UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

WORKING PAPERS IN ECONOMICS

No 609

Carbon Pricing: Transaction Costs of Emissions Trading vs. Carbon Taxes

by

Jessica Coria and Jūratė Jaraitė

January 2015

ISSN 1403-2473 (print)

ISSN 1403-2465 (online)

Department of Economics
School of Business, Economics and Law at University of Gothenburg
Vasagatan 1, PO Box 640, SE 405 30 Göteborg, Sweden
+46 31 786 0000, +46 31 786 1326 (fax)
www.handels.gu.se   info@handels.gu.se

EFMD EQUIS ACCREDITED

Carbon Pricing: Transaction Costs of Emissions Trading vs. Carbon Taxes

Jessica Coria[(1)] and Jūratė Jaraitė[(2)]

Abstract

In this paper we empirically compare the transaction costs from monitoring, reporting and verification (MRV) of two environmental regulations directed to cost-efficiently reduce greenhouse gas emissions: a carbon dioxide (CO_2) tax and a tradable emissions system. We do this in the case of Sweden, where a set of firms are covered by both types of regulations, i.e., the Swedish CO_2 tax and the European Union's Emissions Trading System (EU ETS). This provides us with an excellent case study as it allows us to disentangle the costs of each regulation from other firm-specific variables that might affect the overall cost of MRV procedures. Our results indicate that the MRV costs of CO_2 taxation do not depend on firms' emissions, while they do in the case of the EU ETS. For firms of equivalent emissions' size, the MRV costs are lower for CO_2 taxation than for the EU ETS, which confirms the general view that regulating emissions upstream by means of a CO_2 tax yields lower transaction costs vis-á-vis downstream regulation by means of emission trading.

Keywords: Carbon dioxide emissions; Carbon tax; Emissions Trading; EU ETS; Firm-level data; Sweden

JEL: D23; H23; Q52; Q58

[1]Department of Economics. School of Business, Economics and Law. University of Gothenburg. Gothenburg, Sweden. E-mail: Jessica.Coria@economics.gu.se

[2] Centre for Environmental and Resource Economics, School of Business and Economics, Umeå University, Umeå, Sweden. E-mail: jurate.jaraite@econ.umu.se.

Financial support from the research program Instrument Design for Global Climate Mitigation (INDIGO) is gratefully acknowledged. We thank the Swedish Environmental Protection Agency for kindly supporting the data collection process and Ida Muz for excellent research assistance. We are grateful to Mattias Qvist (Swedish Tax Authority) and Nancy Steinbach (Statistics Sweden) for providing us with information to develop this study. We are also grateful to all the persons who participated in our survey and to Thomas Sterner and Åsa Löfgren for useful comments.

1) Introduction

Much of the literature acknowledges the lack of a generally accepted definition and the wide use of the concept of "transaction costs." As pointed out by Krutilla and Krause (2010), in the environmental economics field, the term "transaction costs" first emerged in the literature on the Coase theorem to refer to the "costs of market transactions" following a rights assignment. Yet over the years the concept has been applied more expansively to account for the fact that environmental regulations establish use or quasi-ownership rights to polluters who are generally qualified for and subject to regulatory review or modification. In this context, "transaction costs" refer to the costs of the regulatory requirements implementing the policy objective. Moreover, it is acknowledged that the regulatory design can be used to reduce transaction costs by two means: excluding smaller participants who pay disproportionately large transaction costs in relation to their pollution, and choosing the point of obligation that minimizes transaction costs (Krutilla and Krause 2010, McCann 2013). For instance, when it comes to the climate change discussion, the general view is that regulating CO_2 emissions upstream by means of a CO_2 tax yields lower transaction costs than regulating polluters downstream through tradable emissions permits since the number of emitters is larger than the number of firms producing or importing fuel (Crals and Vereeck 2005, Metcalf and Weisbach 2009 and Mansur 2012). Moreover, the implementation costs are considered to be lower for a carbon tax than for a tradable permits system since the former makes use of existing social institutions, like tax-collecting organs and tax systems (Pope and Owen 2009, Kerr and Duscha 2014).

Despite a growing body of research on the advantages of emissions taxation vis-à-vis emissions trading (with seminal papers by Weitzman 1974, Polinsky and Shavell 1982 and Stavins 1995, among others), there are no previous studies analyzing empirically whether emissions taxation entails lower transaction costs than emissions trading, mainly due to the absence of case studies where such a comparison is feasible. The present paper contributes to filling this gap by examining the case of Sweden, where a number of polluting firms have been subject to a CO_2 tax since 1991 and to the European Union's Emissions Trading System since 2005. From 2005 the policies have overlapped, implying that a large number of firms have complied with both regulations simultaneously. This provides us with an excellent case study as it allows us to measure transaction costs incurred by firms regulated by these two environmental policies and to disentangle transaction costs of a given policy from other firm-specific variables that might affect the costs themselves.

To empirically compare the transaction costs of the CO_2 tax and the EU ETS, we combine primary and secondary sources of information. Regarding the primary information, in 2013 we conducted a survey asking a relevant sample of Swedish firms a series of questions regarding the monitoring, reporting, and verification costs incurred as part of complying with the CO_2 tax and/or the EU ETS in 2012. Following previous studies, we proxy transaction costs of regulations with the time spent on these activities (internal costs) and the external and capital costs they entail (see McCann et al. 2005 for a review of methods to estimate transaction costs). The primary information was combined with other firm level data including data on CO_2 emissions, employment and turnover.

This combined dataset allows us to develop a comparative analysis of the transaction costs incurred by firms under emission taxes and tradable emission permits. It also enables us to identify differences across sectors, economies of scale, and the rationality for exclusion of smaller participants. From the perspective of firms, any regulation involves some implementation costs, including establishing internal/external administration for monitoring, reporting, and verification, quantifying emissions for the base period, familiarization with allocation rules, software and trading platforms. The focus of our analysis is on transaction costs from monitoring, reporting, and verification (MRV) of emissions since empirical evidence indicates that these costs, at least in the case of the EU ETS, are the most important costs of compliance, with a share that might exceed 70% of the total transaction costs (see e.g., Jaraitė et. al 2010 and Heindl 2012). Hence, our study does not concern implementation costs as both the CO_2 tax and the EU ETS have been in place for many years.

Our results provide empirical support to the claim that transaction costs from MRV are larger under emissions trading than carbon taxation. Our findings also point to different cost structures under the two policies: MRV costs do not vary with firms' emissions in the case of carbon taxation while they do in the case of the EU ETS. By comparing firms of similar emissions' size we find that the MRV costs are lower for the carbon tax than the EU ETS, which confirms the general view that regulating emissions upstream by means of a CO_2 tax yields lower transaction costs vis-á-vis downstream regulation by means of an emissions trading system.

The paper is organized as follows. In Section 2, we briefly describe the Swedish CO_2 tax and the EU ETS, as well as the main MRV procedures of these policies. In Section 3, we discuss the theoretical aspects of MRV transaction costs. In Section 4, we present the data and compare the estimated MRV costs between policies. Finally, Section 5 synthesizes our findings and concludes the paper.

2) The Swedish CO_2 Tax and the EU ETS

In 1991, Sweden implemented the world's highest CO_2 tax, which is directly connected to the carbon content of the fuel.[1] Initially, it was equivalent to €25/tCO_2. After increasing steadily over the last decade, at present it corresponds to €105/tCO_2. Since the tax is very high and Sweden is a small open economy, there has been quite some concern about the competitiveness of some energy-intensive

[1] There is some differentiation among sectors. For example, there is no carbon tax on electricity production but non-industrial consumers have to pay a tax on electricity consumption.

industries. Thus, a number of deductions and exemptions were created for sectors that are open to competition, and a series of reduced rates were applied. For example, Lundgren and Marklund (2010) indicate that during the period 1990-2004, the effective CO_2 tax rate was on average €11/tCO_2; the CO_2 tax varied considerably across sectors, ranging from about €4/tCO_2 in the wood product sector to almost €15/tCO_2 in the food sector. They also find that there is no particular pattern in or relationship between the cost shares of energy and/or fuels and the actual CO_2 tax paid by firms, i.e., high use of CO_2-emitting inputs does not necessarily mean a high CO_2 tax payment.

From January 2011 onwards, industrial installations were exempted from the CO_2 tax for those activities covered by the EU ETS. The same exemption applied to combined heat and power production from 2013 onwards.[2] Nevertheless, from 2005 to 2012, the CO_2 tax and the EU ETS overlapped, implying that firms included in the EU ETS also had to pay a percentage of the CO_2 tax.[3]

Though the CO_2 tax applies to the fuel used by all industrial consumers, in our study we focus only on the firms that file and pay the CO_2 tax to the Swedish Tax Authority (the firms referred to as warehouse or stock keepers)[4]. These firms sell fuel to final consumers, adding on the CO_2 tax to the price consumers pay. These firms may use fuel themselves too, paying and refunding the tax payments related to their consumption completely or partially. When it comes to the MRV requirements, to comply with the CO_2 tax regulation, the warehouse/stock keepers must apply for authorization from the Swedish Tax Agency (STA) to purchase, extract, process, and store fuel. Tax liabilities arise when warehouse keepers consume the fuel or sell the fuel product to a non-authorized party or if the fuel is transferred to the firms' own retail store for further sale. The warehouse keepers must keep records of fuel handling on a monthly basis and report to the authorities, implying an administrative burden. If the fuel is sold to a non-authorized party, the firm must keep records of the buyer and provide information about the buyer's tax status, which is available from the authorities.[5] The authorized warehouse keepers must secure payment of the tax in advance. To this end, the tax is calculated and reported together with the application for authorization. Moreover, they shall record all purchasing and sales of fuel, all transfers of fuel products, and are obliged to take inventory on a regular basis (SKV 531 2012; SKV 663 2013; and SKV 524 and 543 2014).

The STA can make visits to ensure that the warehouse keepers comply with regulations. Otherwise, tax compliance is monitored through random tax audits conducted by the tax authorities. The tax agency can also conduct select audits if they suspect that a firm has misreported taxes. Before

[2] Petrol and unmarked oil are not exempted from CO_2 tax, which is mainly used for transportation purposes.
[3] Since the price of the EU ETS permits was much lower than the Swedish carbon tax level, this harmonization with the EU actually implied a sizeable fall in the price of carbon emissions for most firms (see Bonilla et al. 2012 for details).
[4] For fuels regulated through EU legislation (EU harmonized fuels), an authorized firm is called an authorized warehouse keeper while for the nationally regulated fuels (non-EU harmonized fuels) it is called a stock keeper.
[5] The last day for filing taxes varies between the twelfth day after the end of an accounting period and the twelfth day in the second month after the end of the accounting period.

an audit, the authorities notify the firm in order for it to have all required documents accessible upon the visit. An audit report declares the results of the audit and suggests tax changes, if needed. If a firm is found misreporting taxes, it can either be subject to administrative penalties issued by the tax authorities themselves or – in more serious cases of tax evasion – prosecuted in court.

The EU ETS is thus far the largest emissions trading system in the world. It covers about 12,000 installations, representing approximately 45% of the EU's CO_2 emissions. In Sweden, the sectors included in the EU ETS account for 38% of the country's total CO_2 emissions (Löfgren et al. 2013). These sectors correspond to manufacture of (i) wood and wood products; (ii) rubber and plastic products; (iii) machinery and equipment; (iv) fabricated metal products and motor vehicles; and (iv) trailers and semi-trailers. In addition, all installations in the heat and power sector with a rated thermal input exceeding 20 MW are included in the EU ETS. According to Jaraitė et al. (2013), the number of Swedish installations currently included is the EU ETS is 853, corresponding to 273 firms as some firms own several installations.

Regarding monitoring, reporting, and verifications activities, annual reports are mandatory and must be verified by an accredited verifier, which regulated firms have to pay for. In particular, each firm in the EU ETS is required to measure and supervise all of its CO_2 emissions in accordance with the Swedish Environmental Protection Agency's (SEPA) regulations. Each year by March 31, each firm must report its CO_2 emissions, have the report verified by an independent accredited verifier, and input its yearly emissions in the Swedish emission rights system. Finally, each year by April 30, each firm is required to surrender its emission rights corresponding to its actual emissions for the preceding year. The handover shall be done in accordance with the manual provided by the Swedish Energy Agency. Any firm that does not surrender sufficient tradable emission rights by 30 April of each year to cover its emission during the preceding year is liable for payment of an excess emissions penalty. The current penalty is €100 for each ton of carbon dioxide emitted for which the firm has not surrendered permits (European Parliament and Council 2008).

Note that the procedures for MRV under both regulations are independent. Not only must Swedish firms report to different authorities (STA vs. SEPA), but the MRV requirements are defined in terms of different measurement units (fuel handling vs. verified emissions) and different time frames (monthly vs. annual reporting).

3) Model

Transaction costs of pollution control affect both the efficient level of emissions reductions and the choice of policy instruments. To facilitate the comparison of policy instruments, let us focus on aggregate abatement of CO_2 emissions per unit of time, E, which corresponds to the sum of emissions e_i from N regulated firms ($i = 1, \dots, N$). Let us consider a social planner whose objective is to achieve an emissions cap E^* at minimum cost. Let the function $D(E)$ represent the damages from emissions in monetary units. We follow convention and assume that the damage function is increasing in emissions such that $D'(E) > 0$. We define the cost of pollution reduction for firm i by the cost function $C_i(e_i)$. If the firm is not compelled to reduce its emissions below its unregulated level $\hat{e}_i$, the cost of pollution control is zero (i.e., $C_i(\hat{e}_i) = 0$). Conversely, $C_i(e_i)$ is positive for any emission level $e_i < \hat{e}_i$. We also assume that the costs of pollution control are lower when emissions are higher so that $C'_i(e_i) \leq 0$. Let the function $T_i(e_i)$ represent the firm's i regulatory costs (monitoring, reporting, and verification) associated with the policy instrument chosen to implement the cap on emissions E^*. By analogy to the costs of pollution control, we assume that $T_i(e_i)$ is positive for any emission level $e_i < \hat{e}_i$ and that $T'_i(e_i) \leq 0$. The total cost of an environmental regulation for firm i then corresponds to $C_i(e_i)$ plus $T_i(e_i)$.

The efficient emission level for each firm is found by minimizing the total cost of the externality to society.

(1) $$SC(e_1, e_2, \dots, e_n) = D(E) + \sum_{i=1}^{n} C_i(e_i) + \sum_{i=1}^{n} T_i(e_i).$$

Differentiating equation (1) with respect to each individual emissions e_i, we obtain:

(2) $$D'(E) = -C'_i(e_i) - T'_i(e_i) \;\; \forall\, i.$$

Equation (2) can be used to further show that

(3) $$-C'_i(e_i) - T'_i(e_i) = -C'_k(e_k) - T'_k(e_k) \;\; \forall\, i, k = 1, \dots N, i \neq k.$$

Equations (2) and (3) illustrate two fundamental characteristics of an optimal allocation of pollution: for each firm the marginal damage from pollution is equal to the sum of the marginal cost of pollution control and the marginal transaction cost. Moreover, a necessary condition for social cost minimization is that the marginal cost of an environmental regulation is the same among all firms that carry out positive levels of emissions control.

From Equation (2) it is also clear that if marginal transaction costs are nonzero (i.e., $T_i'(e_i) \neq 0$), the efficient emission level for each firm is higher than in the absence of transaction costs. Moreover, the presence of a fixed component of cost in the transaction cost function $T_i(e_i)$ implies the existence of scale economies in regulatory compliance. In such a case, it might be optimal to exempt smaller firms to reduce the social cost of environmental regulation (Brock and Evans 1985). Let $\tilde{e}$ denote the emissions' threshold at which the total transaction costs of regulating a firm equalize the welfare gains from regulation, i.e, $D(\tilde{e}) = -C_i(\tilde{e}) - T_i(\tilde{e})$. Hence, an exemption should be available for a particular firm emitting $e_i < \tilde{e}$ units of emissions to avoid situations where the benefits of regulation (i.e., reduced social cost of emissions) exceeds the regulatory costs.

We do not attempt to define the functional forms in these formulas. Fortunately, we know that the damages should only depend on the level of emissions. Moreover, taxes and tradable permits are equivalent economic instruments in terms of pollution control cost efficiency, and hence, regardless of the exact nature of the cost function $C_i(e_i)$, the costs of pollution control for a given firm should be the same for the two of them. However, there is no theoretical reason to believe that both instruments entail the same transaction costs $T_i(e_i)$ to firms or that they have a common structure (e.g., see discussion by Stavins 1995). Thus, the comparison between CO_2 taxes and tradable permits in this setting comes down to empirically comparing the transaction costs of the policies. From Equation (2) it is clear that if the marginal transaction costs of these policies are not the same, the optimal level of pollution control for the policy with the largest marginal transaction costs is lower. In addition, in the presence of scale economies in regulatory compliance, the optimal number of firms regulated under each policy will not be the same: more firms should be exempted from the regulation with the largest transaction cost. Hence, by comparing the total transaction costs of taxes and permits for smaller emitters, we can determine which policy is more costly to them.

It is often argued that carbon taxation implies lower administrative and compliance costs than emissions trading since consumption of fuel usually is much easier to monitor than emissions. Moreover, carbon taxation can be administered through government tax collection institutions that are more established and effective than environmental regulatory institutions (see, e.g., Coria 2009 and Pope and Owen 2009). However, there is no study that empirically compares the functional forms of transaction costs between CO_2 taxes and tradable emissions permits. Hence, to fill this gap and to be able to compare these policies, we need the answers to the following questions:

1) Are the total MRV transaction costs higher under the EU ETS than CO_2 taxation?

2) Do the total MRV transaction costs under CO_2 taxation and the EU ETS increase with the level of emissions?

3) Are there any positive spillover effects (or learning-by-doing) for the MRV costs from the interaction of CO_2 taxation and the EU ETS?

4) Do the transaction costs for a given policy differ across sectors?

In the subsequent sections we first describe the data we use to answer these questions and then present the results.

4) Data

To develop the empirical analysis described above, we need to combine primary and secondary sources of information. Regarding the primary information, after a set of exploratory interviews with policymakers and firms, we developed a questionnaire and conducted a survey (in collaboration with the Swedish Environmental Protection Agency) from late April to September 2013.[6] We asked a sample of Swedish firms a series of questions regarding the monitoring, reporting, and verification costs incurred as part of their compliance with the CO_2 tax and/or the EU ETS in 2012.

The sample consisted of 379 firms covered under the Swedish CO_2 taxation and/or the European Union Emissions Trading System (EU ETS) in 2012. Two hundred and twenty-three of these firms were registered as authorized warehouse keepers by the Swedish Tax Agency (around 58.8%), 264 were included in the EU ETS (around 69.7%), and 108 (around 28.5%) were covered by both policies and were thus registered as authorized warehouse keepers and included in the EU ETS in the same year. In total, 130 firms completed the survey (approximately 34.3%). Of the firms that responded, 67 (51.5%) were both authorized warehouse keepers and in the EU ETS in 2012 and 23 (17.7%) stated that they were authorized warehouse keepers but not in the EU ETS. The remaining 40 firms (30.8%) stated to be in the EU ETS but not registered as warehouse keepers in 2012 (see Table 1).

Table 1: Survey Respondents

		CO_2 Tax Firms		
		No	Yes	Total
EU ETS Firms	No	0	23	23
	Yes	40	67	107
	Total	40	90	130

Sources: The survey and the authors' calculations.

To complement the data gathered through our survey, we collected additional information from various sources including the total CO_2 tax payments from the STA, verified CO_2 emissions under the EU ETS from the European Union Transaction Log, and number of employees, turnover, and size categories from the Orbis database (which classifies firms as small, medium, large, or very large depending on a series of criteria regarding operation revenues, total assets, and number of

[6] The exploratory interviews took place from November 2012 to February 2013.

employees).[7] Finally, we collected information on the sector codes (SNI), fuel mix, fuel quantity and CO_2 emissions from fuel combustion from Statistics Sweden (SCB). Disentangling CO_2 emissions from fuel combustion is important since even if carbon taxation overall implies lower administrative and compliance costs, emissions trading might lead to larger emissions reductions as it is based on a broader definition of source stream. Thus, under the EU ETS definition, a source stream includes all fuel or material that enters and leaves the installation and has a direct impact on emissions (Directive 2003/87/EC). In the simplest case it means the fuels streaming into the installation. However, it also covers raw materials that give rise to process emissions (which are included in the calculation of GHG emissions using a mass balance method).

Although we contacted all relevant firms, response rates can always introduce some bias as firms willing to answer may be distinct from the average. Table 2 provides the descriptive statistics for the contacted firms and those that actually completed the survey. It is evident that the latter group includes a larger share of firms that are subject to both regulations and a larger share of firms that belong to the energy sector. This needs to be taken into account yet is not necessarily unexpected or negative. The regulations are complex and the firms that were subject to both CO_2 taxation and the EU ETS might have felt they had more to contribute. From a statistical point of view, the information provided by these double-regulated firms is very valuable as it allows disentangling the costs of each regulation from other firm-specific variables (e.g., management or organizational structure) that might affect the overall cost of MRV procedures regardless of the regulation in place.

Regarding size, besides the size categories from the Orbis database, we grouped the firms into three categories according to their verified CO_2 emissions under the EU ETS relative to the total verified emissions of the whole country. Thus, small emitters are those whose emissions represent up to 0.1% of the country total, medium emitters are in the 0.1–1% range, and large emitters have emissions corresponding to more than 1% of the country's total verified emissions. As shown in Table 2, most firms in our sample and most of the respondents are classified as small emitters in this respect. This is consistent with the fact that the EU ETS is dominated by very few large emitters and a large number of smaller emitters (e.g., see a report by the European Commission and Ecofys 2007).

[7] For example, firms in Orbis are considered to be large when they match at least one of the following conditions: operational revenue higher than 10 million euro, total assets higher than 20 million euro, and more than 150 employees. Similar definitions apply for medium and very large firms, while those that are not included in another category are classified as small firms.

Table 2: Summary of the Descriptive Statistics, 2012

Variable	Unit	Sample		Respondents		CO_2 Tax Firms		EU ETS Firms		Double-Regulated Firms	
		N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
CO_2 tax firms[3]	Dummy	379	0.588	130	0.692	90	1.000	107	0.626	67	1.000
EU ETS firms[2]	Dummy	379	0.696	130	0.823	90	0.744	107	1.000	67	1.000
CO2 tax & EU ETS firms[2,3]	Dummy	379	0.285	130	0.515	90	0.744	107	0.626	67	1.000
Energy sector firms[1]	Dummy	379	0.346	130	0.500	90	0.444	107	0.551	67	0.507
CO_2 emissions, fuel combustion[1]	Ton	244	65 528	103	61 525	70	74 206	95	63 767	62	80 407
Verified CO_2 emissions [2]	Ton	264	69 994	111	65 871	71	67 197	106	67 827	66	70 484
Total CO_2 tax payments[3]	Million EUR	379	8.515	130	3.978	90	5.731	107	0.525	67	0.819
Turnover[4]	Million EUR	357	417.931	123	240.496	86	282.484	102	227.259	65	275.278
Total assets[4]	Million EUR	335	577.558	118	648.917	81	611.549	95	396.958	58	184.038
Fixed tangible assets[4]	Million EUR	338	234.491	119	157.995	83	200.494	99	180.109	63	248.736
Employees[4]	Number	353	932	121	456	85	415	100	533	64	521
Small firms ORBIS[4]	Dummy	378	0.034	130	0.015	90	0.011	107	0.009	67	0.000
Medium firms ORBIS[4]	Dummy	378	0.138	130	0.123	90	0.078	107	0.112	67	0.045
Large firms ORBIS[4]	Dummy	378	0.423	130	0.508	90	0.478	107	0.501	67	0.462
Very large firms ORBIS[4]	Dummy	378	0.405	130	0.354	90	0.433	107	0.374	67	0.492
Small CO_2 emitter	Dummy	264	0.720	111	0.685	71	0.563	106	0.679	66	0.545
Medium CO_2 emitter	Dummy	264	0.216	111	0.243	71	0.338	106	0.245	66	0.348
Large CO_2 emitter	Dummy	264	0.006	111	0.072	71	0.098	106	0.075	66	0.106

[(1)] Sources: 1) Swedish Statistics; 2) European Union Transaction Log; 3) Swedish Tax Authority; 4) Orbis database.

5) The Results

In what follows, we discuss the survey responses and the answers to the questions raised in Section 3.

5.1 Comparing Transaction Costs under CO_2 taxation and the EU ETS

Table 3 presents the MRV costs for three groups of firms: (1) all firms subject to the MRV requirements of the CO_2 tax, (2) all firms subject to the MRV requirements of the EU ETS, and (3) firms subject to the MRV requirements of both regulations. In Table 3, the three groups are denoted *CO_2 tax all firms*, *EU ETS all firms* and *double regulation*, respectively. We have consistently excluded outliers and firms reporting no costs.[8]

As Jaraitė et al. (2010), in our analysis we consider three types of MRV costs: (1) *internal* costs, mainly management and staff time, measured as the number of full-time working days spent on all MRV procedures; (2) *external* costs incurred in terms of consultancy services taken in to be MRV compliant, measured in monetary terms; and (3) *capital* costs, meaning emissions/fuel measurement, monitoring, recording, and data storage equipment needed to comply, measured in monetary terms. In Table 3 we report all these types of *MRV* costs, which we denote as MRV_1 (internal costs), MRV_2 (the sum of internal and external costs) and MRV_3 (the sum of internal, external and capital costs).[9]

From Table 3 it is clear that firms spent a significant amount of time on MRV procedures and that there is a large range of variation in the number of full-time working days spent on all MRV procedures by firms in the sample. On average, firms spent more time on MRV procedures under the EU ETS than under CO_2 taxation (e.g., 38.8 vs. 30.9 days). Nevertheless, according to the non-parametric Wilcoxon-Mann-Whitney test, this difference is not statistically significant (p-value = 0.165). The difference in internal costs is, however, much larger and statistically significant (p-value = 0.010) when we look at the sample of firms subject to both regulations (on average, 33.8 vs. 51.4 days). This is to say that for exactly the same firms, the MRV procedures under the CO_2 tax take, on average, 18 days less than those under the EU ETS. This finding suggests that the MRV requirements are more demanding to comply with under the EU ETS. In addition, when we compare the sample of all firms with the subsample of firms subject to both policies, we see that the firms in the latter group spend on average more time on MRV procedures. The difference in time spent is only statistically significant in the case of the EU ETS (on average, 38.8 vs. 51.4, p-value = 0.074). Firms subject to both regulations are larger than those in the EU ETS all firms group, which might explain this result.

[8] We define a firm as an outlier if its reported MRV costs in terms of full-time working days are higher than 500. In this case, two warehouse keepers were dropped from the sample. Six firms that reported zero full-time working days either for the CO_2 tax, EU ETS, or both were also excluded from the analysis.

[9] The internal costs from total full-time days were converted in monetary terms by assuming eight hours of full-time working day and multiplying these hours by the average hourly wage of a qualified employee working on environmental activities in Sweden.

Moreover, this finding points to a lack of learning-by-doing or synergies between the MRV procedures under the two regulations.

The cost wedge between the two policies remains when we compare the total costs of the time spent on internal MRV procedures plus external and capital costs. In both cases (e.g., MRV_2 and MRV_3), the cost wedge is statistically significant when we compare the CO_2 tax all firms group and the EU ETS all firms group. Hence, external and capital costs seem to be higher in the case of the EU ETS, which increases the wedge between the two policies so it becomes statistically significant (p-value = 0.000 for both MRV_2 and MRV_3). The cost wedge between the two policies is also statistically significant when we analyze the sample of firms that are subject to both regulations (p-value = 0.000 for both MRV_2 and MRV_3).

Table 3: MRV Costs for CO_2 Taxation and the EU ETS

	N	Mean	Std. dev.	Min	Max
Full-time working days spent on all MRV procedures, MRV_1					
Cost CO_2 tax all firms	80	30.9	44.2	0.75	215
Cost EU ETS all firms	104	38.8	63.0	1	372
Cost CO_2 tax double regulation	59	33.8	49.5	1.5	215
Cost EU ETS double regulation	59	51.4	77.1	6	372
Sum of the cost of full-time working days spent on all MRV procedures plus external costs in thousand EUR, MRV_2					
Cost CO_2 tax all firms	80	12.7	17.6	0.264	97.9
Cost EU ETS all firms	104	23.2	29.7	1.056	166.1
Cost CO_2 tax double regulation	59	13.7	19.9	0.528	97.9
Cost EU ETS double regulation	59	29.7	36.0	2.464	166.1
Sum of the cost of full-time working days spent on all MRV procedures plus external and capital costs in thousand EUR, MRV_3					
Cost CO_2 tax all firms	80	15.0	22.2	0.264	114.6
Cost EU ETS all firms	104	26.5	36.3	1.056	221.7
Cost CO_2 tax double regulation	59	16.7	25.2	0.528	114.6
Cost EU ETS double regulation	59	34.1	44.7	2.464	221.7

Sources: The survey and the authors' calculations.

Table 4 presents the breakdown of *internal* MRV costs of CO_2 taxation and the EU ETS for the sample of firms subject to the MRV requirements of both regulations. We report the breakdown estimated as the number of full-time working days spent on monitoring, reporting, and verification, respectively, relative to the total number of full-time working days spent on all MRV procedures. It also shows the breakdown of *total* MRV costs reported by the firms. Clearly, these two breakdowns might differ since the former only includes internal costs (measured as number of full working days), while the latter also includes total MRV costs (in thousand EUR). At any rate, it is clear that the largest differences between the studied policies are related to the costs of verification. That is, in relative terms, the costs of verification are larger under the EU ETS. Firms regulated under the EU

ETS spend a significant amount of resources not only hiring external certified verifiers but also on internal verification, which is used as an input by external verifiers. Moreover, the resources devoted to reporting are (in relative terms) larger under CO_2 taxation, which might be explained by the fact that reporting under this regulation occurs on a monthly basis, while under the EU ETS firms have to report their emissions only once a year. Finally, in all cases monitoring is the activity that makes up the largest share of the MRV costs. Most of our respondents monitor fuel consumption and/or CO_2 emissions on a monthly basis. This is expected in the case of CO_2 taxation as it coincides with the frequency of the reporting. In the case of the EU ETS, firms monitor emissions more often than the required frequency of the reporting. A frequent monitoring might allow them to anticipate and adjust their purchases/sales of permits to ensure compliance with the regulation.

Table 4: Breakdown of the MRV Cost for CO_2 Taxation and the EU ETS

	Estimated Breakdown of Internal MRV Costs (%)			**Reported Breakdown of Total MRV Costs (%)**		
	N	Mean	Std. dev.	N	Mean	Std. dev.
	CO_2 Tax					
Monitoring	59	53.1	18.4	56	45.9	19.6
Reporting	59	39.7	17.0	56	42.5	20.4
Verification	59	7.1	15.5	56	11.6	16.4
	EU ETS					
Monitoring	59	46.9	22.1	58	39.6	21.0
Reporting	59	30.5	17.0	58	29.8	18.2
Verification	59	22.6	13.9	58	30.6	21.3

Sources: The survey and the authors' calculations.

As mentioned before, the EU ETS is based on a broader definition of source stream, as it includes the emissions from not only fuel combustion (covered under the CO_2 tax) but also raw materials. Hence, even if the total MRV costs are larger under the EU ETS than under CO_2 taxation, the cost per unit of emissions might be lower under the former policy as it covers a larger amount of emissions. To account for this, Table 5 reports our three measures of MRV cost (in thousand EUR) per ton of CO_2 emissions, where emissions under CO_2 taxation correspond to those provided by SBC (fuel combustion) and emissions under the EU ETS correspond to the verified emissions reported to the European Union Transaction Log.[10]

Note that, with regard to Table 3, the number of observations in each group decreases since information on CO_2 emissions is unfortunately not available for all firms in our sample. However, from Table 5 it is clear that the differences in MRV costs between the two policies remain even after dividing them by emissions. In all cases, the MRV cost per ton of CO_2 emissions is statistically higher under the EU ETS than under CO_2 taxation both when we compare the sample of all firms subject to

[10] The verified average emissions for the sub-sample of 54 firms that are subject to double regulation correspond to 69 699 tons of CO_2. That is, in this group 99% of the total emissions stem from fuel combustion.

the CO_2 tax and the sample of all firms subject to the EU ETS and when looking at the sample of firms subject to both regulations.[11] If we focus, e.g., on the firms that are subject to both regulations, we can see that the average MRV_1 cost is equal to 6.6 €/tCO_2 under CO_2 taxation and 9.2 €/tCO_2 under the EU ETS. If we consider also external costs, these figures increase to 9.1 €/tCO_2 and 16.5 €/tCO_2, respectively. These costs are by all means high if we compare them with the actual price of CO_2 emissions under both policies. For instance, the price of the EU ETS permits was persistently under 10 €/tCO_2,while the effective CO_2 tax rate over the period 1990-2004 corresponded to around 11 €/tCO_2.

Table 5: MRV Cost, €/tCO_2

	N	Emissions	MRV_1/tCO_2	MRV_2/tCO_2	MRV_3/tCO_2
Cost CO_2 tax all firms	61	66 231	6.4 (28.2)[2]	9.3 (40.4)	9.4 (40.4)
Cost EU ETS all firms	101	70 052	10.6 (32.1)	37.6 (203.0)	38.3 (203.0)
Cost CO_2 tax double regulation	54	69 068[1]	6.6 (29.9)	9.1 (42.3)	9.3 (42.4)
Cost EU ETS double regulation	57	66 406	9.2 (33.1)	16.5 (61.8)	17.1 (61.8)

Sources: The survey and the authors' calculations.
Standard deviations are in parentheses.

In sum, our results indicate that the MRV costs are substantial and exceed the current prices of CO_2 emissions. This is by all means a surprising finding, especially if one considers that most studies analyzing or comparing environmental regulations disregards the role of transaction costs.. Moreover, the costs related to MRV activities under the EU ETS are higher than the costs under CO_2 taxation. The difference is even larger when we look at the group of firms subject to the MRV requirements of both regulations.

5.2 Economies of Scale under CO_2 Taxation and the EU ETS

Table 6 reports the carbon intensity (defined as the ratio of verified CO_2 emissions in the EU ETS to turnover) and the sum of internal and external MRV costs per ton of emissions for small, medium, and large emitters, where as described in Section 4 these categories are based on the firms'

[11] For MRV_1, the difference in the cost per ton of CO_2 emissions is statistically significant at p-value = 0.000 when we compare the sample of all firms paying the CO_2 tax with the sample of all firms paying the EU ETS. The P-value is 0.010 when we look at the sample of firms that are subject to both regulations. For MRV_2 and MRV_3, the difference in the cost per ton of CO_2 emissions is statistically significant at p-value = 0.000 in all cases.

emissions as a proportion of the whole country's total verified emissions. We focus on the sum of internal and external costs since, as pointed out earlier, external costs are quite relevant in the case of the EU ETS due to external verification requirements. Moreover, we exclude capital costs since they are time specific and do not occur on a regular basis.

Table 6: MRV_2 for Small, Medium, and Large Emitters

	CO_2 Tax all firms		EU ETS all firms	
	N	Mean	N	Mean
Small firms				
CO2 intensity (tCO2/th EUR)	35	0.107	65	0.096
MRV_2 (thousand EUR)	37	10.7	72	19.1
MRV_2 €/tCO_2	36	26.5	70	54.1
Medium firms				
CO2 intensity (tCO2/th EUR)	24	0.906	25	0.901
MRV_2(thousand EUR)	20	12.6	23	24.1
MRV_2 €/tCO_2	20	0.24	23	0.53
Large firms				
CO2 intensity (tCO2/th EUR)	6	3.014	8	3.660
MRV_2 (thousand EUR)	6	28.6	8	49.7
MRV_2 €/tCO_2	6	0.08	8	0.10

Sources: The survey and the authors' calculations.

From Table 6 we can observe that while, on average, the total MRV_2 costs are larger for the largest firms in all cases (both under CO_2 taxation and under the EU ETS), the MRV_2 cost per ton of CO_2 emissions is the largest for the smallest firms. Similar patterns were observed by Jaraitė et al. (2010) in the case of Irish firms under the EU ETS. Also, we can observe that for all firm categories, the MRV_2 costs are larger for firms under the EU ETS.

Since we have very few large firms in our sample, we merge firms into two groups in order to test whether the cost differences are statistically significant. Thus, we classify firms as small and large (where the large firms correspond to the medium and large firms in the table). Interestingly, we find that the cost difference between small and large firms is only statistically significant in the case of the firms regulated under the EU ETS (p-value = 0.001). However, we observe that under both regulations the MRV cost per unit of emissions is statistically (and not surprisingly) lower in the case of the large firms (p-value = 0.000).

Our findings indicate that under CO_2 taxation, size does not affect the total MRV costs. This is consistent with a cost structure characterized by a fixed component that can be denoted F_T, where the total cost of MRV does not depend on size but the cost per unit of emissions does. In contrast, the statistical evidence in the case of the EU ETS points out to a cost structure of the type $F_P + t(e)$, where F_P corresponds to the fixed component and $t(e)$ to a variable component that increases with emissions at a decreasing rate. Thus, our results point out to a different structure of the transaction costs of the policies under analysis. By comparing firms of a similar size, we can argue that $F_T < F_P + t(e)$ both for small and large firms, implying that for small emitters the transaction costs of CO_2 taxation are lower than those under the EU ETS. Furthermore, despite the existence of economies of scale, the costs of MRV activities under the CO_2 tax remain smaller than under the EU ETS even for large firms.[12]

To analyze the extent to which transaction costs depend on emissions, we estimate a simple OLS model where the empirical specification corresponds to:

$$(3) \qquad \log(MRV_i) = \alpha_1 + \alpha_2 e_i + +\alpha_3 {e_i}^2 + \alpha_4 X_i + \epsilon_i.$$

We estimate the model for our three measures of MRV costs (e.g., MRV_1, MRV_2, and MRV_3, all expressed in the same measurement units as in Table 3). The explanatory variables include emissions e_i (which in the case of CO_2 taxation correspond to emissions from fuel combustion and in the case of the EU ETS correspond to verified emissions), a matrix X_i of firm characteristics, which serve as control variables (including sector, turnover, number of employees and whether the firm is subject to double regulation), and an error term ϵ_i, which is normally distributed $N\sim(0,\sigma^2)$. Regarding sector, we grouped firms into two categories: energy and non-energy firms.[13]

Note that in our specification, emissions enter the regression in a non-linear way to test for economies of scale. A similar specification was employed by Heindl (2012) to test for economies of scale on the transactions costs of the EU ETS for a sample of German companies.

The results of our OLS models are presented in Table 7. For all OLS estimations, the robust standard errors were calculated as they take into account the potential heterogeneity and lack of normality of the data.

[12] Non-parametric Wilcoxon-Mann-Whitney tests comparing the MRV costs per unit of emissions between CO_2 taxation and the EU ETS for small and large firms support this statement (p-value = 0.011 in the case of small firms and p-value = 0.020 in the case of large firms). The results of the tests should, however, be interpreted with caution since they are based on the small sample sizes.

[13] Energy firms correspond to the NACE code 35 and non-energy firms correspond to all the other NACE codes.

Table 7: OLS Estimation of MRV Costs[1]

Variables	MRV_1		MRV_2		MRV_3	
	CO_2 tax all firms	EU ETS all firms	CO_2 tax all firms	EU ETS all firms	CO_2 tax all firms	EU ETS all firms
Emissions	5.46e-06	4.12e-06**	4.32e-06	3.75e-06**	4.28e-06	3.64e-06**
	(1.00)	(7.09)	(0.79)	(6.38)	(0.83)	(5.23)
Emissions squared	-4.07e-12	-1.59e-12**	-2.53e-12	-1.55e-12**	-2.74e-12	-1.53e-12**
	(0.55)	(6.26)	(0.37)	(6.08)	(0.40)	(5.12)
Turnover	-1.49e-04	1.83e-04	-1.54e-04	-2.98e-05	-2.30e-04	-1.49e-05
	(0.70)	(1.49)	(0.62)	(0.26)	(1.13)	(0.12)
# Employees	-1.55e-04	-1.71e-04**	-1.42e-04	-6.37e-05	-1.22e-04	-8.19-05*
	(1.54)	(2.97)	(1.51)	(1.76)	(1.25)	(2.28)
Double regulation	0.0374	0.506**	-0.082	0.361*	0.040	0.351
	(0.12)	(2.88)	(0.26)	(2.16)	(0.04)	(1.92)
Energy sector	0.318	0.047	0.362	0.212	0.308	0.100
	(1.12)	(0.26)	(1.34)	(1.26)	(1.03)	(0.52)
Constant	2.490**	2.600**	1.826**	2.274**	1.861**	2.439**
	(7.10)	(14.38)	(5.28)	(13.34)	(5.24)	(12.26)
N	60	95	60	95	60	95
R^2	0.15	0.36	0.16	0.27	0.12	0.23

Notes: 1. $p < 0.05$ is denoted * and $p < 0.01$ is denoted **. 2. Robust standard errors are in parentheses.

In line with Heindl's (2012) results and the results of the statistical analysis above, the regression analysis supports the existence of economies of scale in the case of the EU ETS. Our three measures of MRV costs are non-linear in emissions: they increase with emissions at a decreasing rate. In addition (and also in line with the statistical analysis in the previous section), firms subject to both regulations have higher MRV costs than those that are subject only to the MRV requirements of the EU ETS. As mentioned earlier, this finding seems to reflect the fact that these firms are larger, yet it also points to the lack of learning-by-doing effects and synergy effects between the MRV requirements of both policies. Consequently, regulation overlap has implied duplication of transaction costs compared with what the costs could have been with only one policy. In principle, the policies are based on different measurement units (fuel handling vs. verified emissions) and it might be difficult to integrate an emissions trading scheme with the existing tax system. However, the transaction costs of both policies are high, especially when one compares them with the actual cost of the carbon tax and the price of the EU ETS permits. The recommendation would then be to avoid such policy overlapping when possible.

Another interesting result is that the transaction costs are decreasing with the number of employees in the case of the EU ETS. This might suggest that firms that are large in terms of personnel have more experience complying with environmental regulations and hence incur lower transaction costs. The opposite results were reported by Heindl (2012) in the case of German firms in the EU ETS as he found that firms with more than 1,000 employees are experiencing larger overall transaction costs.

The regression analysis confirms that the MRV costs under CO_2 taxation do not depend on emissions. Moreover, control variables that might affect the costs of MRV costs are not statistically significant.

5.3 Transaction Costs across Sectors

As discussed in Section 4, we observe that with regard to the firms in the sample, there is a slight over-representation of firms in the energy sector among our respondents, in particular in the group of firms that are subject to both regulations. In the energy sector, emissions are driven almost entirely by the type and quantity of fuel burned. This means that if the regulator can measure the quantity of fuel that enters the chain, they can accurately assess emissions. We might also expect that energy firms (which are usually quite large and subject to many environmental regulations in addition to those intended to reduce GHG emissions) are less carbon intensive and more efficient in terms of administrative procedures, which might affect their MRV costs. Though the regression analysis did not show any significant difference in MRV costs between firms in the energy sector and firms in the other sectors, in this section we analyze this point more carefully by means of a statistical comparison across groups. To this end, in Table 8 we present the CO_2 emissions intensity per sector (computed as the ratio of CO_2 emissions to turnover), the sum of internal and external MRV procedures (in thousand EUR), and the cost per ton of emissions. As usual, emissions under CO_2 taxation correspond to those from fuel combustion and emissions under the EU ETS correspond to the verified emissions.

Table 8: The MRV Costs in the Energy vs. Non-Energy Sectors

	CO_2 tax all firms		**EU ETS all firms**		**CO_2 tax vs. EU ETS**
	N	Mean	N	Mean	p-value
Energy Sector					
CO_2 intensity (tCO_2/th EUR)	35	0.339	54	0.261	
Emissions	35	28 506	54	28 096	
MRV_2(thousand EUR)	35	13.8	58	22.8	0.009
MRV_2 €/tCO_2	30	0.015	56	29.6	0.001
Non-Energy Sector					
CO_2 intensity (tCO_2/th EUR)	30	1.057	44	0.999	
Emissions	30	105 960	44	127 217	
MRV_2(thousand EUR)	45	11.9	46	23.6	0.001
MRV_2 €/tCO_2	31	0.004	45	47.6	0.001

Sources: The survey and the authors' calculations.

We can observe that – regardless of the policy in place – the emission intensity of firms is lower in the energy sector than in the other sectors. The costs of MRV procedures, however, are slightly higher in the energy sector. One explanation for this is the structure of energy firms – usually they run several plants located in different locations and this might require additional staff resources for MRV procedures. If for the same regulation we compare between sectors (e.g., CO_2 tax for energy vs. non-energy sectors), we find that the differences are only statistically significant for the cost per unit of emissions MRV_2/tCO_2, which is lower in the case of the energy sector whether regulated under CO_2 taxation (p-value = 0.007) or the EU ETS (p-value = 0.000). In contrast, if for the same sector we compare between regulations (e.g., CO_2 tax vs. EU ETS for the energy sector), we find that the MRV costs are statistically higher under the EU ETS in both the energy and non-energy sector (p-values reported in the table).

In sum, the conclusion of this analysis is that the differences in total MRV costs are driven mainly by the policies in place rather than the sectors.

5.5 On the attitudes of the firms towards the transaction costs of the CO_2 taxes and EU ETS.

Besides asking firms about the costs related to MRV activities, our survey included a series of questions aimed to unveil firms' perceptions regarding the evolution of transaction costs over time, as well as the extent to which they agree with statements regarding the costs of the regulations. In particular, we asked firms whether the MRV costs under CO_2 taxation and the EU ETS have increased/decreased over time and whether they think that the EU ETS is too burdensome for small emitters. The responses to these questions are reported in Table 9.

Table 9: Responses to the General Statements

CO_2 tax firms			EU ETS firms		
Agree	Indifferent	Disagree	Agree	Indifferent	Disagree
In terms of the administrative burden, if our firm was given an opportunity to be regulated by only the CO_2 tax or the EU ETS, we would prefer the CO_2 tax					
45	20	14	61	24	16
The EU ETS provides stronger incentives for firms to reduce their CO_2 emissions than does CO_2 taxation					
23	19	37	30	25	46
The volatility of the price of the allowances in the EU ETS has provided firm with strong incentives to reduce their CO_2 emissions					
9	24	47	11	17	74
The EU ETS is too burdensome for small emitters					
50	21	8	75	13	12

Sources: The survey and the authors' calculations.

Our results indicate that most firms agree or strongly agree with the statement that the EU ETS is too burdensome for small emitters. For instance, out of 79 firms subject to the MRV requirements of CO_2 taxation that answered this question, 50 agree or strongly agree with this statement. Out of 100 firms subject to the MRV requirements of the EU ETS that answered this question, 75 agree or strongly agree with this statement. Moreover, if given the opportunity to choose to be regulated only by the CO_2 tax or the EU ETS, most firms would prefer to be regulated through CO_2 taxation. The share of firms that would prefer to be regulated through CO_2 taxation is slightly larger among the firms that are currently regulated under the EU ETS (60% vs. 57% in the case of the firms regulated through CO_2 taxation). These findings might, however, not only be a reflection of the higher transactions costs involved in the EU ETS's MRV procedures, but also indicate a certain degree of skepticism regarding the incentives provided by the EU ETS to reduce emissions. For instance, most firms do not agree with the statement that the EU ETS provides stronger incentives for firms to reduce their CO_2 emissions than CO_2 taxation. The share of firms that do not agree is about 70% both in the case of the firms subject to the CO_2 tax and in the case of the firms in the EU ETS. Moreover, firms do not believe that the price volatility of the allowances in the EU ETS has provided firms with strong incentives to reduce their CO_2 emissions. Again, the share of firms that do not agree with this statement is approximately the same among the firms subject to the CO_2 tax and those in the EU ETS at 89%.

Regarding the evolution of MRV costs over time, out of 39 firms subject to the CO_2 tax that answered this question, 26 indicated that the costs have not increased while 10 firms responded that the costs have increased as a result of new legislation, development of measurement systems and procedures, and increased costs of external verification. Out of 56 firms regulated under the EU ETS that answered this question, 15 indicated that the costs have not increased while 34 responded that the costs have increased due to more stringent requirements for MRV and increased costs of external verification. Clearly we have too few observations to draw conclusions. However, the responses do suggest that it is more common to believe that the costs of MRV procedures have increased over time under the EU ETS than to believe that they have done so under CO_2 tax taxation.

6) Discussion and Conclusions

In this paper we empirically compared the transaction costs from measurement, reporting, and verification between two environmental regulations aimed to cost-efficiently reduce greenhouse gas emissions: a carbon dioxide tax and a tradable emissions system. We chose to look at the case of Sweden, where a set of firms was for some years covered by both respective regulations – the Swedish CO_2 tax and the European Union's Emissions Trading System. This provided us with an excellent case study as it allowed us to disentangle the costs of each regulation from other firm-specific variables that might affect the overall cost of MRV procedures.

In particular, we aimed to answer the following questions: (1) Are firms' MRV transaction costs higher under the EU ETS or CO_2 taxation? (2) Do firms' MRV costs depend on CO_2 emissions? (3) Are there any learning-by-doing effects on firms' MRV costs from the interaction of the CO_2 tax and the EU ETS? And (4), do firms' MRV costs differ across sectors?

Our results indicate that the transaction costs are high, especially compared with the actual cost of the CO_2 tax and the price of the EU ETS permits. This is by all means a surprising finding if one considers that most studies analyzing or comparing environmental regulations disregards the role of transaction costs. In addition, our results point to different structures of the MRV costs under CO_2 taxation and the EU ETS: Under CO_2 taxation the MRV costs do not depend on size while they do in the case of the EU ETS. When comparing the costs between policies we find that the costs are generally higher under the EU ETS than under CO_2 taxation. Moreover, regulation overlap has implied duplication of transaction costs compared to what the costs could have been with only one policy in place. Since the MRV costs of both policies are high the recommendation is therefore to avoid such policy overlap. Furthermore, our results support the implementation of a minimum threshold for actual emissions to avoid that the costs of participation outweigh the benefits of being covered by the scheme. This threshold should ensure that only installations that emit more than a fixed amount of tons CO_2/year are covered by the regulations. From our results is clear that such a threshold should be larger in the case of the EU ETS.

A caveat of our analysis is that we compare the costs of two policies in place and hence disregard start-up costs that might be quite large in the case of the EU ETS. Moreover, we disregard the trading costs under the EU ETS. Including such costs in the analysis could clearly increase the wedge between the transaction costs of the studied policies even further. Also, it is important to highlight that by buying fuel from authorized warehouse keepers, many firms and final clients pay the tax without incurring any MRV costs. Thus, by surveying warehouse keepers we focus on the only firms that have MRV costs related to compliance with the CO_2 tax. This implies that if we had considered the overall coverage of the CO_2 tax, the MRV costs per firm or per ton of CO_2 would have been even smaller.

All in all, our results confirm the general view that regulating emissions upstream by means of a carbon tax decreases transaction costs vis-á-vis downstream regulation by means of emission trading. As described in the paper, transaction costs due to MRV will have a negative effective reducing the optimal level of emissions' reductions in the case of both regulations (though the reduction is larger in the case of emission trading as the transaction costs are higher than in the case of carbon taxation). However, unlike taxes, reducing the stringency of MRV activities will also affect the price of emissions. Indeed, it is well know that (unlike emission taxes), under a trading scheme the price of emission permits is affected by the strength of monitoring and enforcement activities. Moreover, the permit price influences abatement decisions and therefore the enforcement strategy influences the emissions discharge. Thus, the success of an emission trading scheme will certainly depend on the strength of MRV. If not properly handled, this can affect the emission price and hence the aggregate abatement level achieved by the policy in the long term. Hence, MRV procedures related to emissions trading are not only more costly than those related to CO_2 taxation but also much needed if the regulation is to provide real incentives for polluters to reduce emissions.

7) References

Bonilla, J., Coria, J. and T. Sterner. 2012. Synergies and Trade-offs between Climate and Local Air Pollution: Policies in Sweden. Working Papers in Economics 529, University of Gothenburg, Department of Economics.

Bradford, C. 2004. Does Size Matter? An Economic Analysis of Small Business Exemptions from Regulation. *The Journal of Small & Emerging Business Law* 8(1): 1-37.

Brock, W. and D.S. Evans. 1985. The Economics of Regulatory Tiering. *The RAND Journal of Economics* 16(3): 398-409.

Crals, E. and L. Vereeck. 2005. Taxes, Tradable Rights and Transaction Costs. *European Journal of Law and Economics* 20: 199-223

Coria, J. 2009. Environmental Policy, Fuel Prices and the Switching to Natural Gas in Santiago, Chile. *Ecological Economics* 68 (11): 2877-2884.

European Commission. 2003. On the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council.

http://ec.europa.eu/clima/news/docs/regulation_mr_en.pdf

European Comission and Ecofys. 2007. Small Installations within the EU Emissions Trading Scheme.

http://ec.europa.eu/clima/policies/ets/docs/finalrep_small_installations_en.pdf

European Parliament and Council. Directive 2008/101/EC of the European Parliament and of the Council of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community.

Heindl, P. 2012. Transaction Costs and Tradable Permits: Empirical Evidence from the EU Emissions Trading Scheme. Discussion Paper No. 12-021. Centre for European Economic Research.

Jaraitė J., Convery F. and C. Di Maria. 2010. Transaction costs for firms in the EU ETS: lessons from Ireland. *Climate Policy* 10(2): 190-215.

Jaraitė, J., Jong, T., Kažukauskas, A., Zaklan, A., and Zeitlberger, A. Ownership Links and Enhanced EUTL Dataset. European University Institute, Florence, 2013. Available online at http://fsr.eui.eu/CPRU/EUTLTransactionData.aspx

Kerr, S. and V. Duscha. 2014. Going to the source: using an upstream point of regulation for energy in a national Chinese emissions trading system.

Kohn, R. 1991. Transactions costs and the optimal instrument and intensity of air pollution control. *Policy Sciences* 24: 315-332.

Krutilla, K. and R. Krause. 2010. Transaction Costs and Environmental Policy: An Assessment Framework and Literature Review. *International Review of Environmental and Resource Economics* 4: 261-354.

Lundgren, T. and P.O. Marklund. 2010. Climate Policy and Profit Efficiency, CERE Working Paper, 2010: 11. http://www.cere.se/documents/wp/CERE_2010_11.pdf

Löfgren Å, Wråke M., Hagberg T., and S. Roth. 2013. The Effect of EU-ETS on Swedish Industry's Investment in Carbon Mitigating Technologies. Working Papers in Economics No. 565, University of Gothenburg.

https://gupea.ub.gu.se/bitstream/2077/32649/1/gupea_2077_32649_1.pdf

Mansur, E. 2012. Upstream versus Downstream Implementation of Climate Policy. In The Design and Implementation of US Climate Policy (Editors: D. Fullerton and C. Wolfram). Chicago Scholarship Online.

McCann, L. 2013. Transaction costs and environmental policy design. *Ecological Economics* 88: 253-262.

McCann, L., Colby B., K. Easter K.W., Kasterine A. and K.V. Kuperan. 2005. Transaction cost measurement for evaluating environmental policies. *Ecological Economics* 52: 527-542.

Nutek (2005) Näringslivets administrativa bördor. Fyra punktskatter. R 2005:7. Elanders, Stockholm.

Polinsky, A.M. and S. Shavell. 1982. Pigouvian Taxation with Administrative Costs. *Journal of Public Economics* 19: 385-394.

Pope, J. and A. D. Owen. 2009. Emission trading schemes: potential revenue effects, compliance costs and overall tax policy issues. *Energy Policy* 37: 4595-4603.

SKV 525, 2014: Swedish Tax Agency "Godkänd upplagshavare- skatt på energi"; SKV 525, edition 4, March 2014. https://www.skatteverket.se/download/18.15532c7b1442f256bae8ce2/1395067855165/52504.pdf

SKV 531, 2012: Swedish Tax Agency "Regler för betalning, redovisning och återbetalning av punktskatt"; SKV 531, edition 5, May 2012. https://www.skatteverket.se/download/18.71004e4c133e23bf6db800084693/1338212503211/53105svartvit.pdf

SKV 543, 2014: Swedish Tax Agency "Lagerhållare- skatt på energi"; SKV 543, edition 4, March 2014. https://www.skatteverket.se/download/18.15532c7b1442f256bae8eca/1395069481905/54304.pdf

SKV 663, 2012: Swedish Tax Agency "Allmänt om revision"; SKV 663, edition 8, January 2012. https://www.skatteverket.se/download/18.71004e4c133e23bf6db800016010/1325680160883/66308.pdf

Stavins, R. N. 1995. Transaction Costs and Tradable Permits. *Journal of Environmental Economics and Management* 29(2): 133-148.

Weitzman, M. 1974. Prices vs. Quantities. *Review of Economic Studies* XLI: 477-449.