

# The Impact of the Swiss Climate Policy Instruments on the Energy Consumption and Greenhouse Gas Emissions in the Industry and the Service Sector: Evidence from an Ex-Post Evaluation of Microdata



Building Competence. Crossing Borders.

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**What is the effect of the Swiss climate policy mix on firms energy consumption and CO<sub>2</sub> emissions in the industry and service sector?**

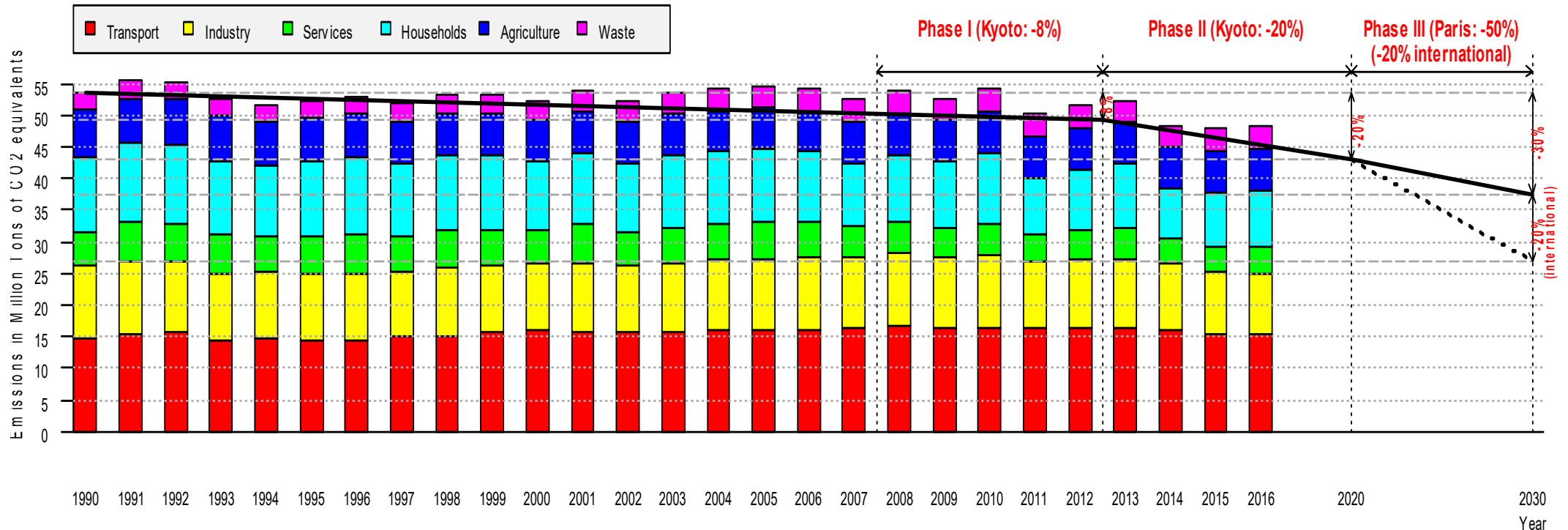
**How much impact have different carbon tax rates on the emissions mitigation?**

# Outline of the presentation

- **Introduction**
- **Research question**
- **Literature**
- **Climate policy instruments for the industry and the service sector**
- **The CO<sub>2</sub> levy and economic incentives**
- **Data**
- **Empirical strategy**
- **Main results**
- **Conclusion**

# Evolution of Switzerland's greenhouse gas emissions by sector, 1990 – 2016 (Data source: FOEN)

Evolution of Switzerland's Greenhouse Gas Emissions by Sector, 1990-2016 (Kyoto Targets for 2012 and 2020 & Paris Target for 2030 indicated)



Source: Swiss Federal Office for the Environment FOEN, Own Calculations (2018)

- In 2016, the industry and service sector accounts for 29.1% (yellow and green bars) of the total greenhouse gas emissions of 48.29 million tons of CO<sub>2</sub>eq.

# Research Question

## Main research question

- What is the effect of the Swiss climate policy mix on firms fossil fuel energy consumption and CO<sub>2</sub> emissions in the industry and service sector?

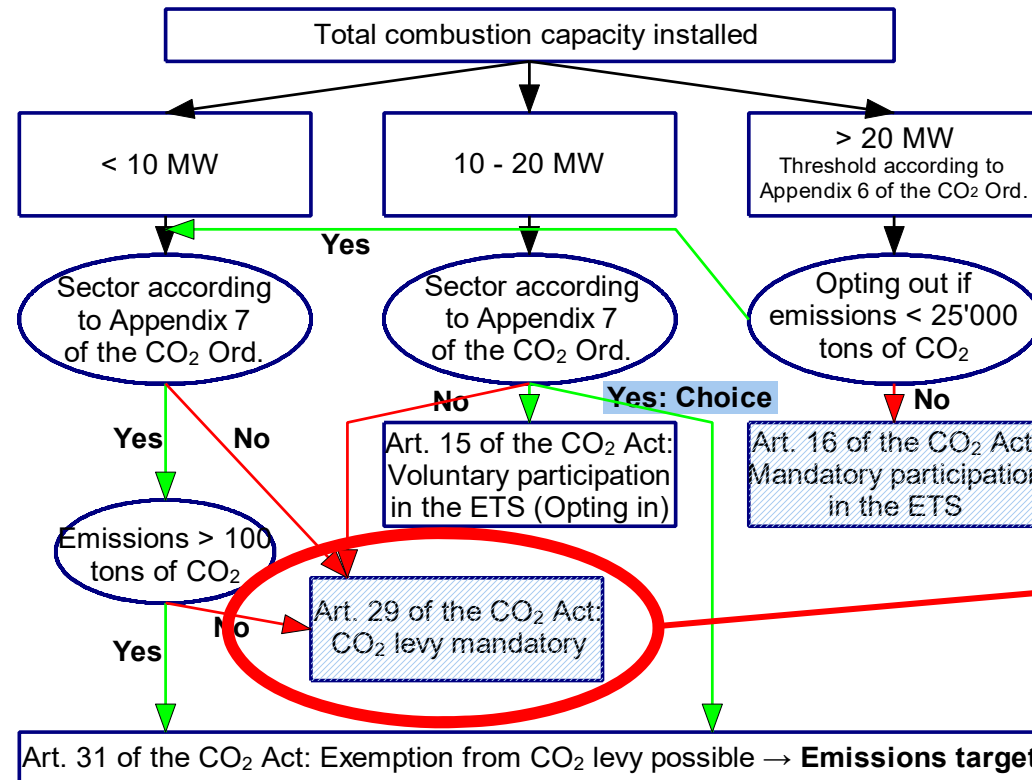
## Objectives

- Quantitative ex-post evaluation of the Swiss climate policy mix (CO<sub>2</sub> levy, target agreement, CH ETS) introduced in 2008.
- Quantifying the impact of different carbon tax rates on the carbon emissions mitigation in the industry and service sector.

# Literature

- «Worldwide 45 national and 25 subnational jurisdictions - representing about half of the global economy and 20% of global GHG emissions - are putting a price on carbon.»  
State and Trends of Carbon Pricing 2018. Annual World Bank Report
- «Detailed overview of ex-post evaluations of explicit carbon taxes.»  
Environmental Tax Evaluation. What can be learnt so far? Leu, T., & Betz, R. (2016)
- «The climate change levy caused plants paying the full rate to reduce CO<sub>2</sub> emissions by between 8.4% and 22.6% more compared to plants that paid the reduced rate.»  
The impact of a carbon tax on manufacturing: Evidence from microdata.  
Martin, R., De Preux, L. B., & Wagner, U. J. (2014)
- «CO<sub>2</sub> mitigation caused by the CO<sub>2</sub> levy varies between 4.3% to 7.1%.»  
Wirkungsabschätzung CO<sub>2</sub>-Abgabe: Synthese. Ecoplan, EPFL, & FHNW. (2015).  
Report on behalf of the Federal Office for the Environment FOEN

# The three main climate policy instruments available in the Swiss Industry and Service Sector



**The CO<sub>2</sub> levy is the instrument for the majority of the firms in the sample.**

- **CO<sub>2</sub> levy:**  
Carbon tax imposed on fossil heating fuels (Default for the majority of the companies).
- **Emissions trading scheme (ETS):**  
Mandatory for 56 CO<sub>2</sub>-intensive companies («cap-and-trade»-principle).
- **Exemption from the CO<sub>2</sub> levy** possible for CO<sub>2</sub>-intensive companies under certain conditions.  
In return, companies have to commit to an **emissions target**.

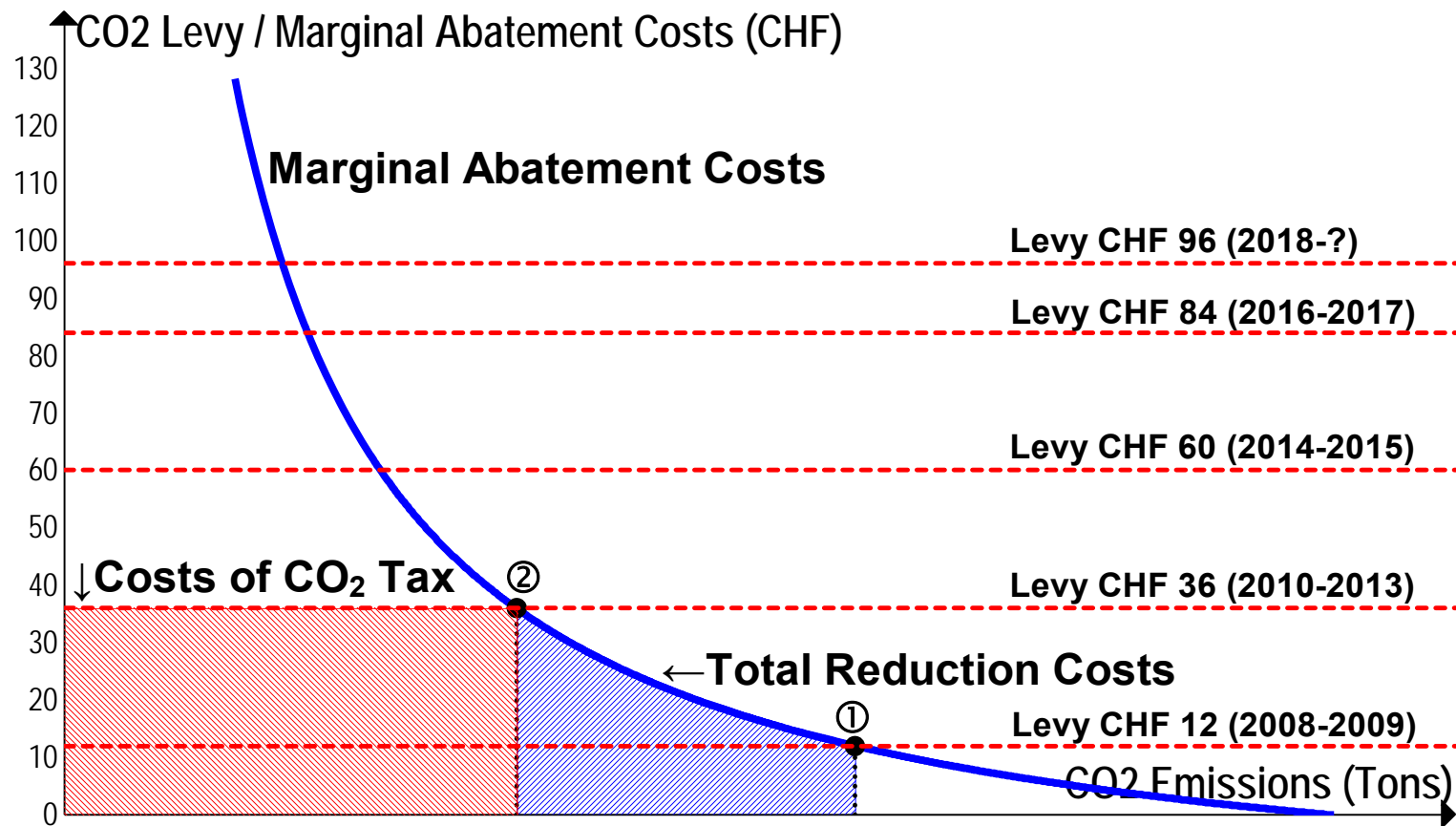
# Taxation of carbon and energy by fuel type and annual crude oil price in CHF/Barrel (Source: FOEN, OECD)

Basic value referring to the CO <sub>2</sub> Ordinance		CHF/Terajoule = CHF/ton of CO <sub>2</sub> × tons of CO <sub>2</sub> /TJ				Oil price (CHF/B.)
year	CHF/ton CO <sub>2</sub>	Heating oil extra light	Heating oil medium / heavy	Other liquid Fuels	Natural gas	Crude oil
2008	12	885	924	1,096	673	109.42
2009	12	885	924	1,096	673	68.85
2010	36	2,654	2,772	3,289	2,020	84.39
2011	36	2,654	2,772	3,289	2,020	99.91
2012	36	2,654	2,772	3,289	2,020	104.36
2013	36	2,654	2,772	3,289	2,020	102.28
2014	60	4,423	4,620	5,482	3,366	93.36
2015	60	4,423	4,620	5,482	3,366	52.33
2016	84	6,192	6,468	7,674	4,712	44.08

Note: On 1 January 2018 the levy was again increased to CHF 96 per ton of CO<sub>2</sub> equivalent. (CHF 1 ≈ USD 1 ≈ EUR 0.85: May 2018).



# Economic incentives for applying for an exemption from the CO<sub>2</sub> Levy



- **Starting position:** CO<sub>2</sub> tax increases from CHF 12 to CHF 36 per ton of CO<sub>2</sub>eq.
- 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.

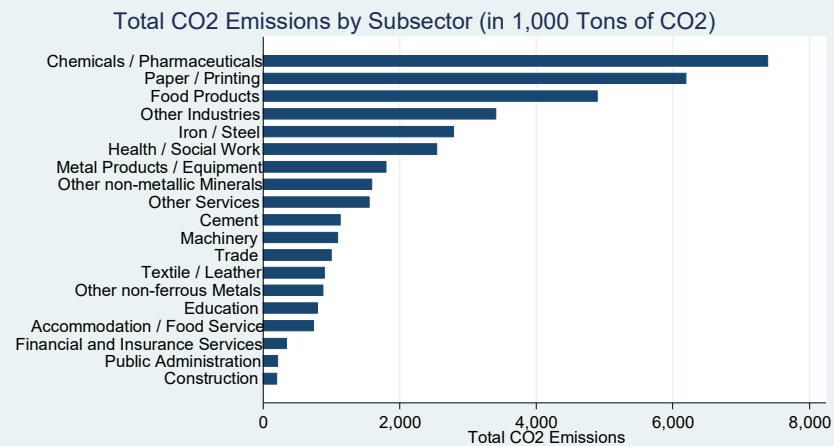
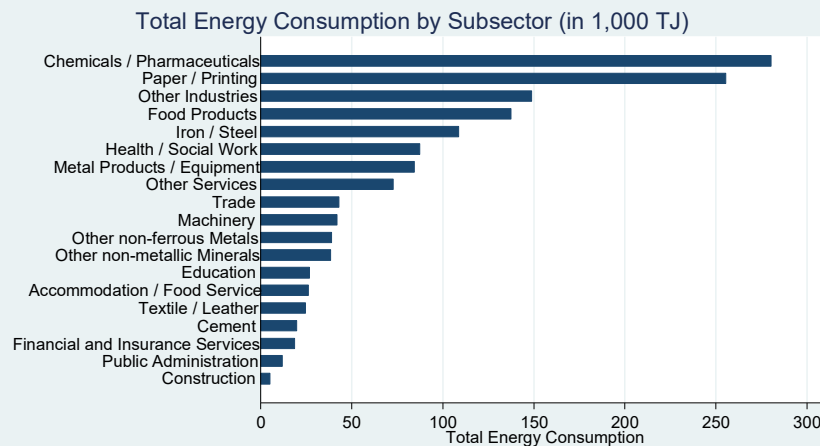
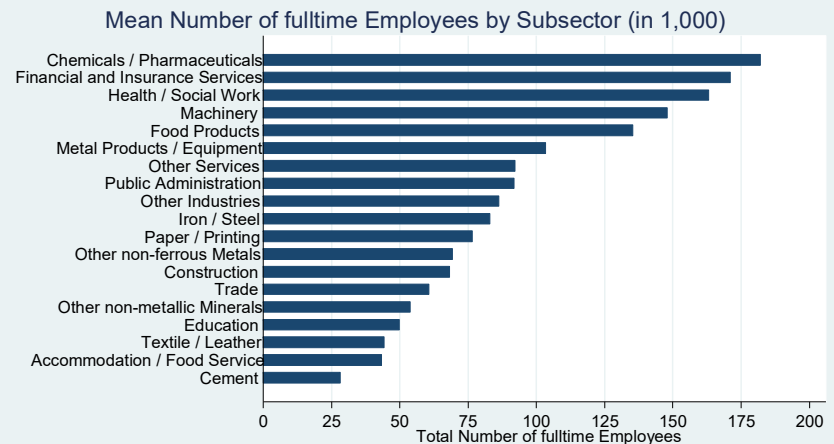
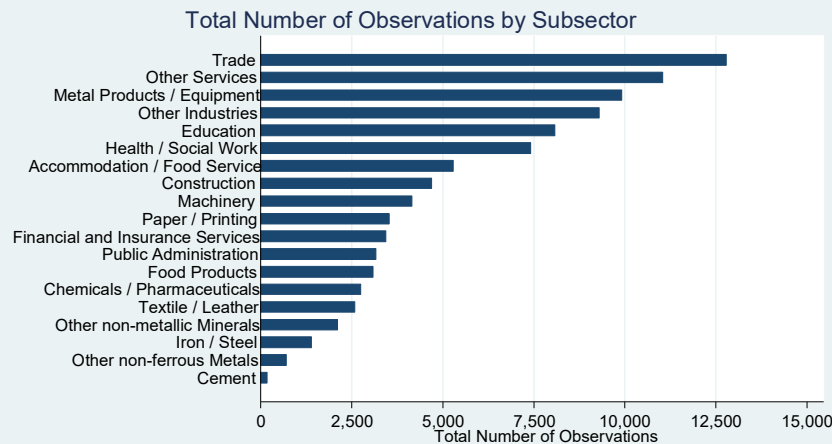
# Data I: Panel data sample

## Firm-level (unbalanced panel) data from the Swiss Federal Office of Energy (SFOE) for the years 1999-2016

- **Estimation sample**
  - 95,531 observations, N = 22,469 firms, T = 18 years
- **Outcome variables**
  - Overall energy consumption by energy sources in TJ
  - CO<sub>2</sub> emission overall and by energy sources in tons (by own calculation)
- **Firm characteristics**
  - Sector and industry indicators, number of full- and part-time employees, firm size (floor area in m<sup>2</sup>)
- **Economy wide information**
  - Heating degree days, indicator of economic activity, real oil price index

# Data II: Graphical summary of sample variables by 19 sectors

## Observations, Employees, Energy Consumption and CO2 Emissions Switzerland, 1999-2016



Data Source: Swiss Federal Office of Energy

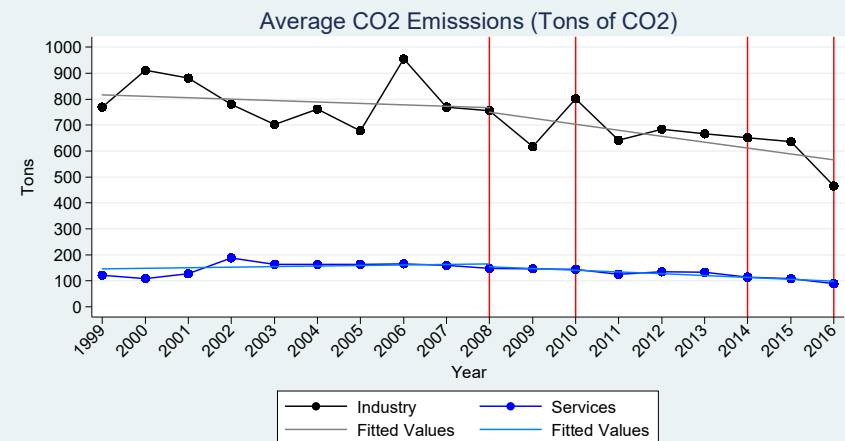
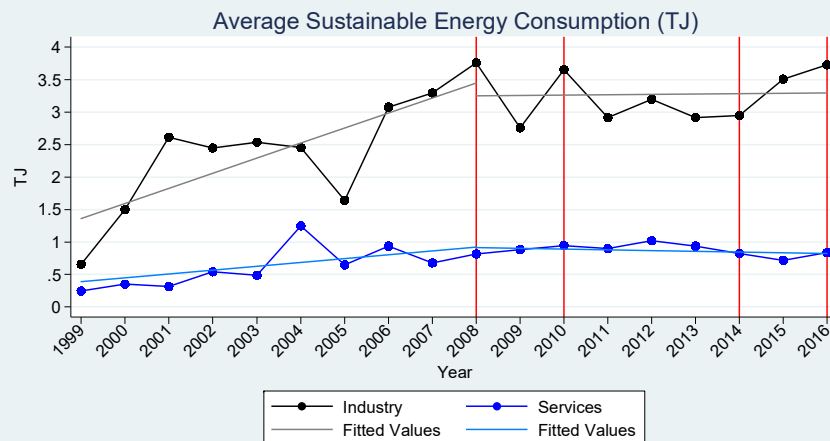
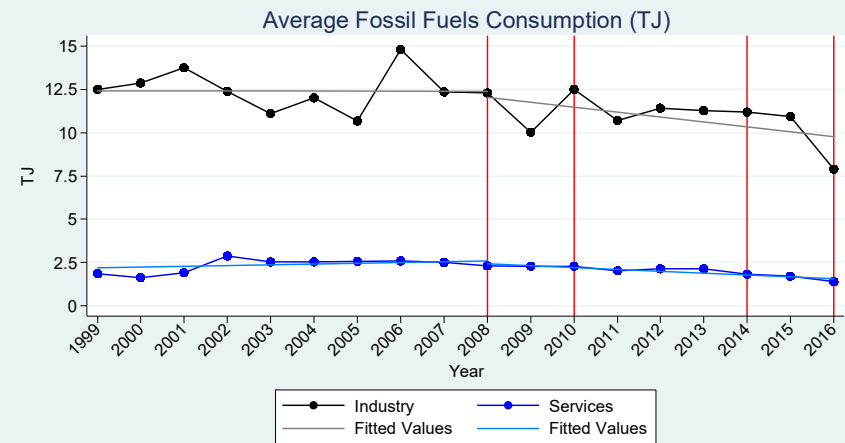
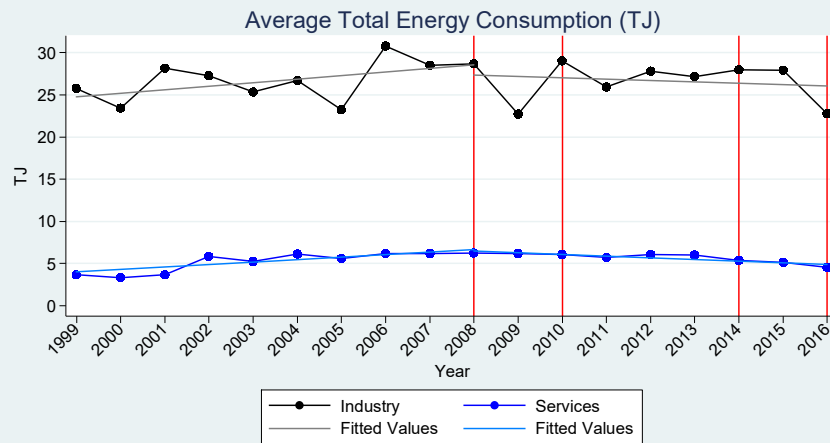
# Data III: Summary statistics of mean energy consumption and carbon emissions by treatment (before / after)

VARIABLES	Before 2008		After 2008		Difference	T-Value
	N = 44,151		N = 51,380			
	mean	sd	mean	sd		
Net Electricity Consumption in TJ	6.53	54.00	6.47	45.54	0.06	0.19
<b>Heating Oil extra light in TJ</b>	<b>1.94</b>	<b>7.72</b>	<b>1.08</b>	<b>4.26</b>	<b>0.86</b>	<b>21.70*</b>
<b>Heating Oil medium / heavy in TJ</b>	<b>0.58</b>	<b>18.50</b>	<b>0.20</b>	<b>8.26</b>	<b>0.38</b>	<b>4.21*</b>
Other liquid Fuels in TJ	0.36	36.88	0.14	16.33	0.22	1.21
Natural Gas in TJ	4.51	49.59	4.49	42.23	0.02	0.07
Net consumption of Local and District Heating in TJ	1.04	25.59	1.21	21.38	-0.17	-1.11
Natural Wood in TJ	0.25	9.09	0.22	5.11	0.03	0.54
Old Wood, Scrap Wood in TJ	0.23	7.77	0.49	23.14	-0.26	-2.24*
Industrial Waste in TJ	0.53	21.53	0.57	18.91	-0.04	-0.31
Total Energy Consumption in TJ	15.97	129.34	14.87	109.84	1.10	1.42
<b>Total Fossil Fuels in TJ</b>	<b>7.39</b>	<b>67.73</b>	<b>5.91</b>	<b>47.04</b>	<b>1.48</b>	<b>3.97*</b>
<b>Total CO<sub>2</sub> Emissions in tons</b>	<b>473.49</b>	<b>4,830.10</b>	<b>359.59</b>	<b>2,945.82</b>	<b>113.90</b>	<b>4.47*</b>

Note: Asterisks indicate the significance level at 5% (\*). Data Source: Swiss Federal Office of Energy

# Data IV: Evolution of the average energy consumption in TJ and CO<sub>2</sub>eq. in tons between 1999 and 2016.

## Average Energy Consumption and CO<sub>2</sub> Emissions (TJ/Tons) Switzerland, 1999-2016



Data Source: Swiss Federal Office of Energy

# Empirical strategy I

## Main empirical goal:

Isolate the effect of the Swiss CO<sub>2</sub> levy on the energy consumption and CO<sub>2</sub> emissions in the service and industry sector.

## Empirical challenges:

- Firms **self-select** into different climate policies
  - **No information** in the data available regarding the question **what policies** apply to specific firms!
  - **Solution:** Only a negligibly small share of firms in the underlying survey sample is supposed to be exempted from the tax. Therefore, the estimation results must be primarily driven by the CO<sub>2</sub> tax.
- Disentangling the different **channels** (e.g. policy effect, heating degree days, economic activity, real crude oil price) explaining the observed reduction in the firms energy consumption and emissions.

# Empirical strategy II

How to capture the impact of the **average** policy effects within a firm, e.g. the tax raises at the different points in time, on firms energy consumption and emissions?

## Firm fixed-effects regression model:

- Exploit **within-firm** variation to estimate the effects for a typical firm in the sample caused by policy changes such as carbon tax raises at different points in time.
- Avoid unobserved **between-firms** variation caused by **time-invariant** firm-specific differences among firms.
- Controlling for economy wide (not firm-specific) indicators.

# Empirical strategy III

Fixed-effects specification:

$$y_{it} = post\_policy'_t \tau + x'_{it} \beta + a'_t \gamma + \alpha_i + \varepsilon_{it}$$

where

- $y_{it}$ : Outcome: Energy consumption in TJ / Emissions of firm  $i$  in year  $t$
- $post\_policy_t$ : Dummy vector for post-policy years (baseline: pre-policy period)
- $x_{it}$ : Vector of firm-specific characteristics (e.g. firm size, number of employees)
- $a_t$ : Vector of economy-wide indicators (e.g. oil price changes, heating degree days, time trends to capture technological progress)
- $\alpha_i$ : Firm fixed-effects (e.g. attitude of management towards clean energy, etc.)
- $\varepsilon_{it}$ : Error term
- Trimming the upper 1% to exclude the ETS companies (Appendix 6 of the CO<sub>2</sub> Ord.).



# Results I: Summary of the fixed effects regression estimates for the consumption of fossil fuels in terajoule (elasticities)

Dependent variable: log(fossil TJ)	Model 1	Model 2	Model 3	Model 4
Regressor				
Dummy CO <sub>2</sub> Tax CHF 12 (2008, 2009)	-0.0360** (0.00871)	-0.0507** (0.00998)	0.0108 (0.0120)	<b>0.0106</b> (0.0121)
Dummy CO <sub>2</sub> Tax CHF 36 (2010, 2011, 2012, 2013)	-0.0792** (0.0110)	-0.101** (0.0151)	-0.0448* (0.0187)	<b>-0.0432*</b> (0.0187)
Dummy CO <sub>2</sub> Tax CHF 60 (2014, 2015)	-0.212** (0.0150)	-0.244** (0.0217)	-0.108** (0.0294)	<b>-0.106**</b> (0.0294)
Dummy CO <sub>2</sub> Tax CHF 84 (2016)	-0.207** (0.0182)	-0.224** (0.0266)	-0.139** (0.0445)	<b>-0.134**</b> (0.0443)
R-squared (within)	0.012	0.043	0.052	<b>0.050</b>
Firm Specific Controls	NO	YES	YES	<b>YES</b>
Economy Wide Controls	NO	NO	YES	<b>YES</b>
Trimmed upper 1%	NO	NO	NO	<b>YES</b>

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.

- By controlling for other effects, the CO<sub>2</sub> levy has a significant negative impact on the fossil fuel consumption.
- The effect is stronger, the higher the CO<sub>2</sub> tax (In 2016 the impact is -13% compared to the baseline period (years 1999-2007)).
- Control variables behave as expected.

# Results II: Summary of the fixed effects regression estimates for the emissions of CO<sub>2</sub> (elasticities)

Dependent variable: log(CO <sub>2</sub> )	Model 1	Model 2	Model 3	Model 4
Regressor				
Dummy CO <sub>2</sub> Tax CHF 12 (2008, 2009)	-0.0490** (0.00871)	-0.0560** (0.0100)	0.00894 (0.0121)	<b>0.00860</b> (0.0121)
Dummy CO <sub>2</sub> Tax CHF 36 (2010, 2011, 2012, 2013)	-0.103** (0.0110)	-0.112** (0.0151)	-0.0544** (0.0188)	<b>-0.0532**</b> (0.0187)
Dummy CO <sub>2</sub> Tax CHF 60 (2014, 2015)	-0.248** (0.0150)	-0.261** (0.0218)	-0.127** (0.0295)	<b>-0.125**</b> (0.0295)
Dummy CO <sub>2</sub> Tax CHF 84 (2016)	-0.246** (0.0181)	-0.241** (0.0267)	-0.164** (0.0446)	<b>-0.161**</b> (0.0443)
R-squared (within)	0.017	0.046	0.058	<b>0.055</b>
Firm Specific Controls	NO	YES	YES	<b>YES</b>
Economy Wide Controls	NO	NO	YES	<b>YES</b>
Trimmed upper 1%	NO	NO	NO	<b>YES</b>

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.

- By controlling for other effects, the CO<sub>2</sub> levy has a significant negative impact on the greenhouse gas emissions.
- The effect is stronger, the higher the CO<sub>2</sub> tax (In 2016 the impact is -16% compared to the baseline period (years 1999-2007)).
- Control variables behave as expected.

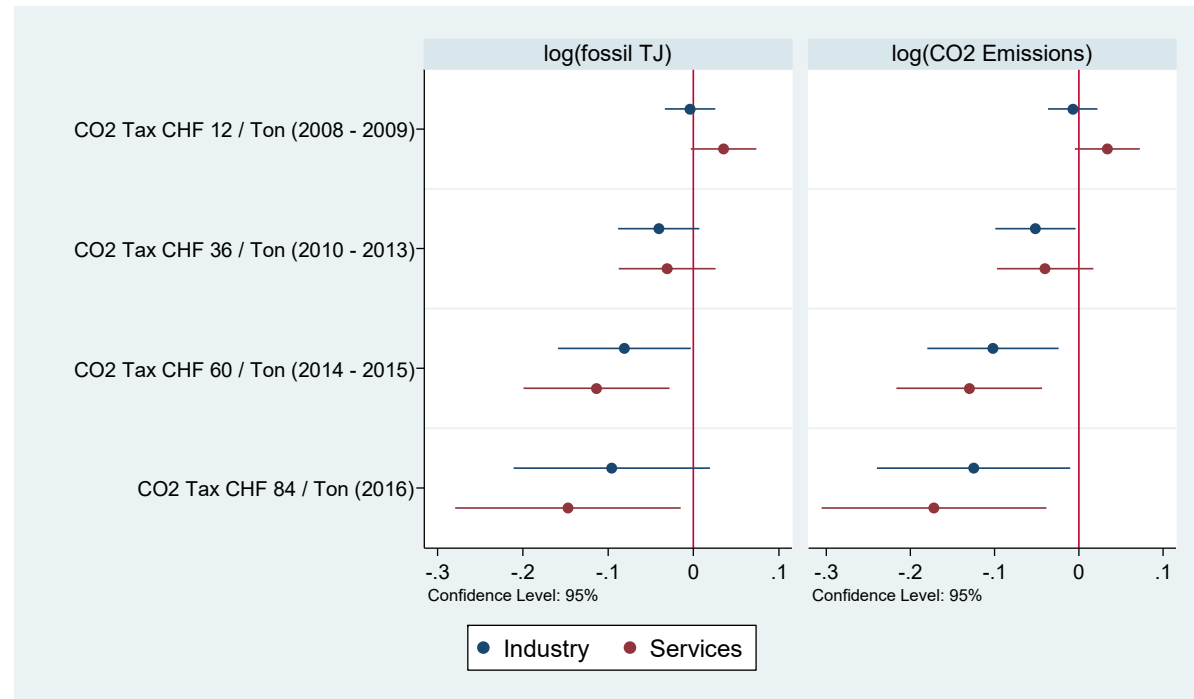
# Results III: Summary of the fixed effects regression estimates for the comparison of the industry and the service sector

Dependent variable:	log(CO <sub>2</sub> )	log(CO <sub>2</sub> )
Regressor	Model 2A	Model 2B
Dummy CO <sub>2</sub> Tax CHF 12 (2008, 2009)	-0.00720 (0.0150)	0.0339 (0.0197)
Dummy CO <sub>2</sub> Tax CHF 36 (2010, 2011, 2012, 2013)	-0.0517* (0.0243)	-0.0401 (0.0292)
Dummy CO <sub>2</sub> Tax CHF 60 (2014, 2015)	-0.102* (0.0398)	-0.130** (0.0441)
Dummy CO <sub>2</sub> Tax CHF 84 (2016)	-0.125* (0.0586)	-0.172* (0.0680)
R-squared (within)	0.052	0.063
Sector	Industry	Services
Trimmed upper 1%	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 main findings remain unchanged.
- The effect of the CO<sub>2</sub> tax in 2016 (CHF 84 per ton of CO<sub>2</sub>eq) is in the industry sector a reduction of 12.5% (= 100 × (-0.125)) compared to the pre-policy period (before 2008).
- The effect of the CO<sub>2</sub> tax in 2016 (CHF 84 per ton of CO<sub>2</sub>eq) is in the service sector a reduction of 17.2% (= 100 × (-0.172)) compared to the pre-policy period.

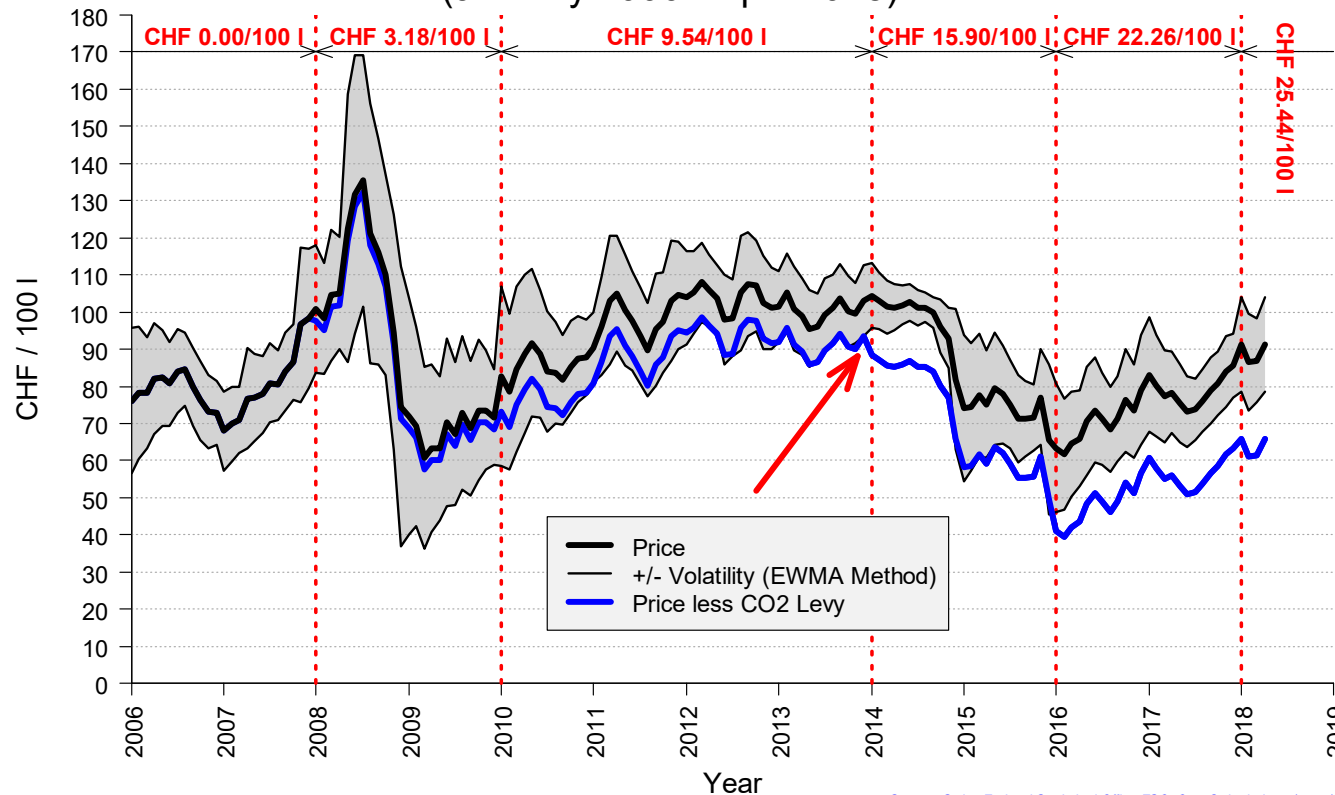
# Results IV: Coefficient plot for the comparison of the industry and the service sector based on the previous regression



- Between 2008 – 2013 (tax rate  $\leq$  CHF 36/ton), the impact of the tax was slightly higher in the industry sector than in the service sector.
- Between 2014 – 2016 (tax rate  $\geq$  CHF 60/ton), the impact of the tax was slightly higher in the service sector than in the industry sector.
- This might be due to more reduction potential in the service sector (lower marginal abatement costs because of potentially more low-hanging fruits). The impact of the CO<sub>2</sub> levy in the service sector could also be confounded through the contributions of the **buildings programme**.
- However, the differences between the two sectors are not significant (CIs' not overlapping).

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

Price Chart of Heating Oil 'extra light' and CO<sub>2</sub> Levy, Category 3'001–6'000 l  
(January 2006 - April 2018)



Source: Swiss Federal Statistical Office FSO, Own Calculations (2018)

- Gross price of heating oil extra light: **Black line.**
- Net price (= gross price – CO<sub>2</sub> tax) of heating oil extra light: **Blue line.**
- Only since 2016 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<sub>2</sub> taxes in the first years after its introduction was quite limited.

# Conclusion and Outlook

## What is the effect of the Swiss climate policy mix on firms energy consumption and CO<sub>2</sub> emissions in the industry and service sector?

- The analysis shows **substantial reductions in the CO<sub>2</sub> emissions** for the average firm in the industry and service sector post-policy, especially so when the CO<sub>2</sub> emissions are heavily taxed (levy  $\geq$  CHF 60 / ton CO<sub>2</sub>eq).
- The estimation results must be primarily driven by the CO<sub>2</sub> tax. In order to avoid paying the CO<sub>2</sub> tax (the stick) companies must agree to an emissions target in exchange (the carrot).

## Outlook

- Further isolation of the effect of CO<sub>2</sub> taxes on emissions could include firm-specific weighted (average) carbon taxes, with weights corresponding to firm shares of the different energy sources (i.e. light fossil fuel, natural gas, etc.) that differ in their CO<sub>2</sub> and tax intensity.

**End of the presentation**

**Thank you very much for your  
attention.**

**Thomas Leu**