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

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ABSTRACT

This paper empirically evaluates the impact of the Swiss climate policy mix introduced in 2008 on the energy consumption and greenhouse gas emissions of firms[1] in the service and industry sector. These sectors contribute roughly to 35% of the final energy consumption and 30% of the emissions. To achieve the 2020 emission targets, the Swiss government employs various policy measures, including price-based instruments, such as emissions trading and the CO_2 levy[2], and non-price-based instruments, such as binding emission targets or building codes. Emission trading is mandatory for companies passing a certain emission threshold. Other measures are optional and allow for an exemption of the levy.

The impact of these energy policies on energy consumption is tested, using a representative sample of more than 22,000 firms in Switzerland, ranging from 1999 to 2016. Panel data regression models are applied in order to identify time-varying policy effects, such as increasing CO_2 taxes, and to isolate them from time-independent, unobserved firm-specific factors. Time trends allow us to capture technological progress. Controlling for other effects including heating degree-days or the growth rate of the economy, we conclude that Switzerland's energy and climate policy has a significant impact on the energy consumption in the industry and service sector.

The paper contributes to the literature on energy and associated greenhouse gas mitigation with its analysis of the effects of introducing multiple climate instruments on Swiss firms. Our results can assist governments to design and adjust policy instruments in order to meet the 2030 Paris goals.

[1] With the term "firm", we mean a separated unit of a company in which employees work in a building, a building complex or in a part of a building. Since our data includes the industry and the service sector, we generally use the term "firm" instead of "plant". The term "company" refers to groups of firms legally held by a parent company.

[2] CO_2 levy is the official name of the carbon tax on fossil heating fuels in Switzerland. Generally, we use the terms "CO_2 levy", "CO_2 tax" and "carbon tax" as synonyms.

Introduction

In 2016, the industry and service sector's share of the total greenhouse gas emissions (GHG) of 48.29 million tons of CO_2eq[3] was 28.9% (Röthlisberger et al., 2018). Switzerland's GHG target for the second Kyoto commitment period (2013 - 2020) is a 20 percent reduction compared to 1990 levels (see Federal act on the reduction of CO_2 emissions, article 3, paragraph 1[4]). Figure 1 shows the evolution of Switzerland's greenhouse gas emissions by sector. Kyoto targets for 2012 and 2020, as well as the Paris targets are indicated.

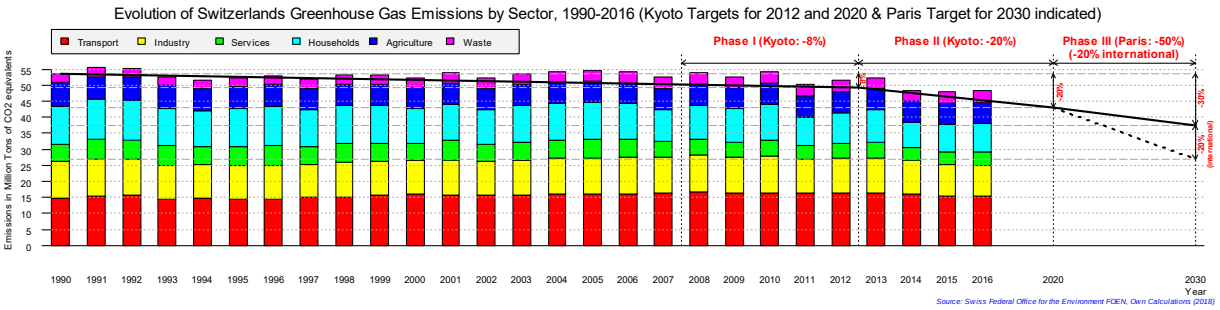

Figure 1: Evolution of Switzerland's greenhouse gas emissions by sector, 1990 - 2016. In 2016, the industry and service sector's share of the total greenhouse gas emissions of 48.29 million tons of CO_2eq was 29.1%. The graph shows Switzerland's emission targets Kyoto I and II as well as Paris 2030. Data Source: Federal Office for the Environment.

In order to achieve this target, the Swiss CO_2 act provides a broad mix of different policy instruments. The most important measure, relevant for the industry and service sector, is the CO_2 levy. The tax base of the CO_2 levy are fossil heating fuels (e.g. heating oil, natural gas, coal) in various sectors[5]. The CO_2 ordinance predefined tax increases as soon as certain emission reduction targets have not been achieved (Article 94 of the CO_2 Ordinance). The initial rate of the tax was CHF 12 per ton of CO_2eq emitted in 2008. The tax was raised in 2010 to CHF 36, in 2014 to CHF 60, in 2016 to CHF 84 and in 2018, it was raised again to CHF 96 per ton of CO_2eq emitted. In 2016, the public revenue from the CO_2 levy was more than CHF 1.074 billion[6].

Literature

In order to achieve the pledge of the Paris agreement, which aims to keep the global average temperature increase to well below 2°C and pursues efforts to limit the increase to 1.5°C, carbon pricing has a substantial role among the climate policy instruments. According to the latest World Bank report (World Bank & Ecofys, 2018) 45 national and 25 subnational jurisdictions - representing about half of the

[3] CO_2eq are CO_2 equivalents; a measured variable that includes CO_2 emissions from fossil fuel use as well as all other greenhouse gas emissions. Generally, we use the terms "GHG", "CO_2" and "CO_2eq" as synonyms.

[4] see https://www.admin.ch/opc/en/classified-compilation/20091310/index.html#a3

[5] Motor fuels are not taxed by the CO_2 levy. Importers of motor fuels are, however, required to domestically compensate 10% of the CO_2 emissions caused by transport by 2020. The transport sector contributes roughly to about one third of the GHG emissions in Switzerland.

[6] Around two third of the levy revenues is uniformly redistributed annually to all residents of Switzerland and to the business community in proportion to their employees' social insurance contributions. One third of the revenue up to a maximum of CHF 450 million flows into the buildings programme for energy efficiency renovations. CHF 25 million is transferred to the technology fund to promote innovative technologies that reduce greenhouse gas emissions and the consumption of resources, support the use of renewable energy and increase energy efficiency.

global economy and 20% of global GHG emissions - are putting a price on carbon, either by taxing emissions, or by using an emissions trading system (ETS). The observed carbon prices vary between less than USD 1 up to USD 140/ton of CO_2eq. It can be assumed, that carbon prices between USD 40 – 80/ton of CO_2eq in 2020 are consistent with the Paris climate goals[7]. Leu and Betz (2016) give a detailed overview of ex-post evaluations of explicit carbon taxes[8]. They discuss difficulties in implementing experimental designs with a proper counterfactual, noting that quasi-experimental methods such as "before and after", "difference in difference" or "fixed effect" models play a dominant role in ex-post evaluation. To avoid the data limitations, computable general equilibrium approaches have turned out to be the best alternative to econometric analysis. However, since CGE results depend on the assumptions made, they often overrate the impacts of a policy change. In addition to the papers already analysed in Leu and Betz (2016), the study by Martin, De Preux, and Wagner (2014) covers similar issues regarding data and methods as addressed in this paper. The authors estimate the impact of a carbon tax on manufacturing plants using panel data from the UK. They compare outcomes between plants subject to the full tax with plants that paid only 20% of the tax. In their paper, they revealed that the carbon tax had a strong negative impact on energy intensity and electricity. Finally, they found out that the climate change levy caused plants paying the full rate to reduce CO_2 emissions by between 8.4% and 22.6% more compared to plants that paid the reduced rate. According to the authors, their study was the first ex-post analysis of the causal impact of such a tax on manufacturing. However, their data was limited to the manufacturing sector, whereas this study is able to compare the industry as well as the service sector.

Regarding Switzerland, three publications on the CO_2 levy are worth mentioning here. Jakob et al. (2016) investigate the impact of the CO_2 levy on emissions-related decisions of the companies. They have conducted an extensive company survey. Based on the survey results, they conclude that companies with high CO_2 emissions have reacted earlier than other companies. These companies tend to include the CO_2 tax into their operative and strategic decisions. For companies with a low-emission level, the low CO_2 taxes of CHF 12 and CHF 36 have not been a strong enough incentive for them to implement emission reduction measures at all. On behalf of the Federal Office for the Environment, two ex-post evaluations of the Swiss CO_2 levy were conducted (Ecoplan, EPFL, & FHNW, 2015). In order to avoid the problem of adequate micro data, the researchers have applied two models. Model A is a time series analysis based on aggregate data; this model is a partial analysis that comprises the two sectors households and economy (industry and services). They have calculated two scenarios: a reference scenario including the CO_2 levy from 2008 to 2013 and a hypothetical scenario without CO_2 levy as a counterfactual for the same period. The extrapolation for these two scenarios is based on data that reaches back to 1978. The mitigation effect of the levy is the difference between the reference scenario and the counterfactual. Model B calculates the counterfactual using a computable general equilibrium approach with 18 sectors. The estimation results of the two models give upper and lower bounds of the CO_2 mitigation that range from 4.3 to 7.1 %.

The Three Main Policy Instruments Relevant to the Industry and Service Sector

According to the CO_2 Act, three policies on reducing greenhouse gases are available in the industry and service sector. The default is the CO_2 levy, which covers more than 50% of the GHG emissions in the industry and service sector. However, under the following conditions companies can be exempted from the carbon tax: (i) Companies exceeding a threshold of a total combustion capacity of 20 MW and being engaged in one of the activities referred to in Annex 6 of the CO_2 Ordinance are exempted. The companies

[7] see Stern and Stiglitz (2017)

[8] There must be a distinction made between explicit and effective carbon tax rates. Since energy production is taxed by other motives than environmental reasons, effective taxes rates tend to be higher than explicit carbon taxes. However, these implicit taxes are often difficult to identify. As a consequence, most of the studies focus on the impact of explicit carbon tax rates.

must belong to one of the following sectors: cement, chemicals and pharmaceuticals, refineries, steel, paper, district heating, steel and minor sectors. These companies then - in return - have to participate on a mandatory basis in the emissions trading scheme that started in 2008. The second phase began in 2013 and is running until 2020 and to date 56 CO_2-intensive companies have been involved in the second phase of the emissions trading scheme (Swiss Emissions Trading Registry, 2018). (ii) Companies with a total combustion capacity between 10 and 20 MW, which are engaged in an activity, referred to in Annex 7 of the CO_2 Ordinance can choose between voluntary participation in the ETS (opting-in) or to commit to a target agreement with the Federal Office for the Environment which leads to an exemption of the CO_2 tax. However, none of this second category of companies has actually decided to participate in the ETS on a voluntary basis. (iii) Smaller companies that do not reach the threshold of a total combustion capacity of 10 MW but are instead engaged in an activity referred to in Annex 7 of the CO_2 Ordinance can be exempted from the CO_2 tax and - in return - commit to a binding carbon emission target if their CO_2 emissions per year reach at least 100 tons. Figure 2 summarises this section by using a flow chart.

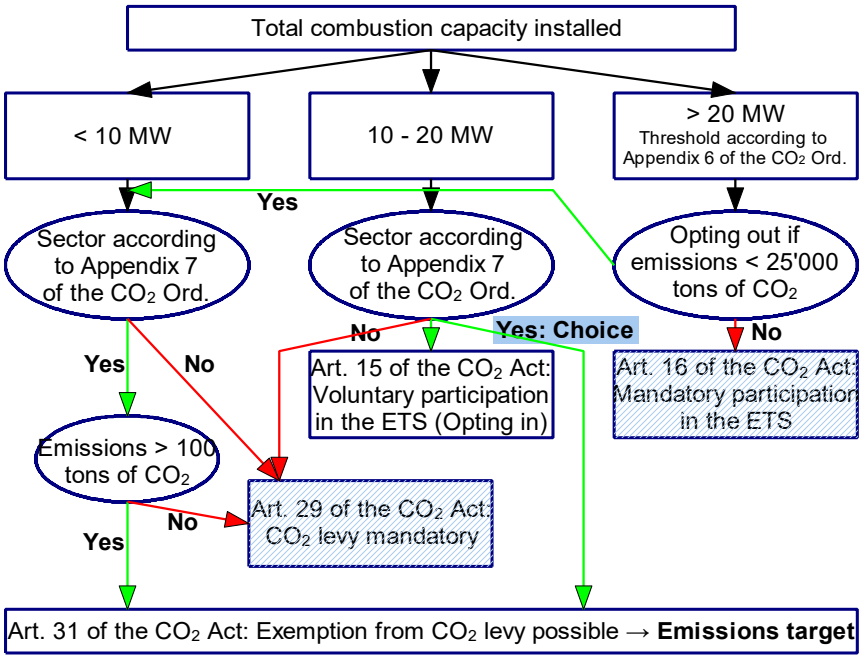

Figure 2: Climate policy instruments in the Swiss industry and the service sector. Source: Federal Office for the Environment.

However, this scheme covers by no means all of the climate and energy policies. Two additional instruments, relevant for the industry and service sector aiming to reduce GHG emissions, are provided by the Federal office for the environment. The first of these instruments is the buildings programme. One third of the revenue from the CO_2 levy has been earmarked for this programme, promoting energy-efficient renovations of buildings and investments in renewable energy. The second instrument is the technology fund, which aims at promoting innovative technologies that reduce GHG emissions and the consumption of resources, at supporting the use of renewable energy and at increasing energy efficiency. Out of the total revenue of the CO_2 levy, CHF 25 million go annually into this fund. The buildings programme overlaps with the three main instruments in the industry and service sector. The SFOE provides two other instruments regarding the electricity sector. One of these instruments is a cost-oriented feed-in tariff system which is established for the promotion of the electricity production by renewable energies. It is financed by a network surcharge. Electricity-intensive companies, however, can

have the network surcharge partially or fully refunded. The second instrument involves competitive calls for tenders to financially support efficiency measures aimed to reduce electricity consumption in the industry, trade and services sectors. The different instruments overlap economic sectors, interact with each other and can actually lead to inefficiencies as well. Betz, Leu, and Schleiniger (2015) disentangle these various links and the interactions amongst this policy mix that.

The CO_2 Levy and Economic Incentives

As mentioned before, tax raises are not ordered by a governmental decree. They follow a path foreseen in the CO_2 Act and which is explicitly described in the CO_2 Ordinance. The original tax levels are in CHF per ton of CO_2eq. These values can easily be converted in CHF per Terajoule by the use of carbon emissions factors. Table 1 illustrates the evolution of the CO_2 levy in its different units since its introduction in 2008. The last column lists the annual crude oil import prices in CHF per barrel. These prices are net import prices without any tax.

Table 1. Taxation of carbon and energy by fuel type and annual crude oil price in CHF/Barrel

Basic value referring to the CO_2 Ordinance		CHF/Terajoule = CHF/ton of CO_2 × tons of CO_2/TJ				Oil price (CHF/B.)
year	CHF/ton CO_2	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: The base value of the CO_2 levy is in CHF per ton of CO_2 equivalents. The tax is converted into CHF per terajoule. The CO_2 levy has been increased four times after the introduction in 2008 according to an emissions reduction path for thermal fuels that was predefined in Art. 94 of the CO_2 Ordinance. On 1 January 2018, the levy was again increased to CHF 96 per ton CO_2 (CHF 1 ≈ USD 1 ≈ EUR 0.85: May 2018). Source: Federal Office for the Environment, Organisation for Economic Cooperation and Development, Swiss National Bank.

In the following section we will pursue the question of how a rational, profit maximizing firm will react to an increase of the CO_2 levy. This response is explained in a market diagram in Figure 3. The marginal abatement costs are assumed to increase with the amount of abatement. If the CO_2 tax increases from CHF 12 to CHF 36 per ton of CO_2eq, a rational firm or company will then reduce its emissions, moving along the marginal abatement cost function from point ① to point ②. Thus, the company will face the total reduction costs of the blue dashed area. For the remaining emissions, it has to pay the CO_2 tax, which imposes costs for the firm of the red dashed area. By committing to a binding reduction target of the same emissions reduction that the tax causes, the company can be exempted from the CO_2 tax in the amount of the red dashed area. Consequently, such companies reach the same reduction targets, yet by only bearing the total reduction costs and not the tax costs. This is the incentive to avoid paying the CO_2 tax (the stick) yet agreeing to an emissions target in exchange (the carrot).

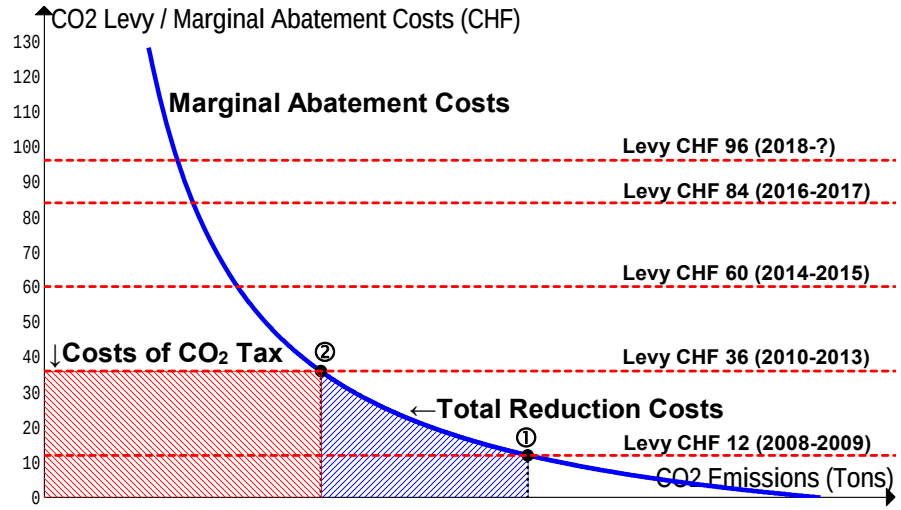

Figure 3. Economic incentives for reducing GHG emissions.

According to Figure 3, a profit-maximising firm will respond to an increase of the CO_2 levy from CHF 12 to CHF 36 by reducing its emissions along the marginal abatement cost curve from the intersection with the lower to the intersection with the higher CO_2 levy. In theory, this emissions reduction is the same, no matter whether a company has committed to a target agreement or actually pays the levy. In practice, this could make a real difference[9].

Data

The evaluation is based on data from the annual survey of the energy consumption in the industry and in the service sector carried out by Swiss Federal Office of Energy (Sauvin, Scherer, Ferster, & Muff, 2017). Based on the federal business and enterprise register (Swiss Federal Statistical Office (SFSO), 2018) a representative sample of 12,000 firms[10] had to report their final energy consumption every year from 1999 to 2016. The mean response quote over the relevant years was 50%, therefore, the number of observations varies between 2,185 in 1999 and 6,501 in 2016. The SFOE defines 19 sectors, based on the two-digit general classification of economic activities code (Swiss Federal Statistical Office (SFSO), 2008). Details on firm observation and sector statistics are given in Figure 7 in the appendix. Firm observations are being followed over an average period of five years. The underlying dataset is a combined pooled cross section and unbalanced panel data, containing 95,531 observations from 22,469 firms. Table 2 presents summary statistics of the average energy consumption by treatment. The period between 1999 and 2007 can be characterised as "before" and the period between 2009 and 2016 as "after", since the CO_2 tax was first introduced with a levy of CHF 12 per ton of CO_2eq emitted in 2008. Hence, the two treatments are the observations before 2008 and after 2008. The test statistics show that the average consumption of fossil fuels per firm (heating oil extra light, heating oil medium, total fossil fuels) and the total CO_2 emissions) have decreased significantly, whereas the consumption of old wood / scrap wood has increased significantly.

[9] There is an asymmetric information between the firm and the authority supervising and verifying the reduction path. In general, firms have more information about marginal abatement costs than the government has.

[10] According to the definition of the SFOE, a firm is a separated unit of a company in which employees work with a minimum annual income of CHF 2'300. A unit means a building, a building complex or a part of a building.

Table 2. Summary statistics of mean energy consumption and carbon emissions by treatment (before / after)

VARIABLES	Before 2008 N = 44,151		After 2008 N = 51,380		Difference	T-Value
	mean	sd	mean	sd		
Net Electricity Consumption in TJ	6.53	54.00	6.47	45.54	0.06	0.19
Heating Oil extra light in TJ	1.94	7.72	1.08	4.26	0.86	21.70*
Heating Oil medium / heavy in TJ	0.58	18.50	0.20	8.26	0.38	4.21*
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
Total Fossil Fuels in TJ	7.39	67.73	5.91	47.04	1.48	3.97*
Total CO_2 Emissions in tons	473.49	4,830.10	359.59	2,945.82	113.90	4.47*

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

Figure 4 shows the evolution over time of the following four outcome variables: total energy consumption in TJ, fossil fuels consumption in TJ, sustainable energy consumption and CO_2 emissions in tons.

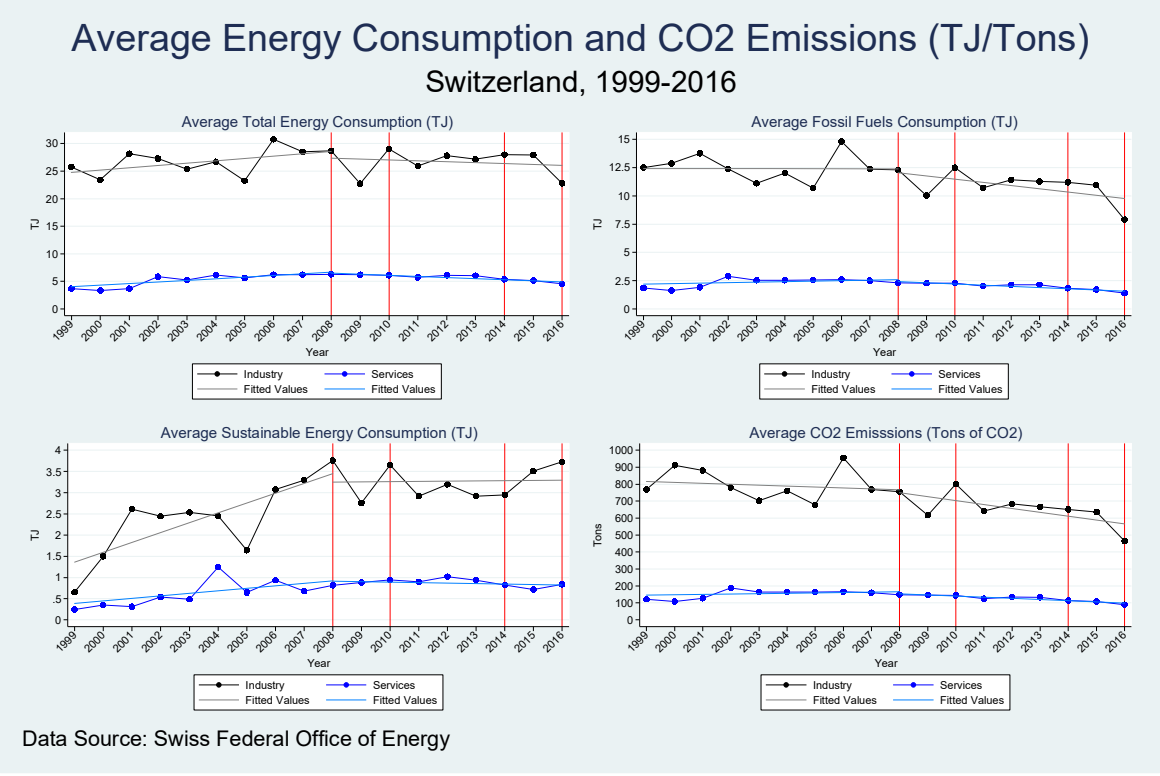

Figure 4. Evolution of the average energy consumption in terajoule and carbon emissions in tons between 1999 and 2016. The 4 vertical red lines indicate policy changes, i.e. CO_2 tax raises from CHF 0 to CHF 12 in 2008 to CHF 36 in 2010 to CHF 60 in 2014 and finally to CHF 84 in 2016. The time series bullet lines indicate the average energy consumption and CO_2 emissions by sector. Additionally indicated are the fitted values for the period before the introduction of the CO_2 levy, as well as for the period after the introduction of the CO_2 levy in 2008.

The upper left panel, including all energies such as fossil fuels, electricity, as well as wood and industry waste, shows that the average total energy consumption remained stable between 1999 and 2016. The upper right panel, containing only fossil energy consumption, which has been taxed since 2008 by the CO_2 levy (e.g. fossil fuels, natural gas), shows a reduction of the consumption of fossil fuels. The lower left panel shows an increasing use of sustainable energy sources (net consumption of local and district heating, natural wood, old and scrap wood) until 2008. The lower right panel shows a similar reduction path of the CO_2 emissions to that of the upper left panel, since the two variables are correlated with each other. These results might be explained by substitution effects towards non-fossil energy.

Empirical Strategy

The main empirical goal of this analysis is to isolate the effect of the Swiss CO_2 levy on the energy consumption and CO_2 emissions in the service and industry sector. Since we are not in a pure randomized controlled trial situation, two empirical challenges could occur with this data. First, as previously pointed out in the description of the available policies (see Figure 2), there is the possibility that firms do in fact self-select into their respective policies (selection bias). Firms that are engaged in an activity listed in appendix 7 of the CO_2 Ordinance and emit more than 100 tons of CO_2eq in one of the preceding two years can, upon request by the Federal Office for Environment FOEN, be exempted from the CO_2 tax by committing themselves to an emissions target. Around 770 companies have chosen to do so and have, therefore, been exempted from the CO_2 levy. Around 370 other companies have agreed to a measures target, which is a simplified model, especially designed for smaller companies, and are, therefore, exempted as well[11]. At the moment the data does not reveal any information about which firms listed in the survey are actually participating in one of these exemption models. However, the industry and service sector in Switzerland comprises more than 500,000 companies[12]. Consequently, paying the CO_2 levy without being given any exemptions does seem to be the standard policy for a typical company. As a result, 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_2 tax.

Another possible self-selection issue is that medium-sized companies which are engaged in an activity listed in appendix 7 of the CO_2 Ordinance have the choice to either opt-into the ETS or to commit to an emissions target (see Figure 2). However, no company has in fact opted voluntarily into the ETS so far despite the fact that auction prices for emissions units have been steadily falling over the past years. According to the Swiss emissions trading registry, the price for one emission unit has fallen from CHF 40 at the beginning of phase II to around CHF 8 (see Swiss Emissions Trading Registry (2018)). Since the Swiss ETS will be linked with the European Union ETS with its more than 11,000 installations, opting in would - at such low prices - be quite attractive for complying firms' emissions. To exclude the most energy- and emissions-intensive firms, we also estimated the model with trimmed data, excluding the top 1% of emitters.

To sum up, our regression model should capture the impact of the average policy effects within a firm, e.g. the tax raises at the different points in time. A firm-fixed effects specification is adequate, since a lot of heterogeneity comes from time-invariant firm-specific factors such as e.g. attitude of the management towards clean energy or differences in business practices. This unobserved (time-invariant) firm heterogeneity might be correlated with the selection into different policies and bias treatment estimates if not accounted for. The baseline is the period from 1999 to 2007, before the first introduction

[11] The current figures are regularly published by the Federal Office for Environment: https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/climate-policy/co2-levy/exemption-from-the-co2-levy-for-companies.html

[12] see Federal Statistical Office: https://www.bfs.admin.ch/bfs/de/home/statistiken/industrie-dienstleistungen/unternehmen-beschaeftigte/wirtschaftsstruktur-unternehmen.html

of the CO_2 levy in 2008. Several dummies measure the impact of the tax raises at several points in time compared to the baseline period. Our fixed effects regression model is:

$$y_{it} = post\_policy_t'\tau + x_{it}'\beta + a_t'\gamma + \alpha_i + \varepsilon_{it}$$

where i = 1, …, 22,469 are the firms i and t = 1999, …, 2016 are the years t; y_{it} is the energy consumption / greenhouse gas emissions of firm i in year t; $post\_policy_t$ are dummies for the different tax levels after the introduction of the CO_2 levy in 2008 as shown in Table 1 (baseline is the period before the first introduction from 1999 to 2007); x_{it} is the vector of firm specific factors such as firm size, measured by the gross floor area in m^2 and the number of employees; a_t is a vector of economy wide (not firm specific) indicators such as heating degree-days[13], an economic barometer predicting how the Swiss economy should perform in the next 3 to 6 months[14], the real crude oil price index as price indicator without taxes and a time trend to absorb technological progress; α_i are the firm fixed effects and ε_{it} is the error term that contains all the other factors determining y_{it}. The continuous variables are in logarithms. To test whether the fixed effects specification is adequate, we first ran a Breusch-Pagan Langrange Multiplier test. The null hypothesis that there is no evidence of significant differences across firms was rejected. Therefore, an OLS regression is not adequate. In a second step we ran a Hausman test (Hausman, 1978) to test the fixed effects specification versus the random effects specification. The null hypothesis that a random effect model is adequate was rejected. The econometric model which best suits this data is a firm-fixed effects regression model.

Results

The results from the analysis of the full data set are given in Table 3, Table 4 and Table 5. Table 3 has as dependent variable the logarithm of the fossil fuels consumption in Terajoule. By controlling for other effects, the CO_2 levy has a significant negative impact on the fossil fuel consumption at the 1% significance level for the years 2014 to 2016. Model 4 shows that the effect of the CO_2 levy, after its introduction in 2008 and 2009 with the amount of CHF 12/ton of CO_2eq, was a 1% reduction compared to the pre-policy period. This effect is not significant, however. Between 2010 and 2015, the reduction rose from 4% to 11% and in 2016, the last year of observation when the CO_2 tax reached a level of CHF 84/ton of CO_2eq, to 13% compared to the pre-policy period. Between 2008 and 2016, the average annual reduction of fossil fuel consumption, due to the CO_2 levy, is 1.4%. The two firm specific control variables (number of fulltime employees and gross floor area in m^2) have the expected negative sign and are, as anticipated, highly significant at the 1% level as well. The time trend, indicating technological progress is negative, but not significant. The heating degree-days have a positive impact on the energy consumption. 1% more heating degree-days lead to 0.4% more fossil fuel consumption. The lagged logarithm of the economic activity is, as expected, positive and significant. The logarithm of the lagged real crude oil price index has the expected negative sign. However, its impact is not significant, which might be due to a short-term inelastic demand for fossil fuels. Trimming the largest emitters from the model does not fundamentally change the results.

[13] Heating degree days are the sum of the average deviation of the outside temperature from 20°C, when the outside temperature is less than 12°C. Since we are estimating the consumption of fossil heating fuels, this is the most important control variable.

[14] see KOF Swiss Economic Institute: https://www.kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-economic-barometer.html

Table 3. Regression results for the consumption of fossil fuels in terajoule.

Dependent variable: log(fossil TJ) Regressor	Model 1	Model 2	Model 3	Model 4
Dummy CO_2 Tax CHF 12 (2008, 2009)	-0.0360**	-0.0507**	0.0108	**0.0106**
	(0.00871)	(0.00998)	(0.0120)	(0.0121)
Dummy CO_2 Tax CHF 36 (2010, 2011, 2012, 2013)	-0.0792**	-0.101**	-0.0448*	**-0.0432***
	(0.0110)	(0.0151)	(0.0187)	(0.0187)
Dummy CO_2 Tax CHF 60 (2014, 2015)	-0.212**	-0.244**	-0.108**	**-0.106****
	(0.0150)	(0.0217)	(0.0294)	(0.0294)
Dummy CO_2 Tax CHF 84 (2016)	-0.207**	-0.224**	-0.139**	**-0.134****
	(0.0182)	(0.0266)	(0.0445)	(0.0443)
log(number of fulltime employees)		0.176**	0.163**	0.148**
		(0.0156)	(0.0188)	(0.0176)
log(gross floor area in m^2)		0.160**	0.141**	0.141**
		(0.0145)	(0.0179)	(0.0176)
Time Trend		0.00162	-0.00720	-0.00745
		(0.00229)	(0.00405)	(0.00403)
log(heating degree days)			0.417**	0.425**
			(0.0392)	(0.0388)
$\log(\text{economic barometer})_{t-0.5}$			0.152**	0.150**
			(0.0362)	(0.0358)
$\log(\text{real crude oil price index})_{t-1}$			-0.0341	-0.0299
			(0.0227)	(0.0225)
Constant	-0.0811**	-1.891**	-3.959**	-4.020**
	(0.00555)	(0.127)	(0.347)	(0.345)
Observations	76,623	72,834	49,356	48,572
R-squared (within)	0.012	0.043	0.052	0.050
Number of firms	17,743	17,013	10,885	10,825
Firm Specific Controls	NO	YES	YES	YES
Economy Wide Controls	NO	NO	YES	YES
Trimmed upper 1%	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.

Since the goal of energy saving is a reduction in greenhouse gas emissions, using the carbon emissions factors, we calculated the CO_2 emissions (compare Table 1). Table 4 has as dependent variable the logarithm of the CO_2eq emissions in tons. By controlling for other effects, the CO_2 levy has a significant negative impact on the emissions of greenhouse gases at the 1% significance level for the years 2010 to 2016. Model 4 shows that the effect of the CO_2 levy, after its introduction in 2008 and 2009 with the amount of CHF 12/ton of CO_2eq, was less than a 1% reduction compared to the pre-policy period. This effect is not significant, however. Between 2010 and 2015, the reduction rose from 5% to 13% and in 2016, the last year of observation when the CO_2 tax reached a level of CHF 84/ton of CO_2eq, to 16% compared to the pre-policy period. Between 2008 and 2016, the average annual GHG emissions reduction, due to the CO_2 levy, is 1.7%. The two firm specific control variables (number of fulltime employees and gross floor area in m^2) have the expected sign and are, as anticipated, highly significant at the 1% level as well. The time trend, indicating technological progress, is negative and significant at the 5% level. The heating degree-days have a positive impact on the CO_2 emissions. 1% more heating degree-days lead to 0.4% more emissions. The lagged logarithm of the economic activity is, as expected, positive and significant. The logarithm of the lagged real crude oil price index has the expected negative sign, but is not significant.

Table 4. Regression results for the emissions of CO_2.

Dependent variable: log(CO_2) Regressor	Model 1	Model 2	Model 3	Model 4
Dummy CO_2 Tax CHF 12 (2008, 2009)	-0.0490**	-0.0560**	0.00894	**0.00860**
	(0.00871)	(0.0100)	(0.0121)	(0.0121)
Dummy CO_2 Tax CHF 36 (2010, 2011, 2012, 2013)	-0.103**	-0.112**	-0.0544**	**-0.0532****
	(0.0110)	(0.0151)	(0.0188)	(0.0187)
Dummy CO_2 Tax CHF 60 (2014, 2015)	-0.248**	-0.261**	-0.127**	**-0.125****
	(0.0150)	(0.0218)	(0.0295)	(0.0295)
Dummy CO_2 Tax CHF 84 (2016)	-0.246**	-0.241**	-0.164**	**-0.161****
	(0.0181)	(0.0267)	(0.0446)	(0.0443)
log(number of fulltime employees)		0.172**	0.159**	0.145**
		(0.0155)	(0.0188)	(0.0175)
log(gross floor area in m^2)		0.156**	0.135**	0.134**
		(0.0144)	(0.0176)	(0.0174)
Time Trend		-0.000507	-0.00826*	-0.00828*
		(0.00230)	(0.00405)	(0.00403)
log(heating degree days)			0.410**	0.417**
			(0.0396)	(0.0391)
log(economic barometer)$_{t-0.5}$			0.147**	0.144**
			(0.0363)	(0.0358)
log(real crude oil price index)$_{t-1}$			-0.0459*	-0.0424
			(0.0228)	(0.0226)
Constant	4.136**	2.373**	0.426	0.379
	(0.00552)	(0.126)	(0.346)	(0.344)
Observations	76,623	72,834	49,356	48,572
R-squared (within)	0.017	0.046	0.058	0.055
Number of firms	17,743	17,013	10,885	10,825
Firm Specific Controls	NO	YES	YES	YES
Economy Wide Controls	NO	NO	YES	YES
Trimmed upper 1%	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 next step is a comparison between the industry und the service sector. Table 5 shows that the main findings remain unchanged. The effect of the CO_2 tax in 2016 (CHF 84 per ton of CO_2eq) is in the industry sector a reduction of 12.5% (= 100 × (-0.125)) compared to the pre-policy period, whereas in the service sector it is 17.2% (= 100 × (-0.172)) compared to the pre-policy period.

Table 5. Regression results for the comparison of sectors.

Dependent variable: Regressor	log(fossTJ) Model 1A	log(fossTJ) Model 1B	log(CO_2) Model 2A	log(CO_2) Model 2B
Dummy CO_2 Tax CHF 12 (2008, 2009)	**-0.00406**	**0.0352**	**-0.00720**	**0.0339**
	(0.0150)	(0.0196)	(0.0150)	(0.0197)
Dummy CO_2 Tax CHF 36 (2010, 2011, 2012, 2013)	**-0.0408**	**-0.0307**	**-0.0517***	**-0.0401**
	(0.0243)	(0.0290)	(0.0243)	(0.0292)
Dummy CO_2 Tax CHF 60 (2014, 2015)	**-0.0810***	**-0.114****	**-0.102***	**-0.130****
	(0.0397)	(0.0437)	(0.0398)	(0.0441)
Dummy CO_2 Tax CHF 84 (2016)	**-0.0958**	**-0.147***	**-0.125***	**-0.172***
	(0.0587)	(0.0674)	(0.0586)	(0.0680)

log(number of fulltime employees)	0.204**	0.111**	0.201**	0.106**
	(0.0242)	(0.0238)	(0.0243)	(0.0237)
log(gross floor area in m^2)	0.104**	0.180**	0.0979**	0.172**
	(0.0229)	(0.0253)	(0.0226)	(0.0251)
Time Trend	-0.00504	-0.0152*	-0.00622	-0.0153*
	(0.00530)	(0.00626)	(0.00527)	(0.00631)
log(heating degree days)	0.466**	0.390**	0.461**	0.382**
	(0.0500)	(0.0612)	(0.0501)	(0.0624)
$\log(\text{economic barometer})_{t-0.5}$	0.107*	0.234**	0.104*	0.224**
	(0.0487)	(0.0540)	(0.0486)	(0.0545)
$\log(\text{real crude oil price index})_{t-1}$	-0.00988	-0.0339	-0.0207	-0.0489
	(0.0296)	(0.0350)	(0.0295)	(0.0355)
Constant	-3.870**	-4.540**	0.512	-0.120
	(0.460)	(0.515)	(0.457)	(0.516)
Observations	25,157	23,415	25,157	23,415
R-squared (within)	0.045	0.060	0.052	0.063
Number of firms	4,769	6,249	4,769	6,249
Sector	Industry	Services	Industry	Services
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.

Figure 5 shows a coefficient plot with the estimation results of Table 5. This plot enables to compare the impact of the increasing CO_2 levy between the industry and service sector visually. The graph exploits the variation in the tax levels over time, by sector and by outcome type (TJ or CO_2). The confidence level plotted is 95%. This graph illustrates that within the first six years, with the tax level being CHF 36/ton or less, the impact of the tax was slightly higher in the industry sector than in the service sector. However, the higher taxes starting in 2014 had a stronger impact on the service sector. The differences might be caused due to more reduction potential in the service sector (lower marginal abatement costs) whereas the industry sector had already partially reached its emissions-reduction-potential at the beginning of the tax policy. Due to a more energy-intensive production in the industry sector, the incentive to save energy had always been higher in the production sector even without taxes being imposed. The service sector, in contrast, picked the low-hanging fruits only when the tax had reached at least CHF 60 per ton CO_2eq. However, the overlapping confidence intervals reveal that the differences between the two sectors are not significant.

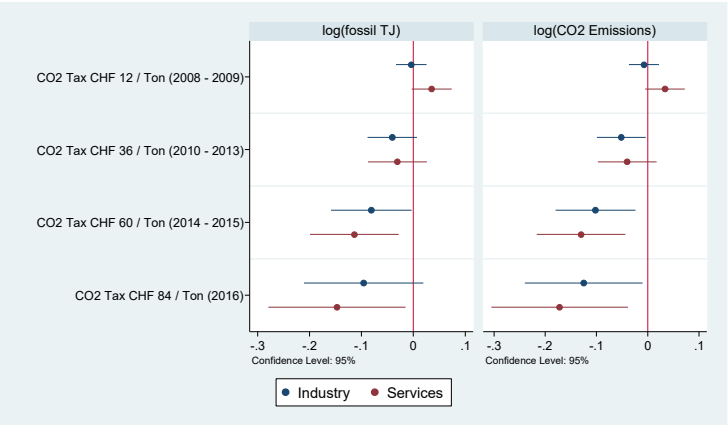

Figure 5. Coefficient plot of the different CO_2 levys by sector and by outcome type (TJ or CO_2). The confidence level is 95%.

The service sector could also profit more by the buildings programme than the industry sector. Since 2010, one third of the tax revenue, up to a maximum of CHF 450 million, has been earmarked for the buildings programme. The cantons annually contribute another CHF 60 to CHF 100 million for the use of renewable energies. Many cantons have also established their own regulations and building codes. The buildings programme was developed jointly by the cantons and the Confederation and is aimed for energy-efficient renovation of buildings and investment in renewable energies, waste heat recovery and the optimisation of building services technology (see Konferenz Kantonaler Energiedirektoren (EnDK) (2018)). An application for a building subsidy can be made for single- and multiple-family houses as well as commercial buildings. The main energy consumption in the service sector is caused by the heating and air-conditioning systems of the buildings. The impact of the CO_2 levy on energy savings and emissions reduction in the service sector could be confounded in that our estimations might be too optimistic since certain firms might receive subsidies through the buildings programme.

Robustness Check

As already mentioned in the section on data, our sample is an unbalanced panel for various reasons. The most important one is that every year 20% of the small and medium firms in the sample are replaced by other firms. Therefore, the average time a firm participates in the survey is five years[15]. Some of the responses to the changes in the CO_2 levy might at least partly be explained by this year-to-year sample change. To address this concern, we estimate a reduced panel with no gaps, including only firms with at least 12 consecutive years of observations. Furthermore, only firms that participate before and after the introduction of these policies in 2008 are chosen for this reduced sample. To exclude firms with mandatory participation in the ETS, companies of the cement sector are completely omitted from the sample. The results are summarized in Table 6 in the appendix. The main findings remain unchanged. The impact of the CO_2 levy has even increased in the industry sector, whereas in the service sector the tax impacts on the CO_2 emissions are not significant at the 5% level any more. This result could be biased towards large industry firms, since the restriction of a five-year participation time does not hold for these firms. Big emitters in the industry sector have stronger financial incentives to reduce their carbon emissions and to save energy as well. In the service sector, however, the variation is large, since, as already mentioned, other incentives (buildings programme or cantonal legislation) that are not captured by this data could play a role in saving energy and reducing carbon emissions.

Conclusion and Outlook

To sum up, we return to the original research question: What is the effect of the Swiss climate policy mix on firms' energy consumption and CO_2 emissions in the industry and service sector? The analysis has shown substantial reductions in the CO_2 emissions for the average firm in the industry and service sector post-policy, especially when the CO_2 emissions are heavily taxed (Tax ≥ CHF 60/ton CO_2eq.). Figure 6 shows a price chart of heating oil on a monthly basis. The black line is the gross price and the blue line is the net price of heating oil after subtracting the CO_2 tax. Until 2014, this net price had not moved out of the normal price range measured by the volatility. This is consistent with the results of our econometric analysis which revealed that the impact of the low CO_2 taxes of the first years was quite limited. However, after raising the tax to CHF 60/ton of CO_2eq, the net price dropped out of the natural price fluctuations of heating oil (see red arrow). Firms responded to this higher tax by intensifying their energy saving measures or by substituting towards lower carbon-intensive energy sources such as natural gas or wood.

[15] For a detailed description of the random sampling see Sauvin et al. (2017).

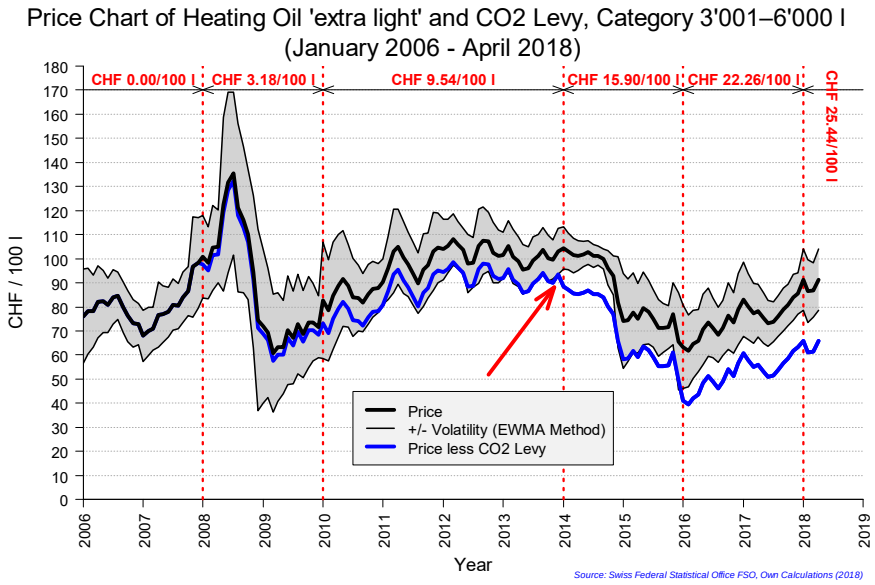

Figure 6. Price chart of heating oil extra light in CHF / 100l. The black line is the gross price and the blue line is the net price (minus the CO_2 levy). The shaded area is a volatility measure around the price (exponentially weighted moving average method). The graph shows that until 2014 the net price was within the normal range of the heating oil price. Only the tax increase in 2014 began to push the net price out of the price range.

Taking into account the above, this analysis can be regarded as a first contribution towards an ex-post analysis of the effectiveness of the Swiss climate and energy policy instruments as a whole, but especially the CO_2 levy, in the industry and service sector, based on firm-specific data. The CO_2 levy is the main instrument in these two sectors for reaching the emissions targets. Every increase of the CO_2 tax triggers a process in the management of the companies and firms. Profit-maximizing firms, or the companies they belong to, must reduce CO_2 emissions along their marginal abatement cost curve to the intersection with the tax level. If companies want to be exempted from the tax on the remaining emissions, they must commit to a binding reduction target. In theory, the emissions reduction is the same in both cases – i.e. by tax or by target agreements. In practice however, it all comes down to being able to monitor whether these promised reductions are actually reached.

Further isolation of the effect of CO_2 taxes on emissions would 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_2 and tax intensity. Distributional and employment-related aspects could be another research question. Finally, all of these results should be used for the fine-tuning of the policy instruments in order to achieve the 2030 Paris targets.

Appendix

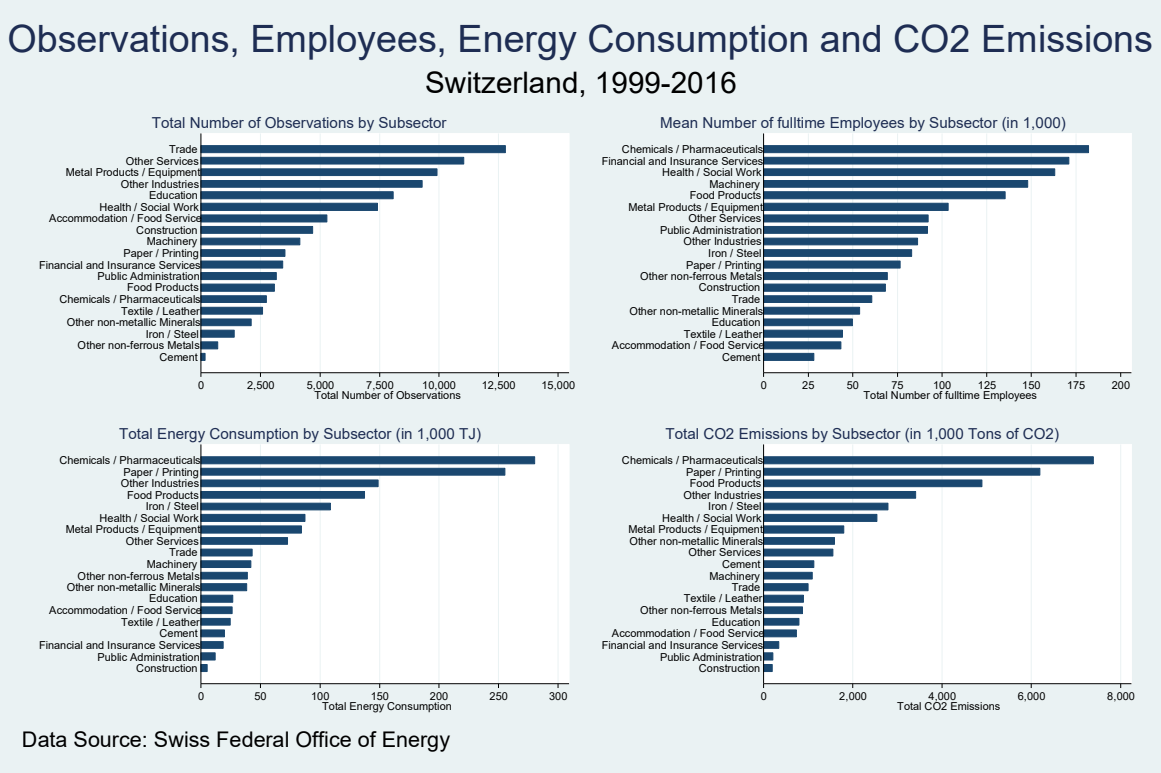

Figure 7. Graphical summary of sample variables by sector. Note: The number of observations is representative regarding the subsector share. The mean number of fulltime employees shows the distribution of the size of the firms. Total energy consumption and CO_2 emissions is an indicator of the energy intensity of the firms. Data Source: Swiss Federal Office of Energy.

Table 6. Regression results with the reduced panel data.

Dependent variable: log(CO_2)		SECTOR	
Regressor	Industry & Services	Industry	Services
Dummy CO_2 Tax CHF 12 (2008, 2009)	**0.0172**	**-0.0118**	**0.0750***
	(0.0166)	(0.0200)	(0.0295)
Dummy CO_2 Tax CHF 36 (2010, 2011, 2012, 2013)	**-0.0822****	**-0.0870****	**-0.0533**
	(0.0280)	(0.0329)	(0.0526)
Dummy CO_2 Tax CHF 60 (2014, 2015)	**-0.166****	**-0.151****	**-0.151**
	(0.0450)	(0.0527)	(0.0853)
Dummy CO_2 Tax CHF 84 (2016)	**-0.240****	**-0.210****	**-0.243**
	(0.0681)	(0.0782)	(0.134)
log(number of fulltime employees)	0.265**	0.333**	0.181**
	(0.0383)	(0.0504)	(0.0587)
log(gross floor area in m^2)	0.104**	0.0984**	0.112*
	(0.0274)	(0.0339)	(0.0445)
Time Trend	-0.00191	0.000138	-0.0104
	(0.00603)	(0.00695)	(0.0118)

log(heating degree days)	0.450**	0.482**	0.441**
	(0.0603)	(0.0685)	(0.118)
log(economic barometer)$_{t-0.5}$	0.130*	0.0612	0.285**
	(0.0531)	(0.0657)	(0.0911)
log(real crude oil price index)$_{t-1}$	-0.0847*	-0.0582	-0.101
	(0.0365)	(0.0418)	(0.0717)
Constant	0.853	0.765	0.359
	(0.554)	(0.656)	(1.017)
Observations	18,873	12,395	6,478
R-squared (within)	0.082	0.081	0.090
Number of firms	1,598	1,048	620

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.

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