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Prices vs. Quantities: An Empirical Study of Firms' Instrument Choice*

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Abstract

A longstanding theoretical discussion on the merits of prices vs. quantities for regulating emissions under uncertainty exists in environmental policy literature. However, empirical evidence w.r.t. instrument choice has not been put forward so far. In particular, very little is known about instrument preferences from the perspective of firms. Investigating Swiss climate policy provides an ideal field for encountering both of the above concerns. In Switzerland, firms can self-select between a tax (with a wage-based tax exemption) and emissions trading (with a grandfathering mode of permit allocation) to regulate their CO_2 emissions. In our paper, we empirically investigate this self-selection mechanism based on a cross section of Swiss firm-level data. Specific theory on Swiss policy design identifies the influential factors as being permit allocation, wages, uncertainty in abatement costs and the flexibility of firms' abatement technologies. We confirm evidence for the first two factors, but were unable to find evidence for the latter ones. Moreover, high-abatement firms tend to choose permit trading.

Keywords: Prices vs. Quantities, Instrument Choice, Swiss Climate Policy, Environmental Policy à la Carte
JEL classification: Q58, Q54, D81, D82

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1 Introduction

It is widely accepted by environmental economists that market-based instruments are the preferred policy to reduce harmful emissions. In turn, if firms face uncertainty in the costs of abating these emissions, the choice between a price or a quantity instrument matters. There is extensive theoretical literature on the relative merits of the instruments in this context (i.e. a tax vs. permit trading vs. a hybrid instrument vs. the simultaneous use of tax and permit trading). If, in addition, asymmetric information is assumed between the regulatory authority and the firms, theory suggests a "Policy à la Carte", i.e. a self-selection mechanism with the instrument choice being delegated to firms (Krysiak and Oberauner, 2010).

However, empirical research on instrument choice on these issues is still a largely unexplored domain. In our paper, we alleviate the lack of evidence by empirically investigating the instrument preferences of firms when the regulatory authority allows them to choose between a tax and permit trading. We have chosen the self-selection mechanism that is implemented in Switzerland as providing optimal data for our empirical research on instrument choice.

Single instrument regimes are extensively investigated in environmental economic literature to regulate firms' emissions. Market-based instruments – such as a tax and permit trading – are widely accepted in economics as the preferred instruments to achieve a cost-effective outcome. While a tax and permit trading both perform equally under complete information, the choice between a price and a quantity instrument become critical if there is uncertainty with regard to firms' abatement costs (Baumol and Oates, 1988; Weitzman, 1974). The preferability of a tax or permit trading in a single instrument regime when uncertainty makes a first-best outcome impossible is investigated by Williams III (2002). Numerous variations of market-based policy designs have been developed so far (e.g. hybrid regulation proposed by Roberts and Spence (1976)). Except for Mandell (2008) and Krysiak and Oberauner (2010), all theses approaches share one thing in common: Ex-post (i.e. once the uncertainty has been resolved), they all end up with either a tax or permit trading to regulate all firms.

Mandell (2008) pioneers a new frontier with respect to policy choice. He was the first to attempt a policy design in which the market is separated into parts that are regulated by different instruments simultaneously. He proposes to regulate one part of the market by a tax and the other by permit trading, which results in a reduction of the welfare loss incurred by uncertainty under a single instrument regime. In the approach of Mandell (2008), instrument assignment takes place ex-ante with abatement costs of firms being common knowledge. Hence, a socially optimal assignment of firms to instruments is ensured.

Taken a step further, Krysiak and Oberauner (2010) additionally allow for abatement costs being firms' private knowledge. The regulatory authority offers firms the choice of instrument, i.e. between a tax and permit trading, and firms then choose the one with the lowest expected costs. They show that by offering the firms a "policy menu", the same results can be achieved as with Mandell (2008), yet under more restrictive assumptions.

A variant of the approach presented by Krysiak and Oberauner (2010) is implemented in Switzerland. The Swiss confederation offers firms a policy menu to regulate carbon dioxide (CO_2) emissions from which firms can choose their preferred instrument. The policy menu consists of a tax (charged on every ton of CO_2) and of permit trading (with free-of-charge permit allocation). The revenue of tax payments is refunded to taxpaying firms based on their gross wages.

This unique policy implementation offers a challenging spectrum of empirical research associated with the prices versus quantities debate and the performance of different instruments subject to equal economic conditions. Moreover, it offers valuable information on the incentives that this policy menu offers firms when choosing between the tax and permit trading. The main focus of our paper concerns the latter field of research. We empirically investigate firms' instrument preferences and test the theoretical model provided by Krysiak and Oberauner (2010) on Swiss firm data. Our findings provide valuable insights that can be applied to future environmental policy design and implementation.

Empirical instrument choice is evaluated in a cross-section analysis based

on firm-level data from the manufacturing industries in Switzerland. Data stem from a survey that was conducted in the course of a research project for the WWZ Forum, University of Basel, to reveal the effects of climate policy in Switzerland at firm level.

Our theoretical model on Swiss climate policy suggests instrument choice in favor of emissions trading whenever the expected value of permit allocation net of trade-specific fixed costs outweighs the expected benefits unter the tax (i.e. the expected tax refund plus a flexibility-uncertainty advantage under a tax net of tax-specific fixed costs). Our results gained from a logit regression on instrument choice confirm the evidence regarding permit allocation and the tax refund. We were unable, however, to find evidence that under uncertainty more flexible firms prefer the tax. Moreover, high-abatement firms tend to choose emissions trading.

The paper is organized as follows. In the next section, we briefly review the existing literature on the choice of prices versus quantities in environmental regulation. In Section 3, Swiss climate policy is introduced. The theoretical model is presented in Section 4. Data and variables for our empirical analysis are sketched in Section 5. In Section 6, the empirical model specifications and results are discussed. Finally, we conclude in Section 7.

2 Related Literature

The main theoretical foundation for our analysis originates from the prices versus quantities discussion in the environmental policy literature initiated by Weitzman (1974), advanced among others, for example, by Roberts and Spence (1976), Mandell (2008), and Krysiak and Oberauner (2010), and reviewed by Hepburn (2006).

Weitzman (1974) has shown, that from a social perspective, firms should be regulated by a tax whenever the slope of the marginal abatement cost function outweighs the slope of the marginal damage function in absolute terms, and uncertainty renders a first-best outcome impossible. A quantity instrument is preferable when the opposite is true.

The choice of instrument to be implemented has gained particular at-

tention in the context of climate change mitigation. Contributors to the discussion on instrument choice for countering greenhouse gas (GHG) emissions and stock pollutants in general are – among others – Hoel and Karp (2002), Pizer (2002) and Newell and Pizer (2003). Due to the uncertainties inherent in the regulation of GHG emissions, the authors emphasize the relative merits of a tax. First and foremost and in line with Weitzman (1974), they argue that flat marginal damages of GHGs make the tax superior in efficiency terms to emissions trading. In contrast, by adding enforceability considerations to the analysis under uncertainty, Rohling and Ohndorf (2010) argue in support of a quantity instrument in the context of climate-related policies. Enforcement concerns, however, are only an issue in the international context of national sovereignty.

Roberts and Spence (1976) were the first to introduce the concept of a mixed or hybrid instrument. They propose a scheme of tradeable permits with a price ceiling and a price floor for permits (i.e. a tax and a subsidy) with an ex-post choice of instrument depending on how the uncertainty is resolved. Their approach results in a single instrument regime with all firms regulated by one of the three instrument. Pizer (2002) admits a hybrid system with a "safety valve" to be a good alternative to the tax in the regulation of greenhouse gases.

In contrast to Roberts and Spence (1976), Mandell (2008) presents a mixed regulation with the simultaneous use of different instruments. In his approach, the market is separated into a tax-regulated part and a part that is regulated by permit trading. Compared to a single tax or single permit trading, an emissions level can be achieved that comes closer to the efficient level, thereby reducing the welfare loss due to uncertainty. Mandell (2008) shows, that it can be optimal to use only a tax, but it is never optimal to only use permit trading. To optimally assign the firms to the instruments, the regulatory authority needs information on the technology used by firms to abate emissions, i.e. on the cost structure of abating emissions.

Krysiak and Oberauner (2010) take this approach a step further and allow for asymmetric information between the regulatory authority and firms with regard to their implemented technology. By offering firms the choice between

a tax and permit trading – accompanied by a tax exemption and/or partly auctioned permits – they show that firms self-select the instrument that is optimal from a social point of view. In their approach, the regulator has to set a tax as if it were the only instrument to be implemented and to allocate as many permits as necessary for the expected price for permits to equal the tax.

To our knowledge – besides Krysiak and Oberauner (2010) – only one paper exists that explores firms' choice of instrument to regulate pollution emissions. Delmas and Marcus (2004) discuss the firms' preferences between a command-and-control (CAC) instrument and negotiated agreements based on the transaction costs incurred by those instruments. However, the authors derive neither cost-minimizing analytical nor empirical criteria for instrument choice. Moreover, their focus is on transaction costs, but not on the costs that accrue from abatement and regulation, which are, however, the main drivers in firms' decision behavior.

An approach similar to Krysiak and Oberauner (2010) is implemented in Switzerland to regulate firms' carbon dioxide emissions. For our empirical analysis on which instrument firms prefer – based on Swiss firm-level data – we first introduce Swiss climate policy.

3 Swiss Climate Policy Design

By January 2008, active measures to combat climate change were implemented in Switzerland. Private individuals and firms were obliged to pay a carbon dioxide tax (CO_2 tax) on the combustion of fossil fuels. This means, private individuals are charged a tax whenever they purchase fossil fuels for heating or cooling. Firms are charged the tax whenever they use fossil energy resources in their production processes to generate heat, cooling or electricity.[1]

If the firms' share of fossil fuels were large compared to total inputs and if firms' competitiveness might be violated by the tax, firms were offered the

[1]Carbon dioxide emissions from transport are regulated separately.

possibility of being exempted from the tax (Swiss Federal Assembly, 1999). This option is predicated on their committing to a legally-binding reduction in their carbon dioxide emissions at a predetermined level. While large firms are allocated free permits that correspond to their reduction target and are free to trade their allowances (buy and sell), small- and medium-sized firms are only allowed to buy permits in order to cover emissions in excess of their quantity target.[2]

According to this policy design, firms explicitly have the choice to be either regulated by a price (the CO_2 tax) or else by a quantity instrument (permit trading, CAC with permit purchase option). Large firms are free to choose between the tax and permit trading. For the time being, we pass over the discrimination of small- and medium-sized firms in their lack of choice between the tax and permit trading. We will examine this aspect more thoroughly at a later stage in our analysis.

Specific design elements for both instruments are legally documented in the CO_2 Act, passed by the Swiss parliament in 1999 (Swiss Federal Assembly, 1999). Firms that opted for the tax paid 12 Swiss francs on every ton of carbon dioxide emitted in 2008. The tax rate follows a phasing-in process that is conditional on annual national reduction achievements.[3] Tax revenues are refunded to taxpaying firms based on their gross wages. According to the Swiss Federal Office for the Environment (2010c), the tax refund rate in 2008 is approximately 37 Swiss francs per 100,000 Swiss francs gross wages.

Permit trading is operated in a cap-and-trade style. Those firms that chose to be regulated via permit trading are required to hold an account at

[2]The Energy Agency for the Economy (EnAW) serves as an intermediator between the Swiss confederation and firms. It provides three quantitative commitment models to firms. Large energy-intensive firms are intended to join the Energy Model in conjunction with permit trading participation. For small- and medium-sized firms, alternative measures were designated. These firms either commit to a specific value target (Benchmark Model) or else to a plan of actions (model for small- and medium-sized firms – SME Model). Firms in the Benchmark or SME Model do not receive free permits, but are permitted to buy emission allowances on the permit market to cover emissions when they fail to meet their specific targets. Thus, Swiss climate policy design discriminates against small- and medium-sized tax-exempted, low-abatement-cost firms by prohibiting them from selling their excess emissions on the market.

[3] While the tax rate was not increased in 2009, it was raised to 36 Swiss francs in 2010, as the national emission reduction target was not met in 2008.

the National Emissions Trading Registry. By June 2010, a total of 405 installations of all industries held an account at the registry (Swiss Federal Office for the Environment, 2010b). The permit allocation method used is grandfathering, i.e. free-of-charge permit allocation based on historic emissions, with the emission allowances referred to as Swiss Units (CHUs).[4]

Taken together, climate policy implementation events in Switzerland occur in the following order. First, the Swiss confederation specifies a certain tax rate (12 Swiss francs in 2008) for tax paying firms and sets an overall cap for carbon emissions (aggregated individual reduction targets) for emissions trading firms. Moreover, it announces to refund tax receipts and to allocate permits free of charge. Second, after policy announcement, firms can choose between the two instruments. They will compare the expected costs under both instruments and choose the one for which these costs are lower. Finally, according to the incentives provided under the chosen instrument, firms decide on their carbon dioxide emissions abatement level.

Section 4 analyzes this policy design from a theoretical point of view.

4 Theoretical Model

The theoretical model of firms' instrument choice between a tax and permit trading to be tested for Swiss firm data is adopted from Krysiak and Oberauner (2010) and has been adjusted for our present purposes. A continuum of firms with mass one emits a homogeneous and uniformly mixed pollutant. To reduce environmental damage from emissions, the regulator offers firms a policy menu that consists of a tax and permit trading, from which firms choose their preferred instrument (self-selection mechanism). There is uncertainty concerning emissions abatement costs that only resolves when the abatement decision has to be made. Besides, the technology used to abate

[4]According to the CO_2 Act (Swiss Federal Assembly, 1999), the determination of firms' individual reduction targets is based on their historic abatement measures, the costs of abatement measures, their international competitive position, and their expected output growth. The correlation coefficients between historic emissions (2006 and 2007) and permit allocation in 2008 amount to 0.9919 and 0.9915, respectively. Thus, it is reasonable to assume a pure grandfathering mode of permit allocation.

emissions differs among firms and is private knowledge. The self-selection mechanism ensures that the resulting asymmetric information problem between the regulator and the firms will be overcome. Krysiak and Oberauner (2010) further allow for two additional "fine-tuning" variables (tax exemption modeled as a lump sum and partly auctioned permits) to ensure a socially optimal self-allocation of firms to instruments.

This approach is adjusted to two specific Swiss climate policy design elements. First, the tax exemption is modeled as a refund of tax revenues for taxpaying firms based on their wages. Second, the allocation of permits is solely based on historic emissions (grandfathering) that coincide with emissions in the absence of any regulation. In addition, we allow for instrument-specific fixed costs that are supposed to differ substantially between the tax and permit trading.[5]

The decision criterion for the choice of instrument is the difference in the expected costs of abatement of the instruments, or differently formulated making it conditional on emissions, the difference in expected savings from emitting the pollutant.

If a firm chooses to pay the tax t, it will maximize its savings[6] from emitting emissions e

$$\max_{e \geq 0} \quad S_t(e) = (\alpha + \theta)e - \frac{e^2}{2\beta} - te + \tau w - F_t, \tag{1}$$

where θ denotes uncertainty, τ the refund rate of tax revenues, w the firm's gross wages, and F_t the fixed costs incurred with the tax.[7] Furthermore, the firm's technology is expressed by the parameters $\alpha \geq 0$ and $\beta > 0$.

Eq. 1 characterizes the firm's savings from emitting a pollutant, minus the tax payment, plus the refund share of tax revenues that is conditional on the firm's wages, and minus the tax-specific fixed costs.

[5] We expect the fixed costs to be low or even zero for the tax, but substantial for permit trading. Costs for trading firms comprise the efforts to get exempted from the tax, the EnAW membership fee, consulting costs, monitoring, reporting and verification, etc. (Oberauner and Krysiak, 2010).

[6] Firm's marginal savings from emitting correspond inversely to firm's marginal abatement costs.

[7] Subscript t indicates the tax.

Uncertainty is characterized by the parameter θ that is firm-specific, but correlated among firms with $\rho \in (0, 1]$. θ has an expected value of zero and a positive variance of σ^2.

Firms are heterogeneous in two dimensions: they differ in their savings parameter β and in their wages w.[8] Let the joint density of β and w be $f(w, \beta)$. From Krysiak and Oberauner (2010), we know that firms with a high β choose the tax, whereas firms with a low β choose permit trading. The intuition for this sorting under the self-selection mechanism is the following. Firms under a tax are more flexible in adjusting their emissions to random influences than firms under emissions trading due to the correlation between firms' savings and the permit price. Consequently, a more flexible firm (high β) is better off by choosing the tax in expected saving terms. There is a single firm that is indifferent in the choice of instrument due to expected savings equality. The indifferent firm is tagged by the technology parameter $\beta_{crit}(w)$ which is, in turn, conditional on wages. Hence, all firms with a combination of (w, β) such that $\beta \in [0, \beta_{crit}(w))$ will participate in permit trading. Otherwise, i.e. if $\beta \in [\beta_{crit}(w), \infty)$, firms will pay the tax. Furthermore, $f(w, 0) = 0$, $f(0, \beta) = 0$, $\lim_{w\to\infty} f(w, \beta) = 0$ and $\lim_{\beta\to\infty} f(w, \beta) = 0$.

τ is endogenously determined as the ratio of tax revenues to taxpaying firms' gross wages.

Solving the first-order condition of (1) for emissions gives the optimal emissions level for a firm that pays the tax:

$$e_t^* = \beta(\alpha + \theta - t). \tag{2}$$

Given firms' allocation to instruments as proposed by Krysiak and Oberauner (2010), τ is

$$\tau = \frac{\theta_E\, t + t\,(\alpha - t) \displaystyle\int_0^\infty \int_{\beta_{crit}(w)}^\infty \beta f(w, \beta)\, d\beta\, dw}{\displaystyle\int_0^\infty \int_{\beta_{crit}(w)}^\infty w f(w, \beta)\, d\beta\, dw}, \tag{3}$$

[8] As shown by Krysiak and Oberauner (2010), heterogeneity with regard to α has no effect on the results and is therefore assumed to be constant across firms.

with $\theta_E = \int_0^\infty \int_{\beta_{crit}(w)}^\infty \beta\theta f(w,\beta)\, d\beta\, dw$ and $\mathcal{E}(\theta_E) = 0$.

Substituting Eq. (2) and (3) into Eq. (1) and taking expectations results in expected savings from emitting of

$$\mathcal{E}\left(S_t(e_t^*)\right) = \frac{\beta}{2}(t^2+\alpha^2) - \alpha\beta t + wt\,(\alpha - t)\,\frac{\int_0^\infty \int_{\beta_{crit}(w)}^\infty \beta f(w,\beta)\, d\beta\, dw}{\int_0^\infty \int_{\beta_{crit}(w)}^\infty w f(w,\beta)\, d\beta\, dw} + \frac{\beta}{2}\sigma^2 - F_t. \tag{4}$$

Analogously, if a firm chooses to participate in permit trading, it maximizes the savings function[9]

$$\max_{e \geq 0} \quad S_p(e) = (\alpha + \theta)e - \frac{e^2}{2\beta} + p(\psi\bar{e} - e) - F_p. \tag{5}$$

p denotes the price of permits, ψ the allocation rate of permits to historic emissions $\bar{e}$, and F_p the fixed costs. The price term in Eq. (5) is positive when the firm is a seller of permits, and negative in case the firm holds a buyer position.

The optimal level of emissions of a firm participating in emissions trading is then

$$e_p^* = \beta(\alpha + \theta - p). \tag{6}$$

The price of permits is endogenously determined, as it depends on the number of firms that choose permit trading. Calculating the market-clearing price of permits gives

$$p = \alpha - \psi\bar{e}\,\frac{\int_0^\infty \int_{\beta_{crit}(w)}^\infty f(w,\beta)\, d\beta\, dw}{\int_0^\infty \int_{\beta_{crit}(w)}^\infty \beta f(w,\beta)\, d\beta\, dw} + \theta_p, \tag{7}$$

with $\theta_p = \int_0^\infty \int_{\beta_{crit}(w)}^\infty \theta\beta f(w,\beta)\, d\beta\, dw / \int_0^\infty \int_{\beta_{crit}(w)}^\infty \beta f(w,\beta)\, d\beta\, dw$, reflecting the price uncertainty due to uncertainty in firms' savings. Furthermore, we have $\mathcal{E}(\theta_p) = 0$, $\mathcal{E}(\theta\theta_p) = \rho\sigma^2$ and $\mathcal{E}\left(\theta_p^2\right) = \rho\sigma^2$.

[9]Subscript p indicates permits.

As shown by Krysiak and Oberauner (2010), for a policy menu design to be optimal, the expected price of permits has to equal the tax rate. Then, expected marginal savings among all firms are equalized, and firms' savings from emitting are at a maximum. Thus, when choosing an instrument from the policy menu, a firm anticipates an optimal policy and expects the price of permits to equal the tax, i.e. $\mathcal{E}(p) = t$.

With a price of permits as in Eq. (7), optimal emissions as in Eq. (6), and taking into account that $\mathcal{E}(p) = t$, the expected savings from emissions are

$$\mathcal{E}\left(S_p(e_p^*)\right) = \frac{\beta}{2}(t^2 + \alpha^2) - \alpha\beta t + \psi\bar{e}t + \frac{\beta}{2}(1-\rho)\sigma^2 - F_p. \tag{8}$$

From Eq. (4) and (8) the intuition of a firm's instrument choice becomes obvious. A firm benefits from uncertainty under both instruments. However, this benefit is larger when the firm chooses the tax due to the better adjustment possibilities of emissions to shocks.

Given the expected savings under both instruments, the decision criterion for the choice of instrument of a firm is

$$\begin{aligned}\Delta =& \mathcal{E}\left(S_p(e^*)\right) - \mathcal{E}\left(S_t(e^*)\right) = \\ =& \left(\psi\bar{e}t - F_p\right) - \left(wt\left(\alpha - t\right) \frac{\int_0^\infty \int_{\beta_{crit}(w)}^\infty \beta f(w,\beta)\, d\beta\, dw}{\int_0^\infty \int_{\beta_{crit}(w)}^\infty w f(w,\beta)\, d\beta\, dw} + \frac{\beta}{2}\rho\sigma^2 - F_t \right).\end{aligned} \tag{9}$$

Hence, a firm chooses to participate in emissions trading whenever the expected benefits of trading outweigh the expected benefits under the tax. Otherwise, the firm chooses to pay the tax, i.e. when Δ is negative. The benefits of permit trading are characterized by the value of permits allotted to a firm minus the trade-specific fixed costs. By contrast, the benefits of the tax comprise the refund of tax receipts (the first term in brackets of Eq. (9)), plus the flexibility advantage under uncertainty of taxpaying firms, and net of the fixed costs to be incurred with the tax payment. A firm is indifferent between the instruments when the expected benefits under emissions trading equal

the expected tax-specific benefits (i.e. the firm with technology parameter $\beta_{crit}(w)$).

5 Data and Variables

To prove the empirical evidence of the theoretical model, firm-level data of Switzerland's manufacturing industry were used. Data were obtained from a survey conducted in fall 2009 in the course of a research project on the effects of Swiss climate policy on firms for the WWZ Forum, University of Basel (Oberauner and Krysiak, 2010). The universe for the survey was specified as manufacturing industries in the German-speaking part of Switzerland with 30 employees or more.[10]

The survey sample was constructed on the basis of four sources. The first and main source is a random draft of the Swiss Federal Statistical Office (FSO) from September 2009, drafted proportional to grouped employees and industries (FSO survey sample). Second, to increase their share in the sample, a selection of emissions trading firms was added (published on the National Emissions Trading Registry). Third, firms in the manufacturing industry listed at the SIX Swiss Exchange were integrated for the purpose of increasing the number of firms expected to possess good levels of data availability. Finally, a selection of ISO-14001 certified firms were added because these promised a higher chance of climate-related data availability. Except the firms that were obtained from the FSO, selection problems arose. It was not possible to ensure conformity in all the criteria specified for the universe.

By fall 2009, 1829 firms were surveyed by means of a written questionnaire; 125 responded to our survey inquiry. Out of the response sample, 72 firms were left that met the requirements for our analysis and could unambiguously be assigned to either tax or permit trading (response sample). Due

[10]Only manufacturing firms were taken into account, as they are more concerned with climate policy issues than, for example, the service industries (the involved industries are listed in Table 5 in the Appendix). To avoid any distortions from translation, only firms in the German-speaking part of Switzerland were considered. Regional differences were not to be expected. To increase the chance of firm data availability, labor staff was set to a minimum of 30.

to missing values in some of the explanatory variables, and depending on the specification estimated, further observations were dropped by listwise deletion. Figures 1 and 2 illustrate the distributions of employees and industry affiliation for the FSO survey and the response sample. We only consider the FSO survey sample for comparisons, as it comprises more than 70 percent of firms surveyed, and as information on labor staff and industry affiliation was not available for the remaining sources.

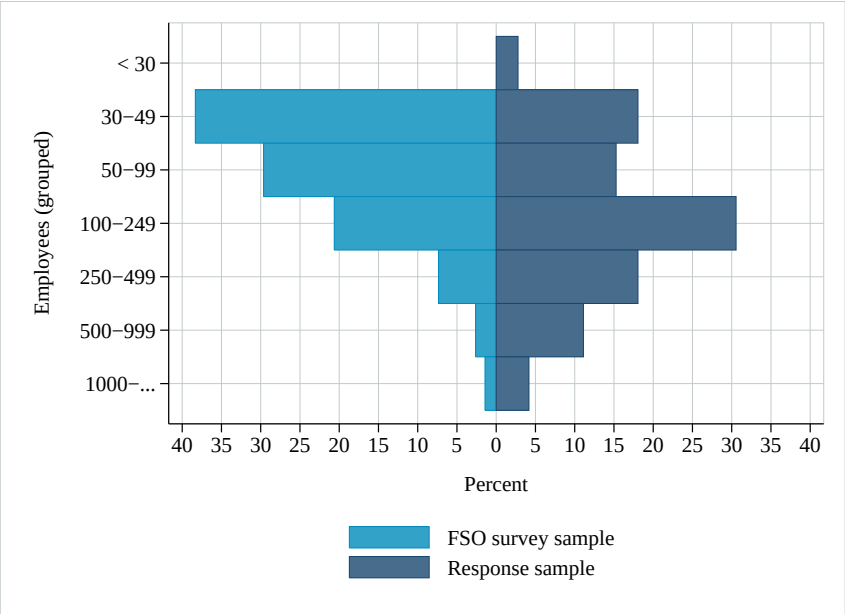

Figure 1: Distributions of firms' (grouped) employees in the FSO survey and the response sample (*source: sample draft of the Swiss Federal Statistical Office from September 8, 2009 and survey data*)

While the FSO survey sample is positively skewed with respect to the number of employees, the response sample approaches being a normal distribution. Thus, small firms are underrepresented in our analysis.[11] In contrast, distributions of firms' industry affiliation are quite similar. Only the shares of the food, beverages and tobacco industries and the chemical and pharmaceu-

[11]Larger firms may be better informed and may collect more data on climate-related issues, thereby facilitating questionnaire completion.

tical industries are disproportionately high in the response sample, whereas energy provision, water provision and treatment and the manufacture of wood products are underrepresented.

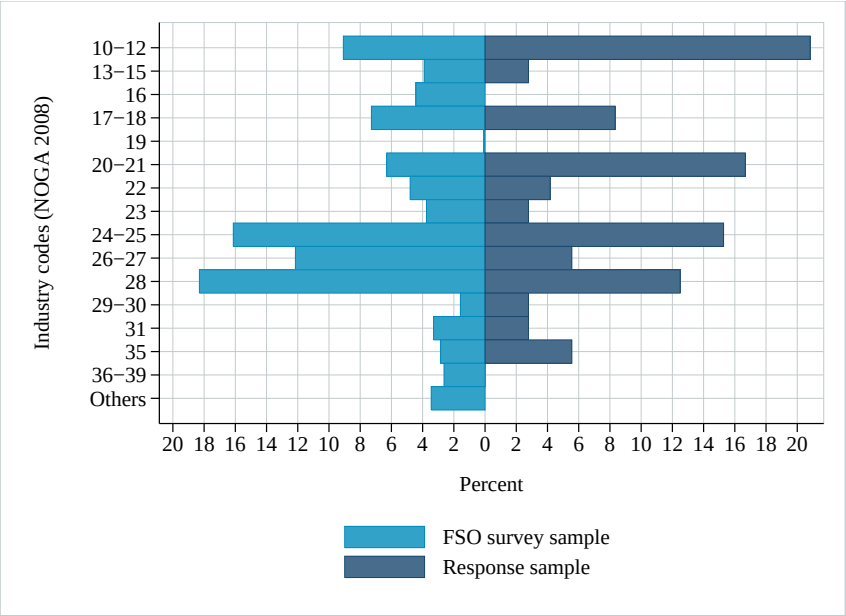

Figure 2: Distributions of firms' industry affiliation in the FSO survey and the response sample (*source: sample draft of the Swiss Federal Statistical Office from September 8, 2009 and survey data*)

Testing the theoretical model of Section 4, and more precisely in order to predict instrument choice according to the decision criterion in Eq. (9), data on the chosen regulatory instrument, the potential allocation of permits to all firms, firms' gross wages, as well as measures of firm flexibility in adjusting emissions to shocks and of their exposure to uncertainty were needed. Questionnaire design specifics and data transformations on these variables are briefly sketched in the following and are summarized in a list of variables in Table 1.

Table 1: List of variables

Variable	**Label**
Instrument	Dummy variable indicating instrument choice (1=emissions trading, 0=tax)
Emissions	Emissions intensity: emissions in 2008 divided by sales in 2008 [million Swiss francs]
Wages	Wage intensity: gross wages in 2008 [million Swiss francs] divided by sales in 2008 [million Swiss francs]
Flex	Composite variable indicating flexibility of abatement technology in adjusting emissions to abatement cost shocks
Uncert	Composite variable indicating firms' exposure to uncertainty in abatement cost
$Flex * Uncert$	Interaction term of *Flex* and *Uncert*
Abate_low	Dummy variable indicating low overall abatement in 2008 (less than 5 %) – reference dummy
Abate_mod	Dummy variable indicating moderate overall abatement in 2008 (5 – 19 %)
Abate_high	Dummy variable indicating high overall abatement in 2008 (20 % or more)
LnSales	Natural logarithm of sales in 2008 [million Swiss francs]

First of all, the variable *Instrument* indicates instrument choice and serves as the dependent variable in our empirical model. Since two instruments are offered by the Swiss government, namely a tax and emissions trading, *Instrument* is a binary variable and takes on one of the two values:

$$Instrument = \begin{cases} 1 & \text{emissions trading with probability } p, \\ 0 & \text{tax with probability } 1-p. \end{cases}$$

The dependent variable is constructed based on three questions formulated to identify the instrument assignments as being mutually exclusive. Firms were queried on exemption from the tax, on participation in one of the models provided by the Energy Agency for the Economy (see Footnote 2) and, finally, on participation in permit trading. Firms have to pay the tax

whenever they purchase fossil fuels. So, they must get exempted from it in order to avoid being within the tax regime. Only firms that host the Energy Model are entitled to participate in permit trading. The question on participation in permit trading serves to ensure correct instrument assignment.

Second, data on the allocation of permits in 2008 were, by definition, only available for firms involved in permit trading. The correlation between the allocation of permits to firms in emissions trading and CO_2 emissions in 2008 was, however, almost perfect, so, the latter serves as a proxy for potential permit allocation in 2008 for all firms.[12] In turn, CO_2 emissions in 2008 were divided by the sales in 2008 to correct for scale effects. This emissions intensity measure is denoted by the variable *Emissions*.

Third, firms were asked for their gross wages in 2008 to measure the influence of the wage-based tax refund on instrument choice. Again, we corrected for scale effects by dividing them by the sales in 2008. The wage intensity variable is denoted by *Wages*.

Finally, to verify the flexibility-uncertainty advantage of the tax, the composite variables *Flex* (to measure flexibility) and *Uncert* (to measure uncertainty) were constructed. Both variables are multiple-indicator measures out of the four Likert items: fuel prices, input prices, output demand and breakdown of production equipment. A five-point scale was employed to indicate the flexibility of a firm's technology to adjust emissions to shocks and its exposure to fluctuations with regard to each item. The scores of the items were averaged to form a flexibility and a uncertainty score for each firm. 5 represents the highest level of flexibility/exposure to uncertainty and 1 the

[12] CO_2 emission data were also available for the year 2006, i.e. before climate policy has been announced by the regulator. The correlation between emissions in 2006 and the allocation of permits in 2008 amounts to 0.9919. However, some observations would have been dropped with this proxy due to missing values. Besides, CO_2 emissions of firms that were allocated permits in 2008 are published on the National Emissions Trading Registry, operated by the Swiss Federal Office for the Environment (2010a). Thus, data quality could have been improved by correcting for errors and missing values when the firm's identity was known. For these reasons, we preferred to use 2008 emissions data, i.e. when climate policy measures were already implemented (the correlation coefficient between 2006 and 2008 emissions data amounts to 0.9816). The correlation between CO_2 emissions in 2008 and permit allocation in 2008 for firms participating in emissions trading and observations used to estimate the empirical model specifications of Section 6 is 0.9891.

lowest. What matters for testing the theoretical model, is the interaction term of $Flex$ and $Uncert$ labeled as $Flex * Uncert$.

To control for further influencing factors, sales in 2008 ($LnSales$) and the overall abatement activity were included in the empirical model. The natural logarithm of sales in 2008 serves to detect potential scale effects in instrument choice. With regard to abatement, firms were asked on a seven-point scale to report their overall abatement of CO_2 emissions in 2008 compared to a situation with no abatement at all. The scale was reduced to three categories with a dummy variable constructed for each category: (1) *Abate_low* indicating abatement lower than 5 percent (reference category); (2) *Abate_mod* indicating abatement between 5 and 19 percent; and (3) *Abate_high* indicating abatement of 20 percent and above.

The small size of the sample and the wide range of industry classes (see Table 5 in the Appendix) made it impossible to reliably control for industry-specific effects. Moreover, since the data on emissions intensity are significantly non-homogeneous within a class of industry, even the use of a dummy variable on emissions-intensive industries is considered inappropriate. For example, although the pharmaceutical industry is associated with emissions-intensive industries, it also covers firms with low intensity. This might be attributable, for example, to fuel substitution or to a firm's core business operating at a low-emission stage in the production chain. Therefore, we consider firm-level comparisons based on emissions intensity, i.e. by the variable *Emissions*, to be more adequate than any comparisons based on industry affiliation.

In the following section, the estimation results are presented for various specifications of the empirical model.

6 Empirical Model Specifications and Results

The full sample used for the estimation consists of 30 firms that participate in emissions trading and 42 that pay the tax. Due to the binary character of the dependent variable $Instrument$, a logit model is used for the regression analysis. Thus, in our empirical model, the conditional probability of

choosing emissions trading has the form

$$\begin{aligned} Pr(Instrument_i = 1|\mathbf{x}) =& \Lambda(\beta_0 + \beta_1 * Emissions_i + \beta_2 * Wages_i \\ &+ \beta_3 * Flex * Uncert_i + \beta_4 * Abate\_mod_i \\ &+ \beta_5 * Abate\_high_i + \beta_6 * LnSales_i), \end{aligned} \tag{10}$$

with $\Lambda(\cdot)$ as the cumulative distribution function of the logistic distribution. Our theoretical model predicts a positive influence of *Emissions* on instrument choice, i.e. when the emissions intensity is increased, the probability of choosing emissions trading is expected to rise. Hence, we expect a positive value for the estimated coefficient. In contrast, firms benefit from a high tax refund when wages are high, making the tax more attractive. The coefficient's sign for *Wages* is therefore expected to be negative. Theory also suggests a negative effect of the flexibility-uncertainty value ($Flex * Uncert$) on firms' preference for emissions trading. The remaining control variables included in the empirical model are the abatement dummies and the log-transform of sales. Descriptive statistics on the dependent and the explanatory variables are listed in Table 2 for various model specifications. Because of missing values, the listwise deletion procedure reduced the sample size conditional on the explanatory variables involved. The mean of the dependent variable *Instrument* indicates the percentage of firms in emissions trading for the respective specification.

With all the explanatory variables included, the number of observations employed was reduced to 62, due to missing values. The reduced sample contains 36 firms in the tax regime, and 26 in the permit trading regime. The results of our logit estimation for this specification are presented in the first column of Table 3.

The coefficients of *Emissions* and *Wages* exhibit the correct signs and are statistically significantly different from zero at the 1 percent level for *Emissions* and at the 5 percent level for *Wages*. This is not true, however, for the flexibility-uncertainty term. The z-value does not indicate a reliable influence on instrument choice.[13] This holds further for the control variable

[13] Alternative measures of *Flex* and *Uncert* were used to test the model. Among others,

LnSales. So, scale effects in firms' preferences are not to be observed.

Table 2: Descriptive statistics conditional on model specification

	Obs.	Mean	Std.Dev.	Min	Max
Model 1 and 2					
Instrument	62	0.419	0.497	0	1
Emissions	62	32.654	58.614	0.015	287.692
Wages	62	0.238	0.133	0.008	0.730
*Flex*Uncert*	62	9.034	3.631	1.5	17
Abate_mod	62	0.435	0.500	0	1
Abate_high	62	0.306	0.465	0	1
LnSales	62	4.153	1.666	1.501	9.852
Model 3					
Instrument	72	0.417	0.496	0	1
Emissions	72	33.631	56.071	0.015	287.692
Wages	72	0.240	0.127	0.008	0.730
Abate_mod	72	0.417	0.496	0	1
Abate_high	72	0.306	0.464	0	1
Model 4 and 5					
Instrument	42	0.619	0.492	0	1
Emissions	42	46.056	67.241	1.073	287.692
Wages	42	0.216	0.120	0.008	0.571
*Flex*Uncert*	42	9.447	3.557	1.667	17
Abate_mod	42	0.500	0.506	0	1
Abate_high	42	0.333	0.477	0	1
LnSales	42	4.650	1.598	1.589	9.852
Model 6					
Instrument	51	0.588	0.497	0	1
Emissions	51	45.682	62.771	1.073	287.692
Wages	51	0.222	0.115	0.008	0.571
Abate_mod	51	0.471	0.504	0	1
Abate_high	51	0.314	0.469	0	1

The results do not provide evidence in support of the theoretical model

dummy variables were constructed from validity questions that directly asked for flexibility of abatement technology and uncertainty in abatement costs. All alternative measures had one thing in common with the actual measures used, *Flex* and *Uncert*: the coefficients' signs and the z-values do not indicate a statistically significant and monotonously increasing influence of flexibility and uncertainty on the predicted probability of choosing emissions trading. The effects of these alternative measures exhibit, however, robustness in the residual variables with regard to sign, significance and magnitude of coefficients.

with respect to the negative influence of the flexibility-uncertainty term on choosing emissions trading. Firms' instrument choice behavior does not confirm a flexibility advantage under uncertainty for taxpaying firms. This may be attributed to the fact that not only the permit price is uncertain but also the tax rate. If national emission reduction targets could not be achieved in previous years, the tax rate will be gradually increased. Indeed, in 2010 the tax rate was increased from 12 Swiss francs in 2008 and 2009 to 36 Swiss francs (see Footnote 3). So, when choosing an instrument for several periods, Swiss firms are not only subject to price uncertainty in the permit trading regime, but also in the tax regime.

Table 3: Logit regression for instrument choice

	Model 1 *Instrument*	Model 2 *Instrument*	Model 3 *Instrument*
Emissions	0.104***	0.107***	0.116***
	(3.04)	(3.12)	(3.39)
Wages	-22.70**	-26.09**	-27.01***
	(-2.08)	(-2.53)	(-2.74)
*Flex*Uncert*	0.130	0.132	
	(0.85)	(0.85)	
Abate_low	*reference*	*reference*	*reference*
Abate_mod	3.573	3.853*	4.510**
	(1.55)	(1.78)	(2.14)
Abate_high	4.039*	4.188*	5.077**
	(1.70)	(1.87)	(2.29)
LnSales	0.247		
	(0.73)		
Constant	-3.615	-2.084	-1.495
	(-1.09)	(-0.86)	(-0.63)
Observations	62	62	72
p-Value (F-Test)	0.000	0.000	0.000
Pseudo R^2	0.610	0.604	0.628
Count R^2	0.887	0.871	0.875

z statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In turn, in Model 2 and Model 3 we re-estimated a reduced specification

omitting $LnSales$ in the former, and both, $LnSales$ and $Flex{*}Uncert$, in the latter, leading to a larger sample size in Model 3.[14] In the reduced model we observe robust results for the emissions and wage intensity compared to the Model-1 specification. The results reveal a positive influence of the emissions intensity and a negative influence of the wage intensity on the probability of choosing emissions trading (both on a 1 percent significance level). In addition, overall abatement in 2008 indicates a statistically significant influence on instrument choice at the 5 percent level in the reduced model.

Our empirical model has a high predictive power. Instrument choice is correctly classified (i.e. predicted choice corresponds to observed choice) in 87.5 percent of the cases (expressed by Count R^2).[15] Thus, our model covers the most influential determinants of instrument choice and only requires a few variables to predict firms' preference between a tax and permit trading correctly with a high degree of probability.

As the coefficients of the regression represent logits that do not have an intuitive interpretation, we illustrate the dependency of the predicted probabilities on the emissions and on the wage intensity for reference values of the remaining variables in Figures 3 and 4, respectively.

The influence of the emissions intensity on the probability of choosing emissions trading is depicted in Figure 3 for various levels of wage intensity (25th percentile, median, mean and 75th percentile), holding the abatement dummies constant at their respective mean values.[16] The figure illustrates the positive relationship between the emissions intensity, and in turn potential permit allocation, and the probability of choosing emissions trading. As the ratio of CO_2 emissions to sales increases, the probability that a firm chooses emissions trading increases, or stated differently, the probability of a firm choosing the tax decreases. Hence, firms at a low level of wage intensity exhibit a higher probability of choosing emissions trading when their

[14] A Likelihood-Ratio test indicates that the variables $LnSales$ and $Flex * Fluc$ should be removed from the model.

[15] Firms were classified as being 1 (i.e. emissions trading) if their predicted probability was above 0.5 percent. Classification towards the tax then consistently indicates a predicted probability equal to or below 0.5 percent.

[16] The wage intensity for the reduced sample is positively skewed, thus, the median of the wage intensity lies above its mean.

emissions intensity increases. By contrast, firms with a high wage intensity choose emissions trading only when the emissions intensity is relatively high. Then, the benefit of the tax refund is large, and can only be outweighed by a relatively high permit allocation in order to be better off under permit trading.

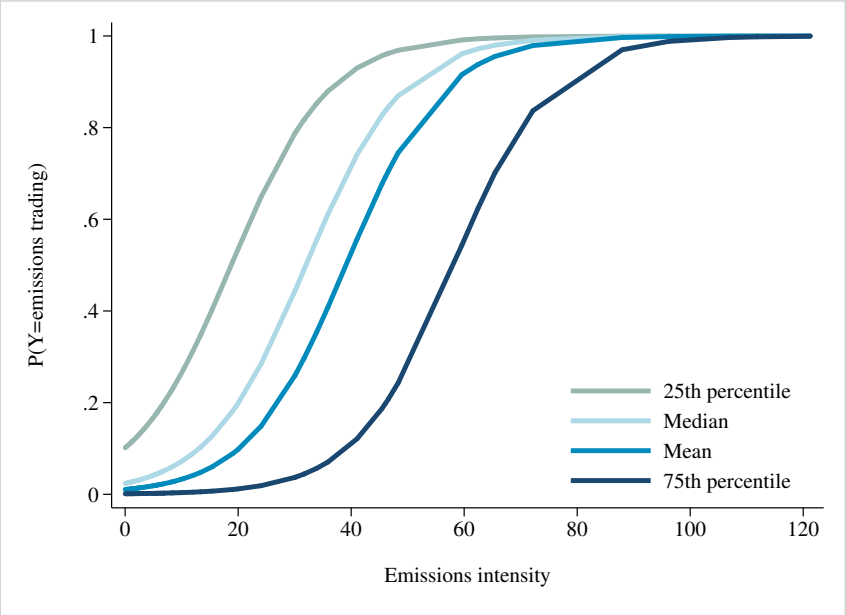

Figure 3: The probability of choosing emissions trading conditional on emissions intensity and various levels of wage intensity: 25th percentile, Median, Mean and 75th percentile (Model 3; *Abate_mod* and *Abate_high* at their respective mean values)

Figure 4 draws the same picture for the probability of choosing emissions trading conditional on the wage intensity for various levels of the emissions intensity.[17] It depicts the negative relation between the probability of choosing emissions trading and wage intensity. The higher the firms' wage intensity, the higher is the probability of choosing the tax. For firms at a low level of emissions intensity, the probability towards the tax is higher when wages increase. Thus, firms with a low emissions intensity (and, in turn, a low level

[17]Emissions intensity is even more positively skewed than the wage intensity.

of potential permit allocation) are better off with a tax, due to the relatively high refund of tax payments. Firms with a relatively high emissions intensity, by contrast, will only be willing to choose the tax when their wage intensity is comparatively high and the tax refund outweighs the value of the potential permit allocation.

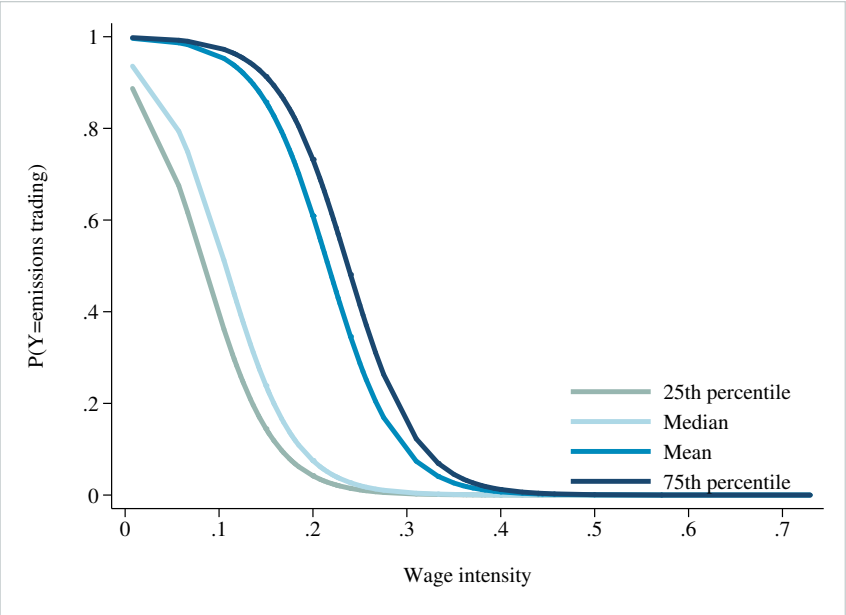

Figure 4: The probability of choosing emissions trading conditional on wage intensity and various levels of emissions intensity: 25th percentile, Median, Mean and 75th percentile (Model 3; *Abate_mod* and *Abate_high* at their respective mean values)

Figures 3 and 4 reflect not only the empirical evidence of the theory with regard to emissions and wages presented in Section 4, but also confirm that firms behave as suggested by the Swiss Federal Office for the Environment (2007a). They propose that firms should participate in emissions trading whenever they exhibit high CO_2 emissions in conjunction with low wages and should pay the tax in the reverse situation.

Estimation results in the third column of Table 3 indicate that firms tend to opt for emissions trading when abatement efforts are relatively high. There

is, however, no rationale behind these results. Depending on the instrument considered, the rational firm sets marginal abatement costs (marginal savings from emitting) equal to the price or to the tax and solves for optimal abatement (emissions). In expectations, optimal abatement (emissions) is (are) the same for both instruments. So, from a theoretical point of view, variances in abatement effort should not be an issue with respect to instrument choice.

One possible reason for this might be that firms participating in permit trading have the prospect of being able to bank their permits beyond the Kyoto period, i.e. beyond 2012 (Swiss Federal Office for the Environment, 2007b).[18] Legislation on Swiss climate policy might be more restrictive in future periods, i.e. the tax might be increased, and the cap for permits might be reduced. Moreover, the free permit allocation mode might be partly substituted by auction (Swiss Federal Council, 2009). In addition, the Swiss confederation intends to link up the national emissions trading system with the emissions trading system run by the European Union (EU ETS) no later than 2013 (Swiss Federal Office for the Environment, 2009). A more restrictive policy in the European Union after the Kyoto period may force Swiss policy design to get tougher in order to be accepted for linkage by the European Commission. One might argue that, both aspects, a more stringent national policy and a trading scheme linkage, might induce permit trading firms to increase abatement efforts to build up a bank of permits for future policy periods. Inter-period banking with a 1-to-1 permit ratio may, however, be an obstacle for linking up with the EU ETS too.

Table 3 presents the results of the logit estimation for all firms in the sample, no matter how much CO_2 they emit and independent of firm size. For small- and medium-sized firms, the Swiss confederation established quantity targets that correspond to a mixture of a CAC instrument and emissions trading (see Footnote 2). Firms with energy costs lower than 200,000 Swiss francs are either regulated by a plan of actions or else by a benchmark (for

[18]Banking to periods beyond 2012 is not established by law so far. However, the Swiss Federal Office for the Environment (2007b) specifies the prospect of banking in its commentary on the CO_2 ordinance (CO_2-Verordnung). Additionally, the Swiss Federal Council (2009) documents the possibility of banking in its proposal to the revision of the CO_2 Act.

homogeneous groups of firms). These firms do not receive permits allocated free of charge and are not allowed to sell excess emissions. But they are permitted to cover their emissions with permits purchased on the permit market in case they should fail to reach their targets. Firms that exhibit energy costs of at least 200,000 Swiss francs are unrestrictedly permitted to participate in emissions trading (Energy Agency for the Economy, n.d.). Therefore, freedom of instrument choice between the tax and permit trading is restricted in our sample of Model-3 specification.

Table 4: Logit regression for instrument choice with freedom of choice

	Model 4 *Instrument*	Model 5 *Instrument*	Model 6 *Instrument*
Emissions	0.0798**	0.0796**	0.0892***
	(2.48)	(2.47)	(2.79)
Wages	-20.11*	-21.20**	-21.43**
	(-1.95)	(-2.18)	(-2.37)
*Flex*Uncert*	0.136	0.135	
	(0.84)	(0.82)	
Abate_low	*reference*	*reference*	*reference*
Abate_mod	2.920	2.980	3.758**
	(1.44)	(1.49)	(2.03)
Abate_high	3.831*	3.914*	4.907**
	(1.77)	(1.84)	(2.39)
LnSales	0.103		
	(0.28)		
Constant	-2.129	-1.463	-1.107
	(-0.66)	(-0.67)	(-0.51)
Observations	42	42	51
p-Value (F-Test)	0.000	0.000	0.000
Pseudo R^2	0.502	0.500	0.557
Count R^2	0.857	0.857	0.863

z statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Taking into account that only firms with energy costs beyond 200,000 Swiss francs exhibit unrestricted freedom of instrument choice, we gain the logit estimation results presented in Table 4.

Specifications of Model 4, 5 and 6 are the freedom-of-choice analogue of Model 1, 2 and 3. The signs of the coefficients are the same for both classes of specifications, i.e. with and without restrictions in freedom of choice. But there are small differences in the statistical significance and in the magnitude of the coefficients. Again, $Flex * Fluc$ and $LnSales$ are omitted from the full model (Model 4) for the same reasons as above, which results in the Model-6 specification. Goodness of fit in Model 6, expressed by Count R^2, is only less than one percentage point lower in the freedom-of-choice specification, whereas the Pseudo R^2 increases.

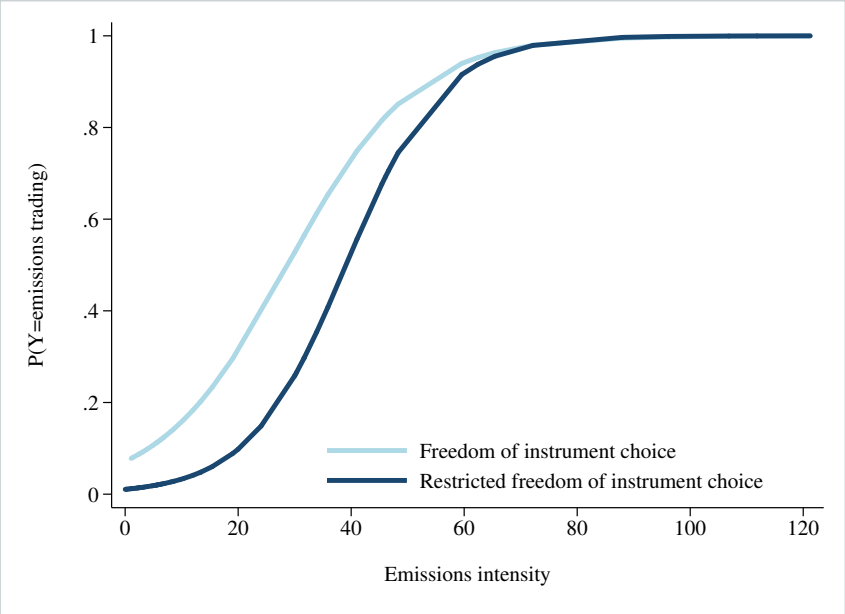

Figure 5: The probability of choosing emissions trading conditional on emissions intensity with restricted and unrestricted freedom of choice (Model 3 and 6; $Wages$, $Abate\_mod$ and $Abate\_high$ at their respective mean values)

The effect of freedom of choice on predicted probability is displayed in Figures 5 and 6, respectively. When firms are free to choose between the instruments, the probability of choosing emissions trading is higher for all levels of emissions intensity (Figure 5). Consequently, if we plot the probability curve as being dependent on wage intensity (Figure 6), the freedom-of-choice

cumulative distribution function is always above the one with restrictions.

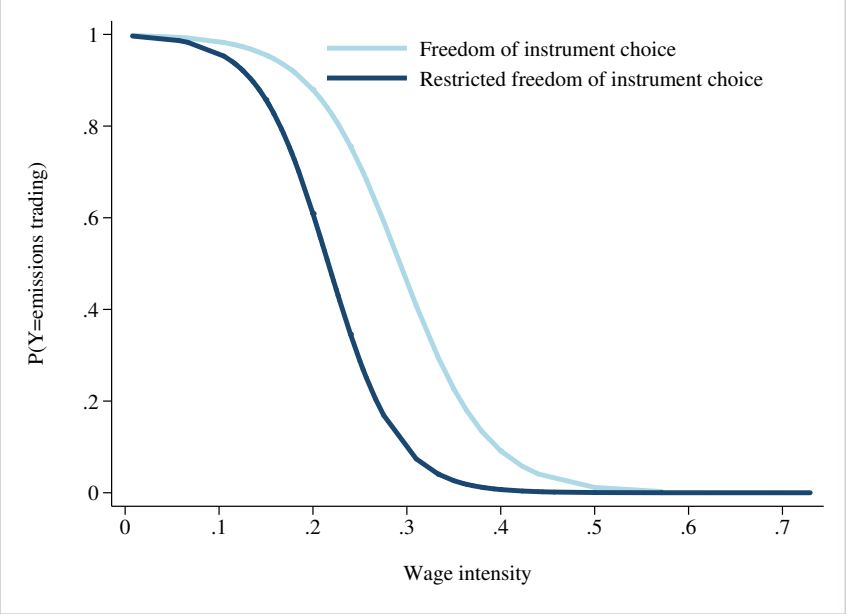

Figure 6: The probability of choosing emissions trading conditional on wage intensity with restricted and unrestricted freedom of choice (Model 3 and 6; *Emissions*, *Abate_mod* and *Abate_high* at their respective mean values)

Figures 5 and 6 make the natural result of abolishing restrictions on instrument choice obvious. The preference in favor of permit trading is enhanced when firms are free to choose. One might argue that allocating free permits even to small- and medium-sized firms and allowing them to sell their excess emissions would enhance the liquidity of the Swiss permit trading scheme, which has suffered from low liquidity and low trade volume in Swiss Units since its beginnings in 2008 (Swiss Federal Office for the Environment, 2008). Moreover, the cost effectiveness of climate mitigation measures would be increased by substituting a CAC-style instrument with pure permit trading. However, this result may not be generally valid, as only large emitters are considered in our freedom-of-choice sample. If unrestricted instrument choice is permitted even to small- and medium-sized firms, the results may change. Fixed costs associated with participating in emissions trading are

substantial compared to the tax (see Footnote 5), shrinking the benefits of free permit allocation.

7 Conclusions

In our paper, we empirically investigate firms' preferences in the choice between a tax and permit trading when the regulatory authority delegates instrument choice to firms. Such a self-selection mechanism is implemented on firms' carbon dioxide emissions in Switzerland. With Swiss firm-level data, we were thus able to contribute to the prices vs. quantities literature with an empirical study on instrument choice from the perspective of firms.

The theoretical framework for our analysis on instrument self-selection is provided by Krysiak and Oberauner (2010). When there is uncertainty with regard to firms' abatement costs and, in addition, asymmetric information between the regulatory authority and the firms, they show that a "Policy à la Carte" dominates a single tax or permit trading regime in expected welfare terms. In order to ensure a socially optimal assignment of firms to the instruments, they allow for partly auctioned permits and/or a tax exemption modeled as a lump sum. We adopt this theoretical approach of firms' instrument choice, remodel it for specific Swiss climate policy characteristics (pure grandfathering of permits, wage-based tax refund for taxpaying firms), and apply it to Swiss manufacturing firm data. Theory suggests that firms choose emissions trading whenever the expected benefits of trading (the value of potential permit allocation minus trade-specific fixed costs) outweigh the expected benefits of paying the tax (the tax refund, plus a flexibility-uncertainty advantage of the tax, and minus tax-specific fixed costs).

Based on the theoretical model, an empirical model of firms' instrument choice was constructed using the tax and participation in emissions trading to characterize the binary dependent variable. Results from a logit estimation do not provide evidence in support of the theoretical model with respect to the flexibility-uncertainty term. Emissions intensity (a proxy for the potential permit allocation of all firms due to missing values for firms that pay the tax) and wages intensity (to indicate the wage-based tax refund) are, however,

crucial in the choice of instrument that firms make. If wages are low (i.e. a firm's tax refund is low), the probability of choosing emissions trading is relatively high, as the benefits under the tax are more easily compensated with the benefits under emissions trading (i.e. the value of permit allocation). In case of high-wage firms, the opposite is true. If the emissions, and thus permit allocation, of a firm are at a low level, the probability of choosing the tax is higher than for a high-emission firm, due to a more dominant tax refund incentive.

In addition to emissions and wages, estimation results reveal significance with regard to abatement activity that is theoretically unfounded. As a matter of fact, we observe high-abatement firms to exhibit a higher probability of choosing emissions trading. This result may be attributed to the banking of permits beyond the Kyoto period. Moreover, the empirical analysis does not detect scale effects with regard to firms' preferences.

Estimation results exhibit a convincing model fit, although only a few explanatory variables were employed. Thus, with only limited information on firms, we are able to predict a firm's preference for one of the instruments correctly with a high degree of probability.

Firms exhibiting low energy costs are restricted in their choice of instrument. They are neither allocated free permits nor are they allowed to sell excess emissions to their quantity target. They are, however, permitted to purchase permits if they are not able to achieve their targets. Restricting our sample to only those firms that are completely free to choose between the tax and permit trading (i.e. firms above a certain energy cost threshold) raises the probability of choosing emissions trading. This may indicate that allocating permits to all firms choosing a quantity instrument and permitting them unrestricted trade in their emission rights might increase not only the cost effectiveness of climate policy design in Switzerland, but it might also enhance liquidity, trade volume and the transparency of the price signal in the permit market. This might only be true when higher fixed costs compared to the tax render permit trading profitable even for small- and medium-sized firms.

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Appendix

Table 5: NOGA 2008 General Classification of Economic Activities (Swiss Federal Statistical Office, 2008)

Code	Industry
10	Manufacture of food products
11	Manufacture of beverages
12	Manufacture of tobacco products
13	Manufacture of textiles
14	Manufacture of wearing apparel
15	Manufacture of leather and related products
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
17	Manufacture of paper and paper products
18	Printing and reproduction of recorded media
19	Manufacture of coke and refined petroleum products
20	Manufacture of chemicals and chemical products
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
22	Manufacture of rubber and plastic products
23	Manufacture of other non-metallic mineral products
24	Manufacture of basic metals
25	Manufacture of fabricated metal products, except machinery and equipment
26	Manufacture of computer, electronic and optical products
27	Manufacture of electrical equipment
28	Manufacture of machinery and equipment
29	Manufacture of motor vehicles, trailers and semi-trailers
30	Manufacture of other transport equipment
31	Manufacture of furniture
32	Other manufacturing
33	Repair and installation of machinery and equipment
35	Electricity, gas, steam and air conditioning supply
36	Water collection, treatment and supply
37	Sewerage
38	Waste collection, treatment and disposal activities; materials recovery
39	Remediation activities and other waste management services