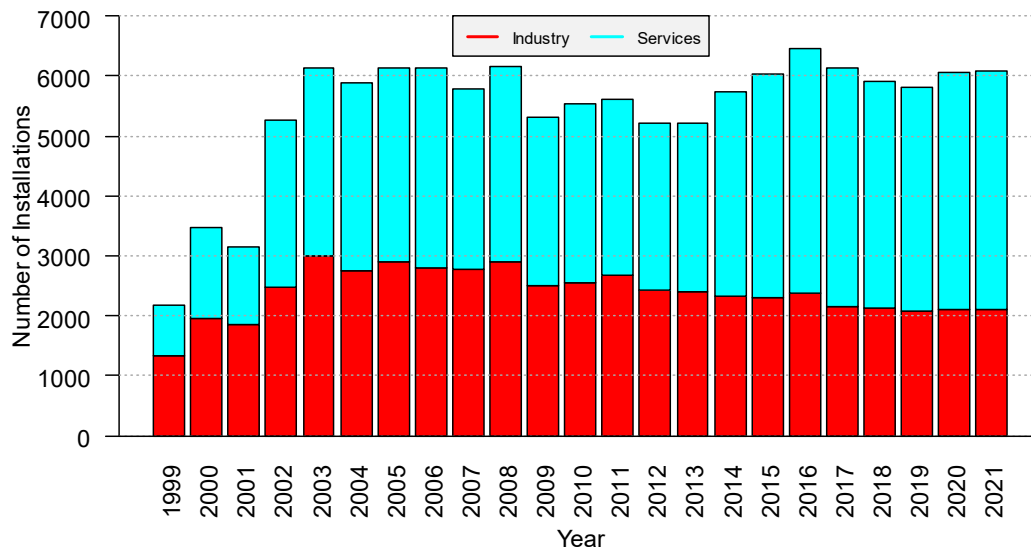
Data Source: Swiss Federal Office of Energy SFOE 2022 (N = 125'425)

Number of Firms grouped by Sector (2013-2019)
Population: Energy Agency of the Swiss Private Sector

Data Source: Energy Agency of the Swiss Private Sector EnAW (N = 41'079)

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SFOE: Representative sample of installations:

- Average energy consumption has been decreasing since 2008.

EnAW: Firms exempted from the CO_2 levy → target agreement:

- The higher average energy consumption of EnAW-firms is due to data on company instead of installation level.

Evolution of the Average Energy Consumption (1999-2021)
SFOE Sample: Energy Consumption in the Industry and Service Sector
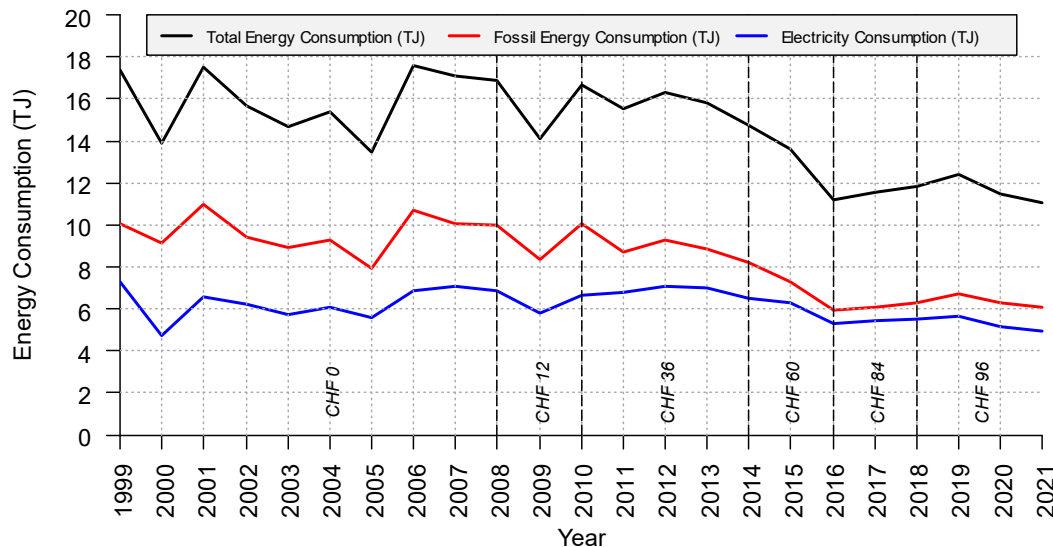
Data Source: Swiss Federal Office of Energy SFOE 2022 (N = 125'425)

Evolution of the Average Energy Consumption (2013-2021)
Population: Energy Agency of the Swiss Private Sector

Data Source: Energy Agency of the Swiss Private Sector EnAW (N = 41'079)

SFOE: Representative sample of installations (absolute Values):

- Average energy consumption has been decreasing since 2008.

SFOE: Representative sample of installations (Index: 2008 = 100):

- Fossil energy consumption (-40%) is decreasing more than electricity consumption (-27%). This might be a hint for substitution processes.

Evolution of the Average Energy Consumption (1999-2021)
SFOE Sample: Energy Consumption in the Industry and Service Sector
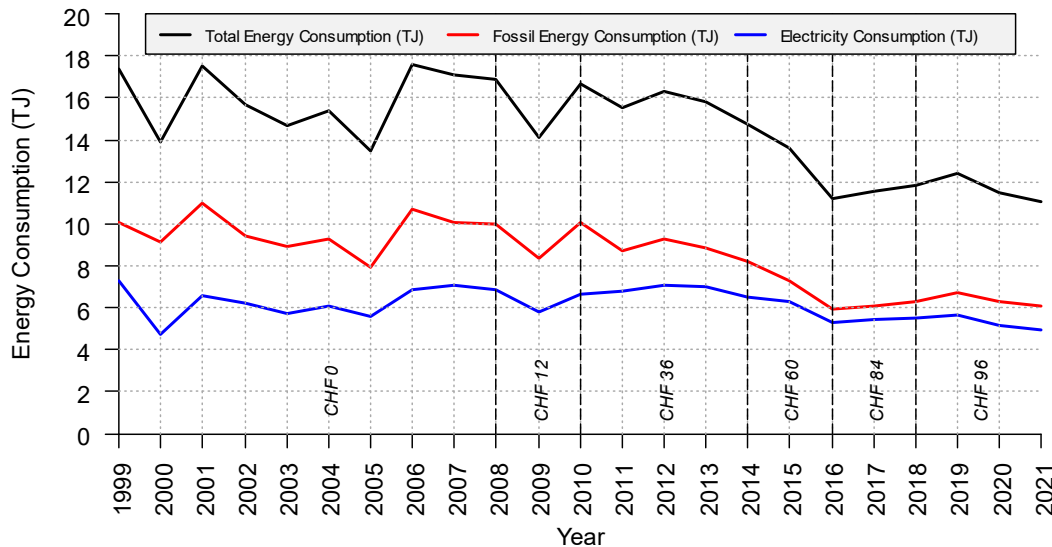
Data Source: Swiss Federal Office of Energy SFOE 2022 (N = 125'425)

Evolution of the Average Energy Consumption (1999-2021)
SFOE Sample: Energy Consumption in the Industry and Service Sector
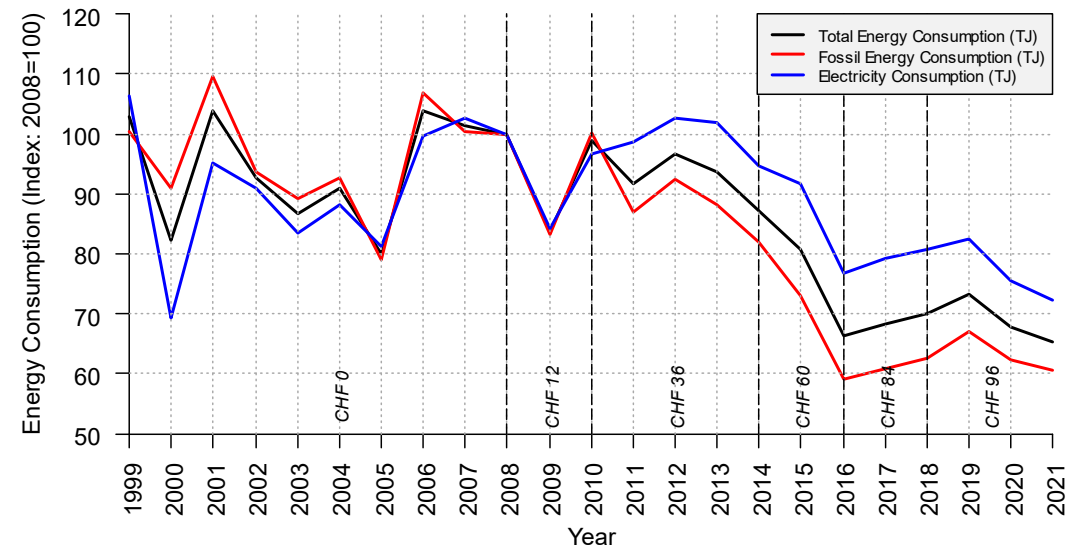
Data Source: Swiss Federal Office of Energy SFOE 2022 (N = 125'425)

Description of the two Datasets IV:
Average Energy Consumption (TJ)

SFOE: Representative sample of installations (absolute Values):

- Average energy consumption of heating oil has been decreasing most since 2008. It is partly substituted by natural gas.

SFOE: Representative sample of installations (Index: 2008 = 100):

- The consumption of heating oil has been decreasing the most (-60%).
- The consumption of district heating is stable → Buildings program, Heating degree-days are decreasing.

Evolution of the Average Energy Consumption by Source (1999-2021)
SFOE Sample: Energy Consumption in the Industry and Service Sector
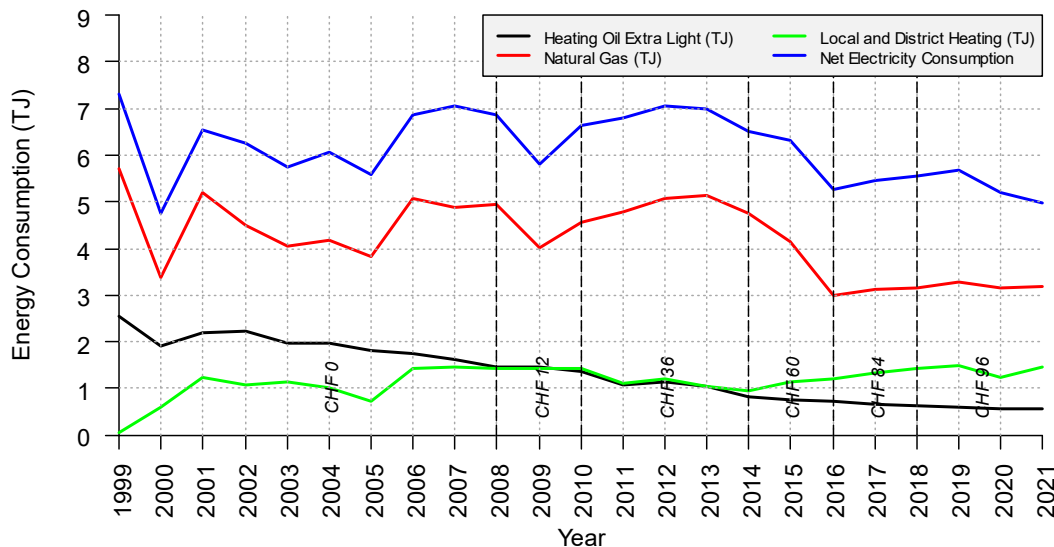
Data Source: Swiss Federal Office of Energy SFOE 2022 (N = 125'425)

Evolution of the Average Energy Consumption by Source (1999-2021)
SFOE Sample: Energy Consumption in the Industry and Service Sector
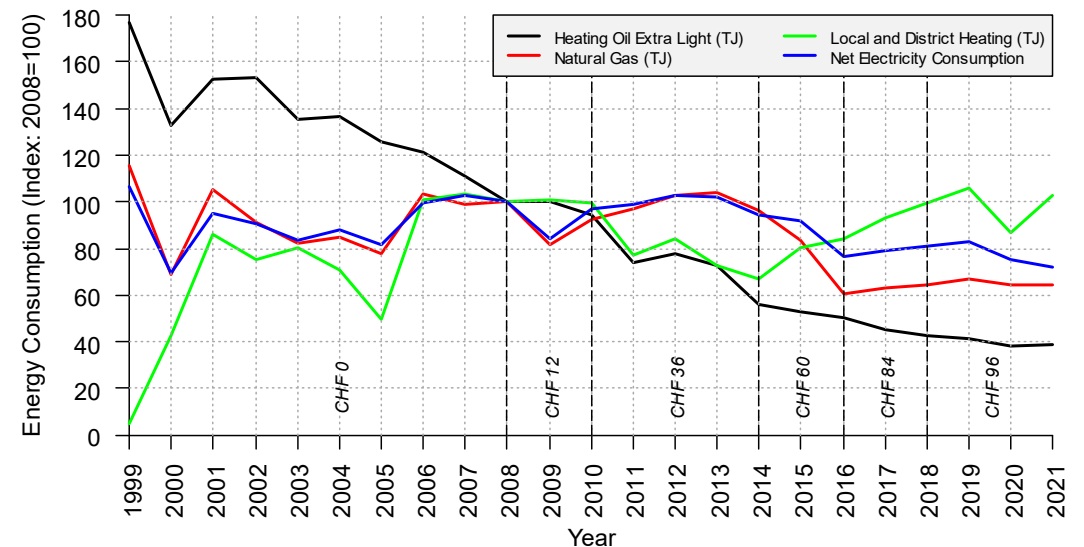
Data Source: Swiss Federal Office of Energy SFOE 2022 (N = 125'425)

Description of the two Datasets V: Average Green House Gas Emissions by Sector (Tons)

SFOE: Representative sample of installations:

- Average greenhouse gas emissions have been decreasing since 2008.

## EnAW: Firms exempted from the CO_2 levy → target agreement:

- The reduction path of the participants with binding target agreements is more stable.

Evolution of Average GHG Emissions by Sector (1999-2021)
SFOE Sample: Energy Consumption in the Industry and Service Sector

Data Source: Swiss Federal Office of Energy SFOE 2022 (N = 125'425)

Evolution of Average GHG Emissions by Sector (2013-2021)
Population: Energy Agency of the Swiss Private Sector

Data Source: Energy Agency of the Swiss Private Sector EnAW (N = 41'079)

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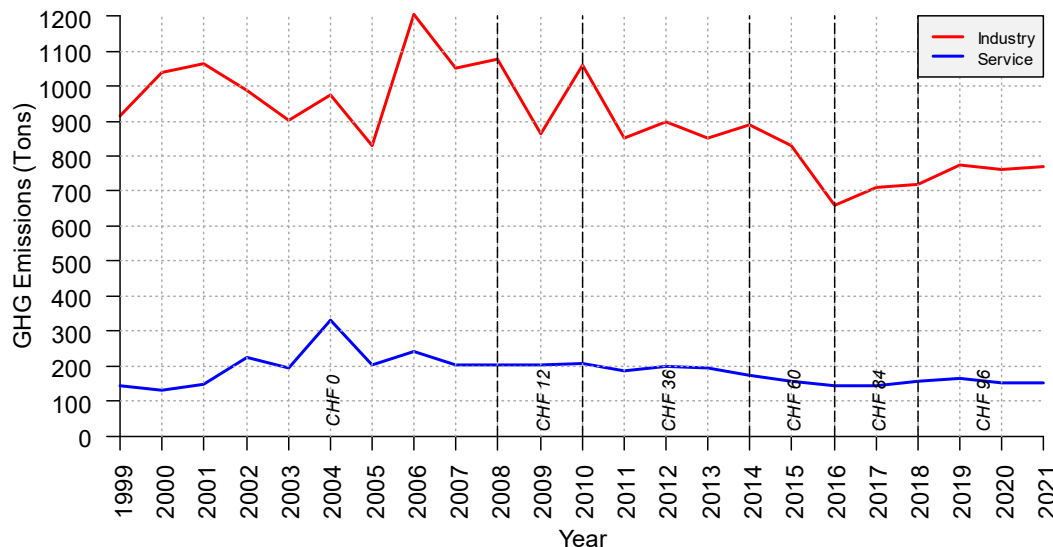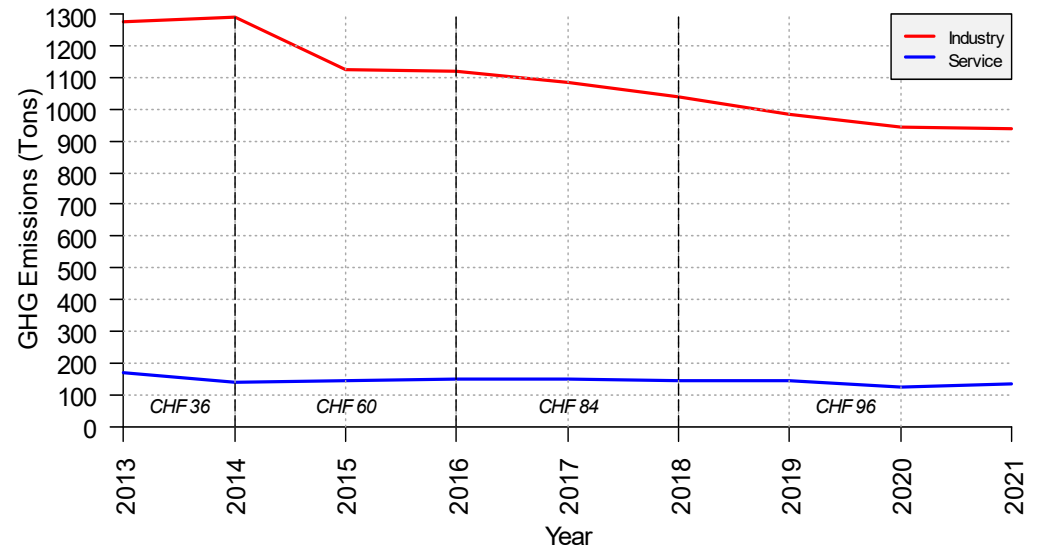
Description of the two Datasets VI:
Average GHG Emissions by Sector (Index: 2008/2013 =100)

SFOE: Representative sample of installations:

- The industry sector reduces average GHG Emissions by ~30% and the service sector by ~25% compared to 2008.

EnAW: Firms exempted from the CO$_2$ levy → target agreement:

- The industry sector reduces average GHG Emissions by 26% and the service sector by 22% compared to 2013.

Evolution of Average GHG Emissions by Sector (1999-2021)
SFOE Sample: Energy Consumption in the Industry and Service Sector

Data Source: Swiss Federal Office of Energy SFOE 2022 (N = 125'425)

Evolution of Average GHG Emissions by Sector (2013-2021)
Population: Energy Agency of the Swiss Private Sector

Data Source: Energy Agency of the Swiss Private Sector EnAW (N = 41'079)

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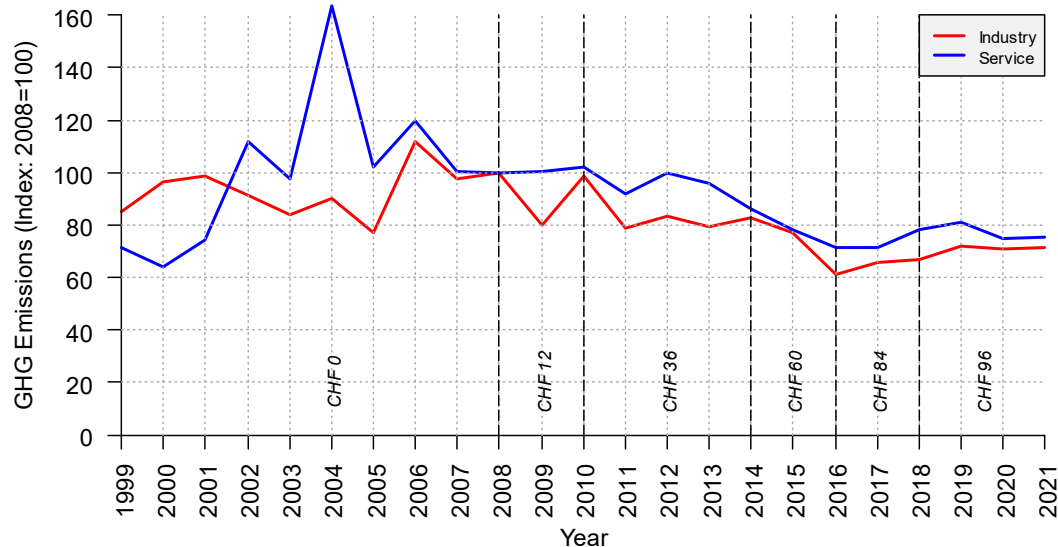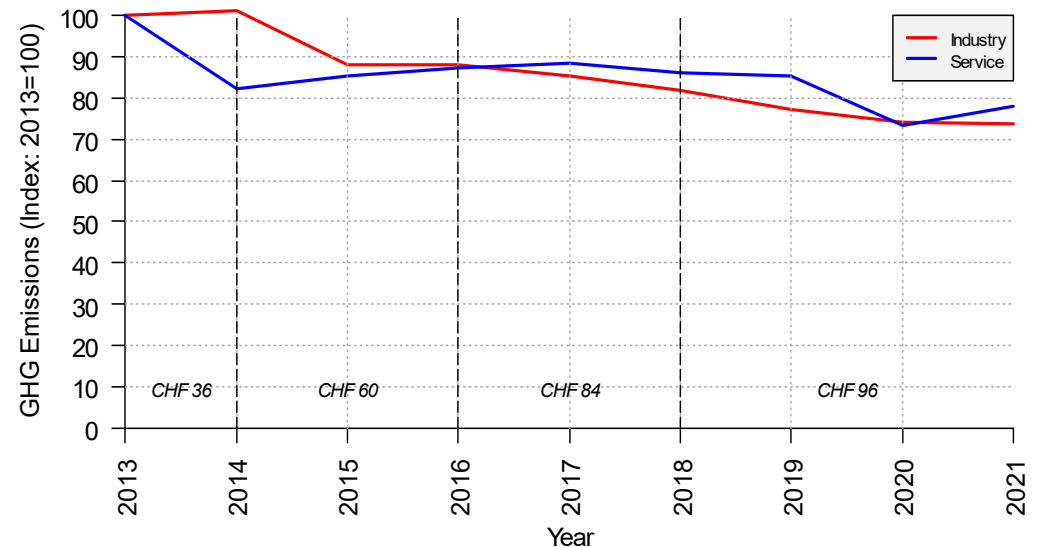
Summary Statistics of Fixed Effects Regression Estimates I: Repesentative SFOE data on firm level (t = 2000, …, 2021)

DEPENDENT VARIABLE: log(Fossil Energy Consumption)	Model 1	Model 2	Model 3	Model 4	Model 5
REGRESSORS (Baseline Period: years 2000-2007)					
After Tax Period (2008-2021)	-0.0823**				
	(0.00919)				
CO_2 Tax CHF 12/Ton (2008-2009)		-0.0189*	-0.0275**	-0.00772	-0.00585
		(0.00826)	(0.00965)	(0.00915)	(0.00915)
CO_2 Tax CHF 36/Ton (2010-2013)		-0.0383**	-0.0506**	-0.0433**	-0.0405**
		(0.00958)	(0.0133)	(0.0126)	(0.0126)
CO_2 Tax CHF 60/Ton (2014-2015)		-0.153**	-0.172**	-0.112**	-0.108**
		(0.0122)	(0.0179)	(0.0189)	(0.0190)
CO_2 Tax CHF 84/Ton (2016-2018)		-0.135**	-0.140**	-0.152**	-0.147**
		(0.0135)	(0.0215)	(0.0278)	(0.0279)
CO_2 Tax CHF 96/Ton (2019-2021)		-0.182**	-0.203**	-0.183**	-0.177**
		(0.0147)	(0.0259)	(0.0329)	(0.0330)
R^2 (within)	0.004	0.012	0.062	0.064	0.063
Number of Observations	111,472	111,472	98,975	98,975	97,897
Number of Installations	23,823	23,823	21,828	21,828	21,722
Firm Specific Controls	NO	NO	YES	YES	YES
Economy Wide Controls	NO	NO	NO	YES	YES
Trimmed upper 1%	NO	NO	NO	NO	YES

Note: Asterisks indicate the significance level at 5% (*) and 1% (**). The standard errors in parentheses are corrected for heteroscedasticity and serial correlation across clusters. Data Source: Swiss Federal Office of Energy.

- The baseline period are the years 2000-2007 (Pre-policy period: No CO_2 tax was levied until 2008).
- By controlling for other effects, the CO_2 levy has a significant negative impact on the fossil energy consumption.
- In period 2019-2021 with a CO_2 levy of CHF 96/ton, the impact is -17.7% compared to the baseline.
- ☝ Installations operating under a target agreement are not identified. Other policies might have an impact as well, e.g. the buildings program.

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Summary Statistics of Fixed Effects Regression Estimates II: Repesentative SFOE data on firm level (t = 2000, …, 2021)

DEPENDENT VARIABLE: log(GHG Emissions) REGRESSORS (Baseline Period: years 2000-2007)	Model 1	Model 2	Model 3	Model 4	Model 5
After Tax Period (2008-2021)	-0.115** (0.00956)				
CO_2 Tax CHF 12/Ton (2008-2009)		-0.0326** (0.00854)	-0.0346** (0.00997)	-0.00727 (0.00948)	-0.00531 (0.00948)
CO_2 Tax CHF 36/Ton (2010-2013)		-0.0610** (0.0100)	-0.0620** (0.0138)	-0.0525** (0.0131)	-0.0490** (0.0131)
CO_2 Tax CHF 60/Ton (2014-2015)		-0.197** (0.0129)	-0.204** (0.0185)	-0.145** (0.0196)	-0.140** (0.0196)
CO_2 Tax CHF 84/Ton (2016-2018)		-0.186** (0.0141)	-0.177** (0.0221)	-0.200** (0.0287)	-0.194** (0.0288)
CO_2 Tax CHF 96/Ton (2019-2021)		-0.247** (0.0152)	-0.250** (0.0266)	-0.241** (0.0338)	-0.234** (0.0339)
R^2 (within)	0.007	0.019	0.064	0.066	0.065
Number of Observations	110,698	110,698	98,264	98,264	97,189
Number of Installations	23,702	23,702	21,714	21,714	21,608
Firm Specific Controls	NO	NO	YES	YES	YES
Economy Wide Controls	NO	NO	NO	YES	YES
Trimmed upper 1%	NO	NO	NO	NO	YES

Note: Asterisks indicate the significance level at 5% (*) and 1% (**). The standard errors in parentheses are corrected for heteroscedasticity and serial correlation across clusters. Data Source: Swiss Federal Office of Energy.

- The baseline period are the years 2000-2007 (Pre-policy period: No CO_2 tax was levied until 2008).

- The effect on green house gas emission is stronger than the effect on fossil energy consumption CO_2 levy. This might be explained by substitution processes from heating oil to natural gas.

- In period 2019-2021 with a CO_2 levy of CHF 96/ton, the impact is -23.4% compared to the baseline.

- ☝ Installations operating under a target agreement are not identified. Other policies might have an impact as well, e.g. the buildings program.

Summary Statistics of Fixed Effects Regression Estimates III: Comparison of the Industry and the Service Sector

FIXED EFFECT REGRESSION MODEL	(1)	(2)	(3)	(4)
DEPENDENT VARIABLES REGRESSORS (Baseline Period: years 2000-2007)	log(Fossil Energy Consumption)	log(Fossil Energy Consumption)	log(GHG Emissions)	log(GHG Emissions)
CO_2 Tax CHF 12/Ton (2008-2009)	-0.00762	-0.00417	-0.00538	-0.00466
	(0.0122)	(0.0135)	(0.0128)	(0.0138)
CO_2 Tax CHF 36/Ton (2010-2013)	-0.0382*	-0.0366*	-0.0475**	-0.0428*
	(0.0175)	(0.0182)	(0.0181)	(0.0188)
CO_2 Tax CHF 60/Ton (2014-2015)	-0.108**	-0.0957**	-0.138**	-0.129**
	(0.0281)	(0.0256)	(0.0288)	(0.0266)
CO_2 Tax CHF 84/Ton (2016-2018)	-0.151**	-0.120**	-0.204**	-0.162**
	(0.0411)	(0.0376)	(0.0424)	(0.0385)
CO_2 Tax CHF 96/Ton (2019-2021)	-0.178**	-0.143**	-0.239**	-0.198**
	(0.0490)	(0.0442)	(0.0501)	(0.0452)
R^2 (within)	0.061	0.063	0.064	0.063
Observations	43,288	54,609	42,689	54,500
Number of Installations	8,058	14,018	7,962	13,999
Sector	Industry	Services	Industry	Services
Firm Specific Controls	YES	YES	YES	YES
Economy Wide Controls	YES	YES	YES	YES
Trimmed upper 1%	YES	YES	YES	YES

Note: Asterisks indicate the significance level at 5% (*) and 1% (**). The standard errors in parentheses are corrected for heteroscedasticity and serial correlation across clusters. Data Source: Swiss Federal Office of Energy.

- The effect of the CO_2 tax in 2019-2021 (CHF 96 per ton of CO_2eq) is in the industry sector a reduction of 23.9% (= 100 × (-0.239)) compared to the pre-policy period before 2008 (Model 3).

- The effect of the CO_2 tax in 2019-2021 (CHF 84 per ton of CO_2eq) is in the service sector a reduction of 19.8% (= 100 × (-0.198)) compared to the pre-policy period before 2008 (Model 4).

- ☝ Installations operating under a target agreement are not identified. Other policies might have an impact as well, e.g. the buildings program.

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Coefficient Plot for the Comparison of the Industry & the Service Sector based on the previous Regression
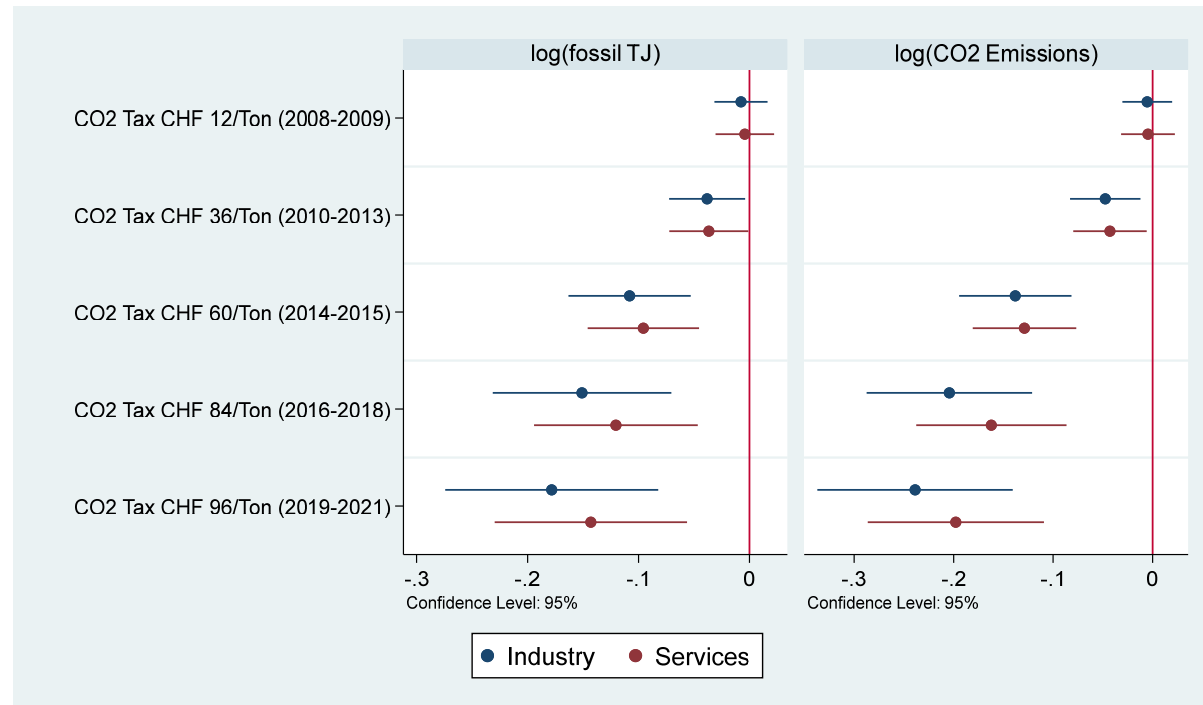
- Between 2008-2013 (tax rate ≤ CHF 36/ton), the impact of the CO_2 levy was small.
  → The impact of the tax rate = CHF 12/ton (= → CHF 3.18/100 l heating oil) was not significantly different from zero.

- Between 2014-2021 (tax rate ≥ CHF 60/ton), the impact of the tax was significantly different from zero and slightly higher in the industry than in the service sector.
  → Due to higher GHG emissions in the industry sector, the reduction potential might be higher than in the service sector.
  → However, the confidence intervals of the two sectors are still overlapping.

Price Chart of Heating Oil extra light (Data source: Federal Statistical Office)

Price Chart of Heating Oil 'extra light' and CO2 Levy, Category: 14'001 - 20'000 l (January 2006 - August 2022)
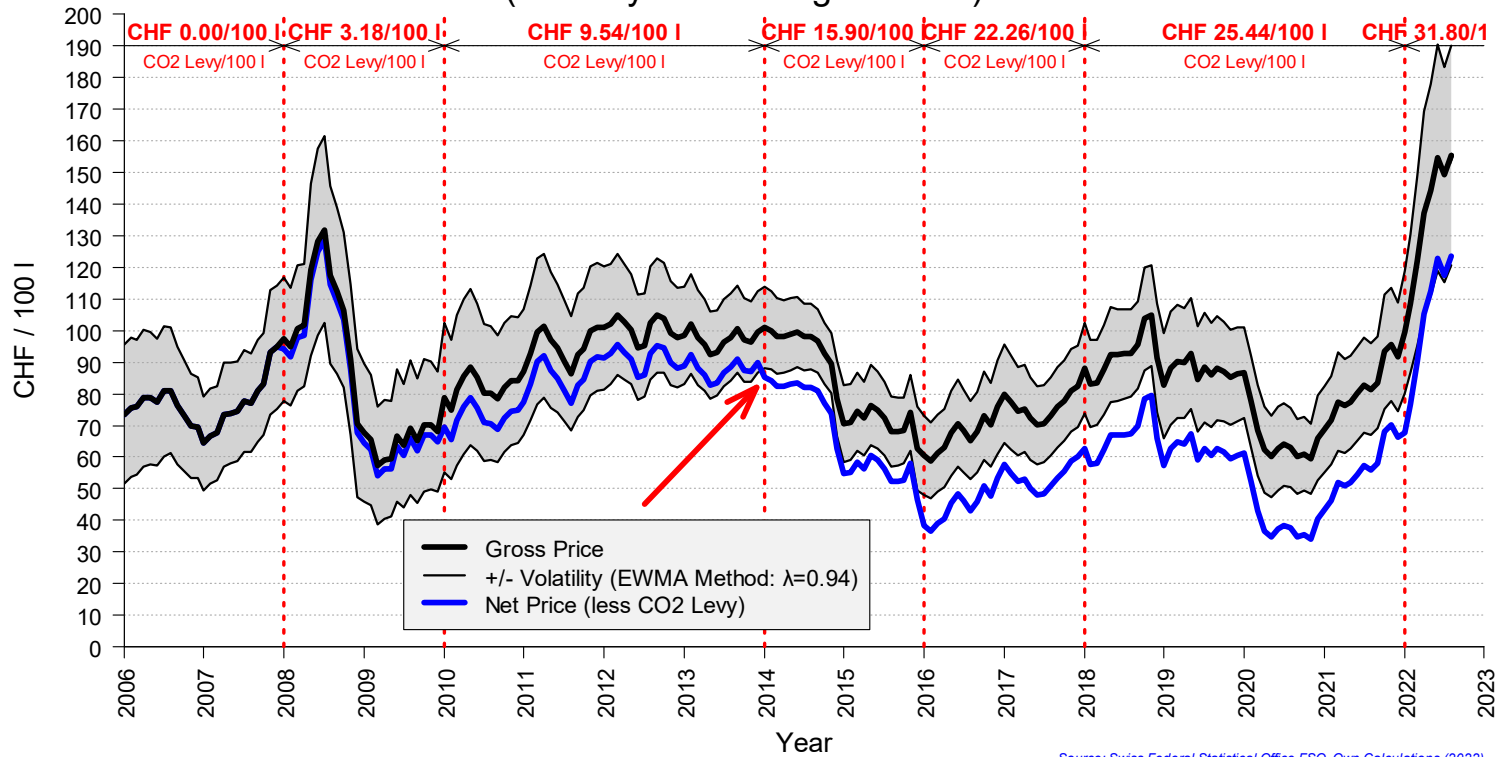
Source: Swiss Federal Statistical Office FSO, Own Calculations (2022)

- Gross price of heating oil extra light: **black line.**

- Net price (= gross price − CO_2 tax) of heating oil extra light: **blue line.**

- From 2016 onwards, the net price dropped out of the natural price fluctuations of heating oil.

- Consistent with the results of the econometric analysis: The impact of the low CO_2 taxes, in the first years after its introduction, was quite limited.

Conclusion and Outlook I

What is the effect of the Swiss climate policy mix on firms energy consumption and CO_2 emissions in the industry and service sector?

- Substantial reductions in the CO_2 emissions for the average firm in the industry and service sector are possible, especially so when the CO_2 emissions are heavily taxed (levy $\geq$ CHF 60 / ton CO_2eq).

- The estimation results must be primarily driven by the CO_2 levy. In order to avoid paying the CO_2 levy (the stick) companies must agree to an emissions target in exchange (the carrot).

- However, to test the null-hypothesis, which states that the impact on greenhouse gas emissions mitigations does not differ between the two groups, firms operating under a target agreement must be identified. This is ongoing work as this presentation has shown.

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What are the challenges facing such a research question?

- Data collecting from a federal as well as from private institution is extensively time consuming.

- SFOE data is collected by survey on installation level, whereas data from the Energy Agency is on company level:
$\rightarrow$ Target agreements versus CO_2 taxes can be disaggregated down to the company level.
$\rightarrow$ The distribution of the reductions among the individual installations belonging to the same company cannot be identified.
$\rightarrow$ However, without linking these two datasets, such information is missing (see previous study).

- Another confounder is the national buildings program.

- Self selection into the target agreement must be considered as well.

Conclusion and Outlook III

There is an ongoing political discussion of eliminating entry restrictions (see slide 6) for the participation in the target agreements program and being exempted from the CO_2 levy instead.

Research to quantify these two instruments is necessary!
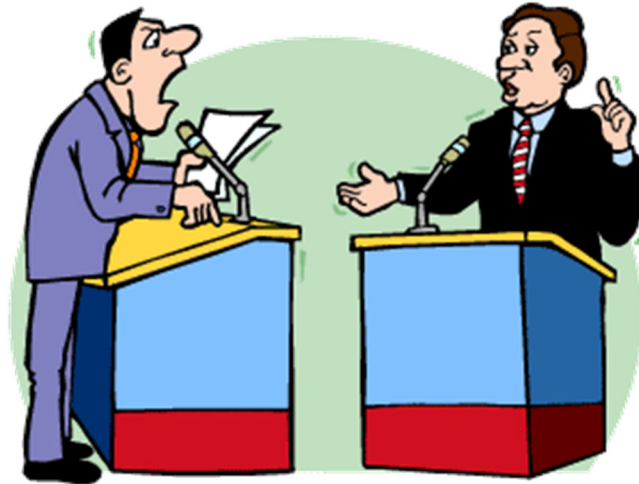
Thank you very much for your attention.

Grazia fitg

Thomas Leu / Armin Eberle