# Transaction Costs of Emissions Trading vs. Carbon Taxes*

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**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 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.

*Key Words:* Climate change; $CO_2$ tax; Emissions trading; Firm-level data; EU ETS; Transaction costs; Sweden. *JEL classification:* D23; H23; Q52; Q58.

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# 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; 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 (e.g. Weitzman 1974), and some theoretical studies analyzing the implications of the existence of transaction costs for optimal taxation (e.g. Yitzhaki 1979; Polinsky and Shavell 1982) and emissions trading (e.g. Stavins 1995; Montero 1997), 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 these costs are relevant for both instruments and 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; 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 and trading costs as these costs are pertinent only for emissions trading programmes.

Our results provide empirical support to the claim that transaction costs from MRV are larger under emissions trading than carbon taxation. 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 primary and secondary data. Section 4 contains our empirical analysis of the data. 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. Initially, it was equivalent to €25/t$CO_2$. After increasing steadily over the last decade, at present it corresponds to €105/t$CO_2$. 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 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/t$CO_2$; the $CO_2$ tax varied considerably across sectors, ranging from about €4/t$CO_2$ in the wood product sector to almost €15/t$CO_2$ 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, industry within the EU ETS were fully exempted from the $CO_2$ tax. The same exemption applied to combined heat and power (CHP) production from 2013 onwards. 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. For instance, in 2012 heat production in CHP faced 7% $CO_2$ tax, while other heat plants were taxed with 94% $CO_2$ tax (for more details see IEA 2013).

Though historically the $CO_2$ tax applied to the fuel used by all industrial and energy producing activities, 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). 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. 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 2012; and SKV 525 2014; SKV 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 selected audits if they suspect that a firm has misreported taxes. Before 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 main sectors included in the EU ETS account for 35% of the country's total $CO_2$ emissions (Löfgren et al. 2014). These sectors correspond to the energy sector (15% of total Swedish $CO_2$ emissions), the metal industry (8%), the mineral industry (6%), refineries (4%), and the pulp and paper industry (3%). In addition, all other combustion installations with a rated thermal

input exceeding 20 MW are included in the EU ETS (European Parliament and Council 2003). According to Jaraitė et al. (2013), in 2012 the number of Swedish installations included in the EU ETS was 853, corresponding to 273 firms as some firms owned 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.[1] In particular, each operator of ETS installation, based on the monitoring rules outlined in the legislation (European Commission 2012a; European Commission, 2012b), writes, implements and updates a monitoring plan which contains all the elements necessary to understand the monitoring of his emissions. Once monitoring is completed, the operator must report for a given year by March 31 of the following year the annual emissions of his installation, calculated in accordance with the methodologies described in his monitoring plan. Before this deadline, the annual emissions report must be verified by the independent accredited verifier. Once verified, the operator must surrender the equivalent number of tradable emission rights by 30 April of that year. Any firm that does not surrender sufficient number of tradable emission rights by 30 April 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 while both regulations regulate and place monetary value on $CO_2$ emissions, 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 The Model

Regulation can vary along two important dimensions: its level of stringency and its coverage. Transaction costs of pollution control affect both dimensions, and so the choice of policy instruments. To show this, let us analyze the emissions' reductions $q_i$ from $n$ regulated firms

[1] For an excellent detailed overview of the EU ETS's MRV activities see Bellassen and Stephan (2015).

$(i = 1, \ldots, n)$. Let $Q = \sum_{i=1}^{n} q_i$ be the aggregate level of abatement, and $B(Q)$ be the total (social) benefit of abatement $Q$. Since the pollutant is uniformly distributed it holds that $\sum_{i=1}^{n} B(q_i) = \beta(\sum_{i=1}^{n} q_i)$. Moreover, we follow convention and assume that $B(Q)$ is increasing and concave in its argument, i.e., $B'(Q) > 0$ and $B''(Q) \leq 0$.

We define the costs of pollution reduction for firm $i$ by the cost function $C_i(q_i)$. We assume that $C_i(q_i)$ is increasing and convex in abatement, i.e., $C_i'(q_i) > 0$ and $C_i''(q_i) > 0$ for any $q_i \in [0, \widehat{e}_i]$ for $i = 1, ..., n$, where $\widehat{e}_i$ corresponds to the uncontrolled level of emissions of firm $i$, of which $q_i$ units are abated and $e_i$ units are released to the environment, i.e., $\widehat{e}_i = q_i + e_i$.

Let the function $T_i(\widehat{e}_i)$ represent the firm's $i$ transaction costs (in the context of our study, the costs of monitoring, reporting, and verification) associated with the policy instrument chosen to implement the abatement target. MRV costs might be of a fixed or variable kind. We assume that $T_i(\widehat{e}_i)$ is non-decreasing and concave in its argument, i.e., $T_i'(\widehat{e}_i) \geq 0$ and $T_i''(\widehat{e}_i) < 0$. Thus, the total costs of an environmental regulation for firm $i$ then correspond to $C_i(q_i) + T_i(\widehat{e}_i)$.[2]

The regulator chooses an aggregate level of abatement levels $q_i$ to maximize social welfare $W(n)$ defined by:

$$W(n) = \sum_{i=1}^{n} B(q_i) - \sum_{i=1}^{n} C_i(q_i) - \sum_{i=1}^{n} T_i(\widehat{e}_i). \tag{1}$$

Differentiating equation (1) with respect to individual abatement $q_i$, we obtain:

$$B'(Q) = C_i'(q_i) + T_i'(\widehat{e}_i) \ \vee \ i = 1, 2, ..., n. \tag{2}$$

Equation (2) can be used to further show that

$$C_i'(q_i) + T_i'(\widehat{e}_i) = C_h'(q_h) + T_h'(\widehat{e}_h) \ \vee i, h = 1, ...n, \ i \neq h. \tag{3}$$

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

[2] In this model the government is assumed to bear no administrative cost.

Let us analyze how the efficient abatement level should be adjusted to reflect MRV costs when these costs are fixed or variable. If the MRV costs are fixed and represented by $F$, it holds that $T_i'(\widehat{e}_i) = 0$ and then equation (2) simplifies to $B'(Q) = C_i'(q_i) \vee i$. Thus, the existence of transaction costs of a fixed nature does not affect the optimal level of abatement of firms. It does, however, affect the optimal coverage of a regulation. In particular, a regulation is efficient only if it produces a net benefit – that is, only if the total benefit produced by the regulation exceeds its total costs. Nevertheless, efficiency requires not just a net benefit, but the greatest possible net benefit. This is to say, a regulation that produces a net benefit should be refined further, if possible, to maximize the net benefit (see Bradford 2004 for further discussion). This economic insight underlies regulatory exemptions, which attempt to increase the net benefit of a regulation by excluding firms or transactions whose regulation imposes a net cost. Assume for instance, that the net benefit of applying the regulation to all $n$ firms is positive, i.e., $W(n) > 0$. But assume further that we can identify a subset of firms $(k, l, \ldots, n)$ for whom the regulation produces a negative net benefit since the cost of regulating them exceeds the benefit produced by their regulation,

$$\sum_{i=k}^{n} B(q_i) - \sum_{i=k}^{n} C_i(q_i) < \sum_{i=k}^{n} T_i(\widehat{e}_i). \tag{4}$$

Note that given equation (4), exempting the subset of firms $(k, l, \ldots, n)$ from the regulation and regulating only the remaining firms $(1, 2, \ldots, j)$ will increase the overall net benefit of the regulation since the net benefit of the regulation as a whole is lower when they are included:

$$\sum_{i=1}^{n} B(q_i) - \sum_{i=1}^{n} C_i(q_i) - \sum_{i=1}^{n} T_i(\widehat{e}_i) < \sum_{i=1}^{j} B(q_i) - \sum_{i=1}^{j} C_i(q_i) - \sum_{i=1}^{j} T_i(\widehat{e}_i).$$

Thus, exempting those firms whose transactions costs exceed the net benefit of the harm reduction would increase the net benefit of the regulation.[3] Given our funcional form for the transaction costs, we can say that it is optimal to exempt from the regulation to all those firms for which,

$$B(q_i) - C(q_i) < F. \tag{5}$$

[3]Complying with government regulations is costly, and regulated firms would prefer to be exempted and avoid some of those compliance costs. They therefore have an economic incentive to modify their behavior to fit within an exemption if the cost of doing so is less than the cost of complying with the regulation. This strategic behavior is, however, outside the scope of this paper.

In sum, the existence of MRV costs of a fixed nature does not only reduce welfare, but also the optimal coverage of the regulation, and by this means, the optimal aggregate level of abatement, which in our setting is reduced from $Q$ to $\widetilde{Q} = \sum_{i=1}^{j} q_i$. Fixed MRV costs do not affect, however, the allocation of pollution control efforts among firms that are not exempted from the regulation, which continue to abate such that the marginal abatement costs are equated across also firms. The optimal level of abatement $\widetilde{Q}$ can be implemented downstream through an emission tax $\tau = B'(\widetilde{Q})$ or throught an emissions trading scheme with an aggregate emissions cap equal to $\overline{E} = \sum_{i=1}^{j} \widehat{e}_i - \sum_{i=1}^{j} q_i$. It can be also implemented upstream through a fuel tax based on carbon content (carbon tax). Indeed, if we assume that the emission coefficient of fuel is constant and equal to $\varkappa$, the emission tax can be replaced by a carbon tax equal to $\tau\varkappa$ per unit of fuel consumed.

We do not attempt to define the functional forms of benefits and abatement costs in equation (5). Fortunately, we know that the benefits should only depend on the aggregate level of abatement. Moreover, (upstream or downstream) 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 $C(q_i)$, 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 (downstream) taxes and tradable permits entail the same transaction costs $F$ to firms. In constrast, empirical evidence seems to suggest that the transaction costs of an upstream carbon tax (denoted as $F_T$) are lower than the transaction costs of a downstream emissions trading scheme (denoted as $F_P$) since consumption of fuel usually is much easier to monitor than emissions. Furthermore, carbon taxation can be administered through government tax collection institutions that are more established and effective than environmental regulatory institutions, entailing lower MRV costs to firms (see e.g. Coria 2009 and Pope and Owen 2009). Thus, it is clear that the comparison between $CO_2$ taxes and the EU ETS comes down to empirically comparing the transaction costs of the policies (see e.g. Coria 2009; Pope and Owen 2009). From Equation (5) it is clear that if the $F_T$ and $F_P$ are not the same, the optimal coverage for the policy with the largest MRV costs is lower.

Assume now that the MRV costs depend on the amount of emissions so that the effect on MRV costs of a marginal increase in emissions is positive, i.e., $T_i'(\widehat{e}_i) > 0$. From equation (2) it

is clear that if marginal transaction costs are nonzero, the efficient level of abatement for each firm is lower than in the absence of transaction costs. Moreover – for the same marginal costs of pollution reduction $C_i'(q_i)$ – the level of abatement of firms for which $T_i'(\widehat{e}_i)$ is large is lower than the level of abatement of those firms for which $T_i'(\widehat{e}_i)$ is low. Finally, by analogy to the case of fixed MRV costs, the existence of MRV costs of a variable nature will also affect the optimal coverage of the regulations. Let $f(\widehat{e}_i)$ denote the variable component of the transaction cost function, where consistent with our assumptions $f'(\widehat{e}_i) > 0$ and $f''(\widehat{e}_i) < 0$. Equation (5) becomes in such case:

$$B(q_i) - C(q_i) < F + f'(\widehat{e}_i).$$

Thus, it is clear that $\vee\ f'(\widehat{e}_i) > 0$, the number of firms that should be exempted from the regulation is larger than when the transaction costs are only of a fixed nature. Let $f_T'(\widehat{e}_i)$ and $f_P'(\widehat{e}_i)$ denote the variable components of the transaction cost functions of a carbon tax and a emissions trading scheme, respectively. As before, the optimal number of firms to be exempted from the regulations will be larger under the policy with the largest variable MRV cost.

Consistent with our theoretical frame, the empirical approach described in the following sections aims to answer the following questions:

- Are the total MRV transaction costs higher under the EU ETS than $CO_2$ taxation?
- Do the total MRV transaction costs under $CO_2$ taxation and the EU ETS increase with the level of emissions?
- 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?

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

# 4 The 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.[4] 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 survey (translated to English) is presented in Appendix B.

The population 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 firms were included in the EU ETS (around 69.7%), and 108 firms (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 firms (51.5%) were both authorized warehouse keepers and in the EU ETS in 2012 and 23 firms (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).

[Insert Table 1 about here]

To complement the data gathered through our survey, we collected additional information from various sources including the total $CO_2$ tax payments from the Swedish Tax Authority, verified $CO_2$ emissions under the EU ETS from the European Union Transaction Log, the 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 employees.[5] Finally, we collected information on the sector codes (SNI) and $CO_2$ emissions from fuel combustion from Statistics Sweden (SCB). Disentangling $CO_2$

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

[5] 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

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. 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 (European Parliament and Council 2003). 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 entire population of firms and those firms that actually completed the survey. It is evident that the latter group includes the slightly smaller shares of small, medium and very larger firms and a slightly large share of large firms. Also, our firm sample consists of a larger proportion 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 this 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 and organizational characteristics which are not observable for researchers) that might affect the overall cost of MRV procedures regardless of the regulation in place.

[Insert Table 2 about here]

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 0.11% range, and large emitters have emissions corresponding to more than 1% of the countrys total verified emissions. As shown in Table 2, most firms in our sample and most of the respondents are classified as small emitters in

employees. Similar definitions apply for medium and very large firms, while those that are not included in another category are classified as small firms.

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).

# 5 The Results

In this section we discuss the survey responses and the answers to the questions raised in Section 3. In Subsection 5.1 we provide a descriptive analysis of the data and in Subsection 5.2 we analyze the data by using the econometric models.

## 5.1 The Descriptive Analysis of Transaction Costs under $CO_2$ taxation and the EU ETS

### 5.1.1 Taxonomy of the MRV Costs

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 and, additionally, in monetary terms ; (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.[6] In Table 3 we report all these types of MRV costs, which we denote as *internal costs*, *internal & external costs* (the sum of internal and external costs) and *internal, external & capital costs* (the sum of internal, external and capital costs).

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 firms*, respectively. This categorization of firms allows us to compare the MRV costs in three dimensions: (1) between

[6]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 gross hourly wage of 396 SEK (about €44) of a qualified employee working on environmental activities in Sweden.

$CO_2$ tax all firms and EU ETS all firms, (2) between $CO_2$ tax double regulation firms and EU ETS double regulation firms, and (3) between $CO_2$ tax/EU ETS all firms and $CO_2$ tax/EU ETS double regulation firms.[7]

[Insert Table 3 about here]

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 (38.8 vs. 30.7 days). Nevertheless, according to the non-parametric Wilcoxon-Mann-Whitney test, this difference is not statistically significant ($p$-value = 0.165, see Table A1 of Appendix A).[8] The difference in internal costs is, however, much larger and statistically significant ($p$-value = 0.010, see Table A2 of Appendix A) when we look at the sample of firms subject to both regulations (on average, 51.4 vs. 33.8 days). This is to say that for exactly the same firms, the MRV procedures of 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 (30.7 vs. 33.8 days under the $CO_2$ tax; 38.8 vs. 51.4 days under the EU ETS). The average difference in time spent is only statistically significant in the case of the EU ETS ($p$-value = 0.074, see Table A3 of Appendix A). The fact that firms subject to both regulations are larger in terms of economic activity and $CO_2$ emissions than those in the EU ETS all firms group (see Table 2) might explain this result. Moreover, this finding points to a lack of learning-by-doing or synergies between the MRV procedures of the two regulations.

The cost wedge between the two policies remains when we take into account the remaining categories of MRV costs – external MRV costs and capital MRV costs. In both cases (i.e. internal

[7]We have consistently excluded unrepresentative firms that misreported the MRV costs and firms that reported no costs. We define a firm as unrepresentative 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.

[8]The results of all performed non-parametric Wilcoxon-Mann-Whitney tests are summarised in Appendix A.

& external costs and internal, external & capital costs), the cost wedge is, on average, statistically significant when we compare the $CO_2$ tax all firms group and the EU ETS all firms group (see Table A1 of Appendix A). Hence, external and capital costs seem to be higher in the case of the EU ETS, which increase the wedge between the two policies so it becomes statistically significant ($p$-value = 0.000 for both internal & external costs and internal, external & capital costs). The difference in costs 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 internal & external costs and internal, external & capital costs, see Table A2 of Appendix A). However, these costs, on average, are not statistically different between the sample of *all* $CO_2$ tax/ETS firms and the subsample of $CO_2$ tax/ETS firms subject to *both* policies (see Table A3 of Appendix A). Again, this result supports our earlier statement that firms regulated by both policies do not benefit in terms of lower transaction costs from the interactions of the MRV procedures of the two environmental policies.

### 5.1.2 The Composition of the MRV Costs

Figure 1 presents the composition of the average total MRV costs of both policies for the sample of firms that are double-regulated. It is evident that in the case of both policies, on average, the internal MRV costs are the most dominant type of costs and the capital MRV costs account for about 5% of the overall MRV costs, which is not surprising knowing that the capital MRV costs are time-specific set-up costs incurred during the initial phases of policy implementation. The share of the internal MRV costs is relatively more significant under the $CO_2$ tax than under the EU ETS (89% vs. 57%), while the external MRV costs, oppositely, are relatively larger under the EU ETS than under the $CO_2$ tax (39% vs. 6%). This relative breakdown of the MRV costs underlines the main difference between the MRV procedures of the two policies – mandatory verification requirements of the EU ETS, which create additional external (and internal) costs for firms under the EU ETS.

[Insert Figure 1 about here]

This difference in the MRV procedures between the two policies is further emphasized by Table 4 that presents the breakdown of the *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* by us 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. Table 4 also shows the breakdown of total MRV costs (internal, external & capital costs) *reported* by the firms (in response to questions A15 and B15 in the questionnaire, see Appendix B).

[Insert Table 4 about here]

From Table 4 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, on average, larger under the EU ETS. According to the non-parametric Wilcoxon-Mann-Whitney test, this difference is statistically significant (in the case of both internal verification costs share and total verification costs share $p$-values are equal to 0.000, see Table A4 in Appendix A). This suggests that 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) significantly larger under $CO_2$ taxation ($p$-value = 0.004 in the case of internal reporting costs share; $p$-value = 0.002 in the case of total reporting costs share), 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, for both policies monitoring is the activity that makes up the largest share of the MRV costs (on average, this share (in the internal and total costs) is statistically larger under $CO_2$ taxation). 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.

### 5.1.3 The MRV Costs per Ton of $CO_2$ Emissions

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 emissions rising from raw materials or products. Hence, even if the total MRV costs are larger under the EU ETS than under $CO_2$ taxation, the costs 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 summarizes our three measures of MRV cost (in thousands euro) per ton of $CO_2$ emissions, where $CO_2$ emissions under $CO_2$ taxation correspond to those provided by SCB (fuel combustion) and $CO_2$ emissions under the EU ETS correspond to the verified emissions reported to the EUTL.[9] It is important to highlight that in this exercise, we do not consider all $CO_2$ emissions covered under the Swedish $CO_2$ tax and the EU ETS in Sweden, but only those of the respondents that completed the survey.

[Insert Table 5 about here]

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. It is evident that few firms in the sample report rather high MRV costs and rather low $CO_2$ emissions leading to very high MRV costs per ton of $CO_2$ emissions (see the mean values and the standard deviations in Table 5 as well as Figure 3 and Figure 4). Because of this the mean value of MRV costs per ton of $CO_2$ emissions is not an informative measure of the central distribution of the data and to acknowledge that we add the median values as well as provide the box plots for one category of MRV costs per ton of $CO_2$ emissions, which show the range of variation in these costs across the firms in the sample (see Figure 2).

[Insert Figure 2 about here]

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 average MRV costs per ton of $CO_2$

[9] The verified average emissions for the sub-sample of 54 $CO_2$ tax 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.

emissions are statistically higher under the EU ETS than under $CO_2$ taxation both when we compare the sample of all firms subject to 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 (see the results of the non-parametric Wilcoxon-Mann-Whitney test in Table A1 and Table A2 of Appendix A).

If we focus, for example, on the firms that are subject to both regulations, we can see that the average internal costs are equal to 6.6€/$tCO_2$ under $CO_2$ taxation and 9.2€/$tCO_2$ under the EU ETS. The median values are 0.22€/$tCO_2$ and 0.63€/$tCO_2$, respectively. If we consider also external costs, the mean values increase to 9.1€/$tCO_2$ and 16.5€/$tCO_2$ and the median values – to 0.26€/$tCO_2$ and 1.31€/$tCO_2$. Additionally, the statistical comparisons of the MRV costs per ton of $CO_2$ emissions between the sample of *all* $CO_2$ tax/ETS firms and the subsample of $CO_2$ tax/ETS firms subject to *both* policies reveal that these costs are not different, again, opposing our expectations of lower MRV costs for double regulation firms.

In sum, our results indicate that for some firms the MRV costs per ton of $CO_2$ emissions are by all means very high (e.g. see Figure 2), especially, when we compare them with the actual price of $CO_2$ emissions under both policies. For instance, the price of 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€/$tCO_2$ (Brännlund and Lundgren, 2010). This is by all means a surprising finding, especially if one considers that most studies analyzing or comparing environmental regulations disregard the role of transaction costs or find by far much smaller estimates. For instance, the earlier studies on MRV costs of the EU ETS find that average costs per emitted ton of $CO_2$ are in the order of €0.04-0.08 per $tCO_2$ (Jaraitė et al., 2010; King et al., 2010; Heindl, 2012).

#### 5.1.4 MRV Cost Distribution and Economies of Scale

The fact that some small emitters have relatively high MRV costs brings us to the investigation of MRV cost distribution and to the analysis of economies of scales.

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 $CO_2$ emissions for small, medium, and large emitters, where as described in Section 4 these categories are based on the firms' verified emissions under the EU ETS as a proportion of the whole country's total

verified emissions. Here and in the rest of this study, 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.

From Table 6 we can observe that, on average, production activities of small emitters are less pollution intensive than the ones of medium and large emitters (0.107 $tCO_2$/th€ vs. 0.906 $tCO_2$/th€ and 3.014 $tCO_2$/th€ ); and while, on average, the total internal plus external MRV costs are larger for the largest firms in all cases (both under $CO_2$ taxation and under the EU ETS), these costs per ton of $CO_2$ emissions are 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 internal plus external MRV costs are larger for firms under the EU ETS.

[Insert Table 6 about here]

Since we have very few large firms in our sample, we merge firms into two groups in order to test whether the average 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 Table 6). Interestingly, we find that, in terms of the total internal and external MRV costs, on average, 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 = 0.000, see Table A5 in Appendix A). However, we observe that under both regulations these costs per ton of $CO_2$ emissions are statistically lower in the case of the large firms ($p$-value = 0.000). These results highlight the importance of measuring transaction costs of any environmental regulations not only per firm but also per unit of pollution control.

Our findings hint that under $CO_2$ taxation, size of $CO_2$ emissions does not affect the total MRV costs. This is consistent with a cost structure characterized by a fixed component that can be denoted by $F_T$, where the total costs of MRV do not depend on size but the costs per unit of $CO_2$ emissions do. In contrast, the statistical evidence in the case of the EU ETS suggests 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 across the two regulations (see Table A6 of Appendix A), 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.[10] This bring us to the conclusion that, despite the existence of economies of scale for both regulations, the costs of MRV activities under the $CO_2$ tax remain smaller than under the EU ETS even for large firms.

### 5.2 The Econometric Analysis of the MRV Costs

The descriptive statistical analysis in subsection 5.2 reveals that only for ETS firms the internal and external MRV costs are increasing in emissions, while for $CO_2$ tax firms these costs appear to be fixed. Also, there is evidence that the MRV costs for both samples of firms exhibit economies of scale, suggesting that the fixed cost component is significant not only for $CO_2$ firms but also for ETS firms. These results derived from the statistical tests should, however, be interpreted with caution since they are based on the small sample sizes as well as they do not take into account other firm characteristics that might explain variation in the MRV costs. To further analyze the extent to which the internal and external MRV costs (hereafter the MRV costs) depend on $CO_2$ emissions and to identity other firm attributes that influence those costs, we estimate several econometric models, assuming that there is an exponential relationship between the MRV costs and $CO_2$ emissions of the following form:

$$MRV_i = \alpha \mathrm{e}^{\beta_1 CO_{2i} + \beta_2 CO_{2i}^2} \tag{6}$$

Taking the natural log of both sides of the equation we have the following equivalent relationship:

$$ln(MRV_i) = ln\alpha + \beta_1 CO_{2i} + \beta_2 CO_{2i}^2 \tag{7}$$

Denoting $ln\alpha = \beta_0$ and adding a matrix $X_i$ of other firm characteristics as well as an error term $\epsilon_i$, the above equation has the form of a linear regression model:

[10] Note that this result does not hold for the internal MRV costs (see Table A6 of Appendix A).

$$ln(MRV_i) = \beta_0 + \beta_1 CO_{2i} + \beta_2 CO_{2i}^2 + \gamma X_i + \epsilon_i \quad (8)$$

The main explanatory variables are $CO_2$ emissions of the firm $i$, $CO_{2i}$, and the squared $CO_2$ emissions of the firm $i$, $CO_{2i}^2$.[11] $CO_2$ emissions enter the model in a non-linear way to capture economies of scale in the MRV costs in terms of $CO_2$ emissions.

Economies of scale from the estimated regression models can be captured in two ways. Firstly, if the estimated $\beta_1$ coefficient for the level of $CO_2$ emissions and the estimated $\beta_2$ coefficient for the squared $CO_2$ emissions are not different from zero, we can predict that the MRV costs are fixed and hence the MRV costs per ton of $CO_2$ emissions are decreasing in emissions. Secondly, if the $\beta_1$ coefficient is positive and the $\beta_2$ coefficient is negative, the MRV costs are increasing in $CO_2$ emissions at the decreasing rate, while the MRV costs per ton of $CO_2$ emissions (as well as the marginal costs) are decreasing. In the case of the $CO_2$ tax, we expect the first relationship to hold, while in the case of the EU ETS – the second one.

The remaining explanatory variables include a dummy variable $double_i$ that is equal to one if the firm $i$ is subject to both the $CO_2$ tax and the EU ETS. From the descriptive analysis in subsection 5.2 we expect the MRV costs for double-regulated firms to be higher. Another dummy variable $energy_i$ identifies in which sector (energy vs. non-energy) the firm $i$ is operating.[12] A priori we might expect firms in the energy sector to be more experienced in monitoring fuel combustion and related $CO_2$ emissions and hence to have lower MRV costs. The number of plants (measured as the number of EU ETS installations) within the firm $i$, $plants_i$, might also explain the MRV costs. Holding all other factors constant, multi-plant firms might be more experienced and hence more efficient in complying with environmental regulations. Also, we might expect firms with higher turnover ($turnover_i$) as well as the larger number of employees ($empl_i$) to incur lower transaction costs.[13]

From the discussion in subsection 5.2 it is evident that the MRV costs vary quite a lot across

[11] In the case of $CO_2$ taxation $CO_2$ emissions correspond to $CO_2$ emissions from fuel combustion and in the case of the EU ETS – to verified $CO_2$ emissions.

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

[13] There might be other firm characteristics (observable and unobservable for researchers) that might explain the MRV costs. In our models we include those variables that were available for us and that were jointly significant after performing the Wald test. This determined the different sets of the explanatory variables across the samples

firms suggesting that the OLS models might be inappropriate due to potentially large residuals and distorted parameters estimation in case of the existence of outliers. From Figure 3 and Figure 4 it is clear that both firm samples include outliers in terms of the MRV costs or/and $CO_2$ emissions. To show the issue of heterogeneity and influential observations and how we deal with it we estimate four regression models for each firm sample. Model 1 is the OLS regression *with* the influential observations; Model 2 is the OLS regression *without* the influential observations and *with* the robust standard errors; Model 3 is the robust regression *with* the influential observations; and Model 4 is the MS-estimator model *with* the influential observations. In the literature, Model 3 and Model 4 are grouped as robust-to-outliers models, which are favorable over the OLS model when outliers are present.[14]

Two influential observations were detected for each firm sample using a measure *dfits* (e.g. see Cameron and Triverdi, 2009). The Breusch-Pagan and Cook-Weisberg test for heteroscedasticity, performed after Model 1, reveals that the $H_0$ of constant variance is rejected for the sample of $CO_2$ tax firms, but not for the sample of EU ETS firms. The $H_0$ of constant variance is not rejected after the exclusion of the influential observations from the sample of $CO_2$ tax firms. The estimated models, when possible, are compared based on model-fit (R-squared), overall model significance (F-statistics) and information criteria (AIC).

The results of the four models for the sample of $CO_2$ tax firms and the sample of EU ETS firms are summarized in Table 7. It is evident that for the both samples Model 3 is more preferable because of lower AIC and higher R-squared values. Unfortunately, the Stata script *msregress* for the MS-estimator does not provide data necessary for computation of R-squared and other fit measures. Therefore we cannot directly compare Model 3 estimators with Model 4 estimators. However, Verardi and Croux (2009) perform some simulations using contaminated data to show that their considered M-estimator is the least biased estimator when compared to the OLS and the robust regression estimators suggesting that Model 4 should be more superior over Model 3. Therefore, the further discussions of the empirical results is based on Model 4 estimators.

(ETS firms vs. $CO_2$ tax firms). The Ramsey RESET test shows that the estimated models for both firm samples are not miss-specified.

[14]See Verardi and Croux (2009) and Baldauf and Silva (2012) for the properties and implementation of these estimators.

[Insert Table 7 about here]

In line with the findings from our descriptive statistical analysis, the regression analysis supports the existence of economies of scale in the case of both policies (see Model 4 estimators). The internal and external MRV costs are non-linear in emissions: they increase with emissions at a decreasing rate. For instance, from Figure 5, which summarizes the marginal effects of $CO_2$ emissions on the MRV costs for both sets of firms based on Model 4 estimated coefficients, it is evident that an increase in $CO_2$ emissions from 10 $ktCO_2$ to 20 $ktCO_2$ increases the MRV costs by about 18.4% for $CO_2$ tax firms and by about 3.89% for EU ETS firms. In going from 500 $ktCO_2$ to 510 $ktCO_2$, the MRV costs are predicted to decrease by about 2.63% for $CO_2$ tax firms and to increase by about 2.3% for EU ETS firms. Furthermore, from the estimated relationships we can find a turning point at which the effect of $CO_2$ emissions on the MRV costs is zero; before this point, the $CO_2$ emissions have a positive effect on the MRV costs; after this point, the $CO_2$ emissions have a negative effect on the MRV costs. In the estimated equation of Model 4, the turning point is 448 837 tons of $CO_2$ emissions in the case of the $CO_2$ tax and 1 226 708 tons of $CO_2$ emissions in the case of the EU ETS. Since the MRV costs for $CO_2$ tax firms are predicted to decrease at lower $CO_2$ emissions levels than for ETS firms, we can infer that economies of scale in the MRV costs in terms of $CO_2$ emissions are larger for $CO_2$ taxation than for the EU ETS.

[Insert Figure 5 about here]

The coefficients of most remaining explanatory variables are individually insignificant but they are jointly not equal to zero, suggesting their importance in explaining variation in the MRV costs. The positive thought insignificant coefficient for $double_i$ variable for EU ETS firm sample hints that EU ETS firms subject to both regulations may have higher MRV costs than those EU ETS firms that are subject only to the MRV requirements of the EU ETS. However, for the sample of $CO_2$ tax firms, the estimated coefficient for $double_i$ variable is negative and significant. These findings suggest that the positive spillover effects from the interaction of the MRV requirements of both policies are present for the MRV costs of $CO_2$ taxation, but not for the MRV costs of EU ETS firms.

The positive coefficient for $energy_i$ variable might hint that the MRV costs are higher for energy firms than for firms operating in other sectors. 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 and other resources for the MRV procedures. For example, in the case of the EU ETS, each plant within a regulated firm is subject to the same MRV procedures. However, this statement is weakened by the fact that the estimated coefficient for $plants_i$ variable was individually and jointly insignificant and, hence, dropped from the econometric models for the sample of EU ETS firms, while the estimated coefficient of this variable for the sample of $CO_2$ tax firms is negative (individually insignificant, but jointly significant) hinting that there is economies of scale in the MRV costs in terms of the number of plants for the MRV procedures of $CO_2$ taxation.

Another interesting result is that the MRV costs of both policies are potentially decreasing with the number of employees and turnover. This might suggest that firms that are large in terms of personnel and output 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.

# 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?.

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. 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.

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Table 1: Survey Respondents

| | Single regulation | Double regulation | Total |
|---|---|---|---|
| No. of $CO_2$ tax firms | 23 | 67 | 90 |
| No. of ETS firms | 40 | 67 | 107 |

*Sources*: The survey and the authors' calculations.

Table 2: Summary of the Descriptive Statistics, 2012

| Variable | Unit | Population | | Sample of 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 | 107 | 0.626 | 67 | 1 |
| EU ETS firms[2] | Dummy | 379 | 0.696 | 130 | 0.823 | 90 | 0.744 | 107 | 1 | 67 | 1 |
| $CO_2$ tax & EU ETS firms[2,3] | Dummy | 379 | 0.285 | 130 | 0.515 | 90 | 0.744 | 107 | 0.626 | 67 | 1 |
| Energy sector firms[1] | Dummy | 379 | 0.346 | 130 | 0.5 | 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 € | 379 | 8.515 | 130 | 3.978 | 90 | 5.731 | 107 | 0.525 | 67 | 0.819 |
| Turnover[4] | Million € | 357 | 417.9 | 123 | 240.5 | 86 | 282.5 | 102 | 227.3 | 65 | 275.3 |
| No. of 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 |
| 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 $CO_2$ emitters[2] | Dummy | 264 | 0.72 | 111 | 0.685 | 71 | 0.563 | 106 | 0.679 | 66 | 0.545 |
| Medium $CO_2$ emitters[2] | Dummy | 264 | 0.216 | 111 | 0.243 | 71 | 0.338 | 106 | 0.245 | 66 | 0.348 |
| Large $CO_2$ emitters[2] | Dummy | 264 | 0.006 | 111 | 0.072 | 71 | 0.098 | 106 | 0.075 | 66 | 0.106 |

*Sources*: 1. Swedish Statistics; 2. European Union Transaction Log; 3. Swedish Tax Authority; 4. Orbis database.

Table 3: MRV Costs for $CO_2$ Taxation and the EU ETS in Full-Time Working Days and Thousands Euro

| | No. of firms | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| *Internal costs*, full-time working days | | | | | |
| $CO_2$ tax all firms | 80 | 30.7 | 44.2 | 0.75 | 215 |
| EU ETS all firms | 104 | 38.8 | 63 | 1 | 372 |
| $CO_2$ tax double regulation firms | 59 | 33.8 | 49.5 | 1.5 | 215 |
| EU ETS double regulation firms | 59 | 51.4 | 77.1 | 6 | 372 |
| *Internal costs*, thousands euro | | | | | |
| $CO_2$ tax all firms | 80 | 10.8 | 15.6 | 0.264 | 75.7 |
| EU ETS all firms | 104 | 13.7 | 22.2 | 0.352 | 130.9 |
| $CO_2$ tax double regulation firms | 59 | 11.9 | 17.4 | 0.528 | 75.7 |
| EU ETS double regulation firms | 59 | 18.1 | 27.1 | 2.112 | 130.9 |
| *Internal & external costs*, thousands euro | | | | | |
| $CO_2$ tax all firms | 80 | 12.7 | 17.6 | 0.264 | 97.9 |
| EU ETS all firms | 104 | 23.2 | 29.7 | 1.056 | 166.1 |
| $CO_2$ tax double regulation firms | 59 | 13.7 | 19.9 | 0.528 | 97.9 |
| EU ETS double regulation firms | 59 | 29.7 | 36 | 2.464 | 166.1 |
| *Internal, external & capital costs*, thousands euro | | | | | |
| $CO_2$ tax all firms | 80 | 15 | 22.2 | 0.264 | 114.6 |
| EU ETS all firms | 104 | 26.5 | 36.3 | 1.056 | 221.7 |
| $CO_2$ tax double regulation firms | 59 | 16.7 | 25.2 | 0.528 | 114.6 |
| EU ETS double regulation firms | 59 | 34.1 | 44.7 | 2.464 | 221.7 |

*Sources*: The survey and the authors' calculations. *Note*: The results of the non-parametric Wilcoxon-Mann-Whitney tests are summarized in Tables A1-A3 of Appendix A.

Table 4: Estimated and Reported Breakdown of the Internal and Total MRV Costs of the Double-Regulated Firms

| | Estimated Breakdown of *Internal* MRV Costs, % | | | Reported Breakdown of *Total* MRV Costs, % | | |
|---|---|---|---|---|---|---|
| | No. of firms | Mean | Std. dev. | No. of firms | Mean | Std. dev. |
| | | | *$CO_2$ tax firms* | | | |
| Monitoring | 59 | 53.1 | 18.4 | 56 | 45.9 | 19.6 |
| Reporting | 59 | 39.7 | 17 | 56 | 42.5 | 20.4 |
| Verification | 59 | 7.1 | 15.5 | 56 | 11.6 | 16.4 |
| | | | *EU ETS firms* | | | |
| Monitoring | 59 | 46.9 | 22.1 | 58 | 39.6 | 21 |
| Reporting | 59 | 30.5 | 17 | 58 | 29.8 | 18.2 |
| Verification | 59 | 22.6 | 13.9 | 58 | 30.6 | 21.3 |

*Sources*: The survey and the authors' calculations. *Note*: The results of the non-parametric Wilcoxon-Mann-Whitney tests are summarized in Table A4 of Appendix A.

Table 5: Summarizing the MRV Costs per Ton of $CO_2$ Emissions

| | No. of firms | | $CO_2$ emissions, t | Internal costs, €/t$CO_2$ | Internal & external costs, €/t$CO_2$ | Internal, external & capital costs, €/t$CO_2$ |
|---|---|---|---|---|---|---|
| $CO_2$ tax all firms | 61 | Mean | 66 231 | 6.4 | 9.3 | 9.4 |
| | | Median | 19620 | 0.3 | 0.3 | 0.33 |
| | | Std. dev. | 139 384 | 28.2 | 40.4 | 40.4 |
| EU ETS all firms | 101 | Mean | 70 052 | 10.6 | 37.6 | 38.3 |
| | | Median | 4 760 | 1.23 | 2.49 | 2.49 |
| | | Std. dev. | 259 484 | 32.1 | 203 | 203 |
| $CO_2$ tax double regulation firms | 54 | Mean | 69068 | 6.6 | 9.1 | 9.3 |
| | | Median | 20 346 | 0.22 | 0.26 | 0.31 |
| | | Std. dev. | 145 779 | 29.9 | 42.3 | 42.4 |
| EU ETS double regulation firms | 57 | Mean | 66 406 | 9.2 | 16.5 | 17.1 |
| | | Median | 12 185 | 0.63 | 1.31 | 1.44 |
| | | Std. dev. | 149 052 | 33.1 | 61.8 | 61.8 |

*Sources*: The survey and the authors' calculations. *Note*: The results of the non-parametric Wilcoxon-Mann-Whitney tests are summarized in Tables A1-A3 of Appendix A.

Table 6: Summarizing the Internal and External MRV Costs for Small, Medium, and Large Emitters, the Sample of All Firms

| | $CO_2$ Tax all firms | | | EU ETS all firms | | |
|---|---|---|---|---|---|---|
| | No. of firms | Mean | Std. dev. | No. of firms | Mean | Std. dev |
| *Small firms* | | | | | | |
| $CO_2$ intensity ($tCO_2$/th€) | 35 | 0.107 | 0.906 | 65 | 0.096 | 0.109 |
| Internal & external costs (th€) | 37 | 10.7 | 13.9 | 72 | 19.1 | 28.5 |
| Internal & external costs (€/$tCO_2$) | 36 | 26.5 | 67.5 | 70 | 54.1 | 242.5 |
| *Medium firms* | | | | | | |
| $CO_2$ intensity ($tCO_2$/th€) | 24 | 0.906 | 2.207 | 25 | 0.901 | 2.159 |
| Internal & external costs (th€) | 20 | 12.6 | 17.4 | 23 | 24.1 | 26.4 |
| Internal & external costs (€/$tCO_2$) | 20 | 0.24 | 0.243 | 23 | 0.53 | 0.434 |
| *Large firms* | | | | | | |
| $CO_2$ intensity ($tCO_2$/th€) | 6 | 3.014 | 3.02 | 8 | 3.66 | 3.834 |
| Internal & external costs (th€) | 6 | 28.6 | 39 | 8 | 49.7 | 33 |
| Internal & external costs (€/$tCO_2$) | 6 | 0.08 | 0.122 | 8 | 0.1 | 0.049 |

*Sources*: The survey and the authors' calculations. *Notes*: 1. The firms were grouped 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 $tCO_2$ emissions represent up to 0.1% of the country total, medium emitters are in the 0.11% range, and large emitters have emissions corresponding to more than 1% of the countrys total verified emissions. 2. The results of the non-parametric Wilcoxon-Mann-Whitney tests are summarized in Tables A5-A6 of Appendix A.

Table 7: The Results from the Econometric Models

| | *$CO_2$ Tax Firms* | | | | | | | | *EU ETS Firms* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | The dependet variable is $log(MRV)$ | | | | | | | | The dependet variable is $log(MRV)$ | | | | | | | |
| Variables | Model 1 | | Model 2 | | Model 3 | | Model 4 | | Model 1 | | Model 2 | | Model 3 | | Model 4 | |
| $CO_2$ | 3.73E-06 | | 1.35E-05 | ** | 1.51E-05 | *** | 1.93E-05 | *** | 3.95E-06 | *** | 4.12E-06 | ** | 4.75E-06 | ** | 3.95E-06 | *** |
| | *0.71* | | *2.17* | | *2.98* | | *3.15* | | *4.31* | | *2.10* | | *2.02* | | *2.95* | |
| $CO_2$-squared | -1.53E-12 | | -1.3E-11 | | -1.58E-11 | * | -2.15E-11 | ** | -1.62E-12 | *** | -2.21E-12 | | -2.76E-12 | | -1.61E-12 | *** |
| | *-0.19* | | *-1.36* | | *-2.00* | | *-2.40* | | *-3.70* | | *-0.70* | | *-0.71* | | *-2.95* | |
| Double | -0.140 | | -0.071 | | -0.216 | | -1.143 | *** | 0.399 | ** | 0.349 | * | 0.247 | | 0.321 | |
| | *-0.28* | | *-0.16* | | *-0.44* | | *-3.99* | | *-2.16* | | *1.89* | | *1.41* | | *0.77* | |
| Energy | 0.430 | | 0.583 | | 0.660 | * | 0.469 | | 0.239 | | 0.255 | | 0.190 | | 0.266 | |
| | *1.09* | | *1.54* | | *1.72* | | *1.39* | | *1.33* | | *1.43* | | *1.13* | | *0.69* | |
| Empl | | | | | | | | | -9.51E-05 | | 1.04E-05 | | -6.90E-05 | | -2.90E-05 | |
| | | | | | | | | | *-1.51* | | *0.21* | | *-1.16* | | *-0.53* | |
| Turnover | -3.25E-04 | | -6.89E-04 | *** | -6.79E-04 | ** | -7.00E-04 | | | | | | | | | |
| | *-1.06* | | *-3.01* | | *-2.29* | | *-1.52* | | | | | | | | | |
| Plants | 0.025 | | -0.054 | | -0.068 | | -0.052 | | | | | | | | | |
| | *0.38* | | *-0.95* | | *-1.08* | | *-0.96* | | | | | | | | | |
| Constant | 1.538 | *** | 1.456 | *** | 1.522 | *** | 2.166 | *** | 2.140 | *** | 2.131 | *** | 2.200 | *** | 2.080 | *** |
| | *2.95* | | *2.96* | | *3.01* | | *9.24* | | *11.34* | | *11.61* | | *12.33* | | *7.64* | |
| No. of firms | 60 | | 58 | | 60 | | 60 | | 95 | | 93 | | 94 | | 95 | |
| F-statistic | 1.49 | | | | 4.28 | *** | | | 6.66 | *** | | | 6.80 | *** | | |
| R-squared | 0.14 | | 0.23 | | 0.19 | | | | 0.27 | | 0.24 | | 0.23 | | | |
| AIC | 192.8 | | 177.3 | | 80.1 | | | | 236.3 | | 229.2 | | 117.9 | | | |

*Notes*:

1. ***p $\leq$ 0.01, **p $\leq$ 0.05, *p $\leq$ 0.1

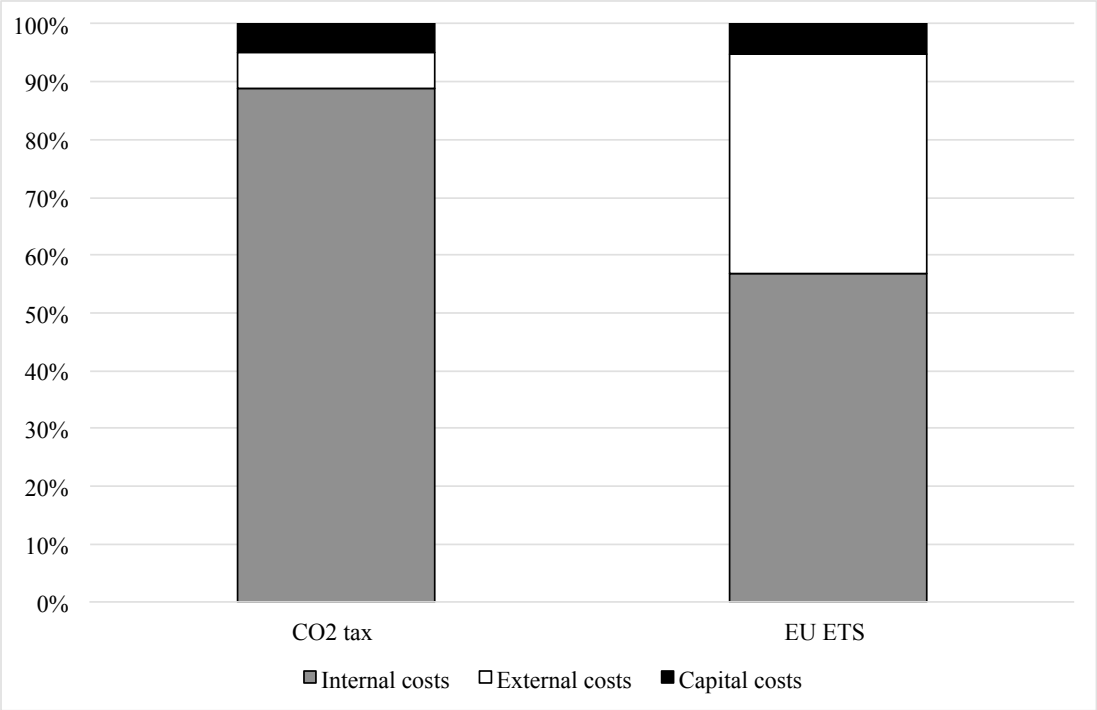
2. T-values are in italic.

3. Model 1: OLS regression, full sample; Model 2: OLS regression with the robust standard errors and without the influential observations; Model 3: robust regression, full sample; and Model 4: MS-estimator, full sample.

4. Model 3 was estimated using Stata commands *rreg* and *rregfit*.

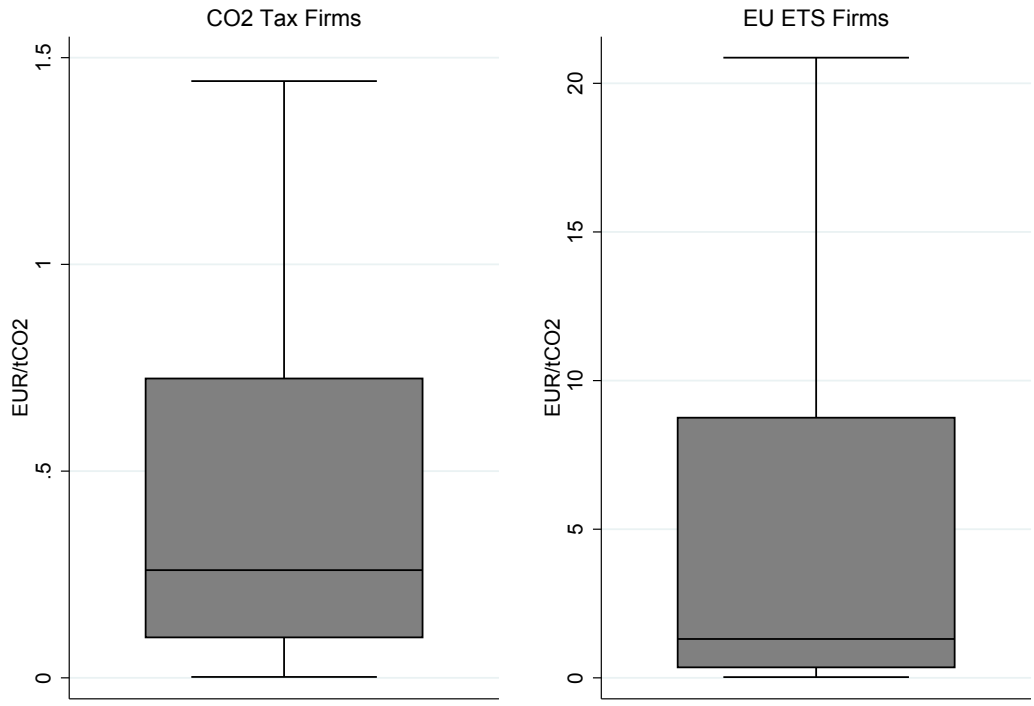
5. Model 4 was estimated using Stata command *msregress*.

Figure 1: Composition of the Average Total MRV Costs of the Double-Regulated Firms



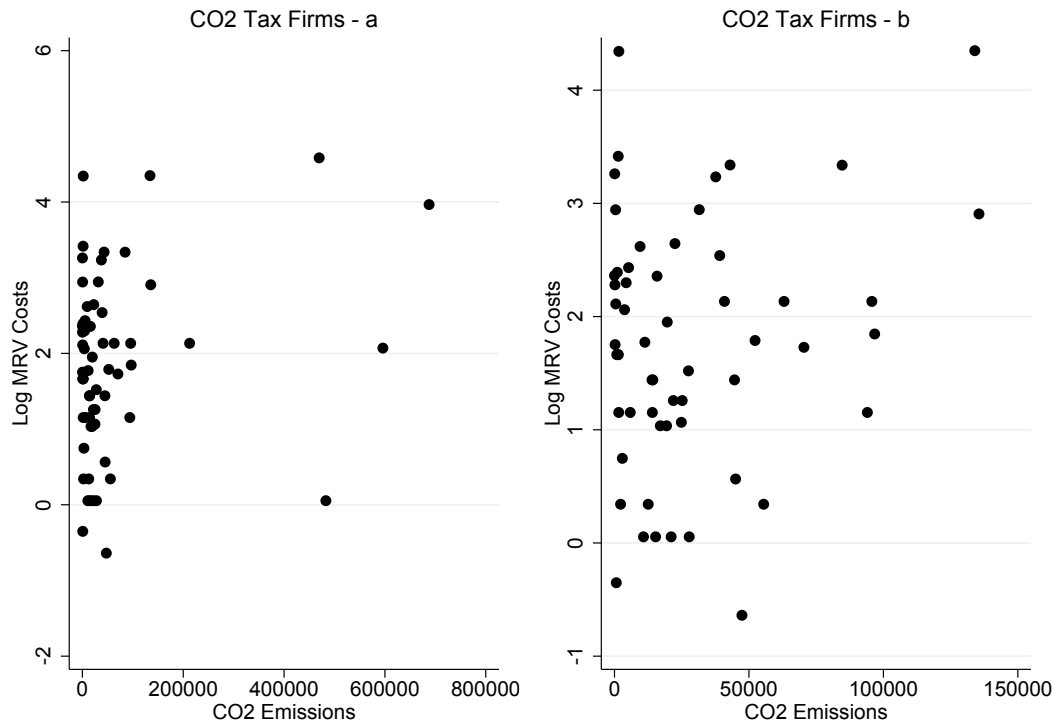

*Sources*: The survey and the authors' calculations. *Note*: As indicated in Table 3, there are 59 double-regulated firms.

Figure 2: The Box Plots of the Internal and External MRV Costs per Ton of $CO_2$ Emissions of the Double-Regulated Firms, €/t$CO_2$



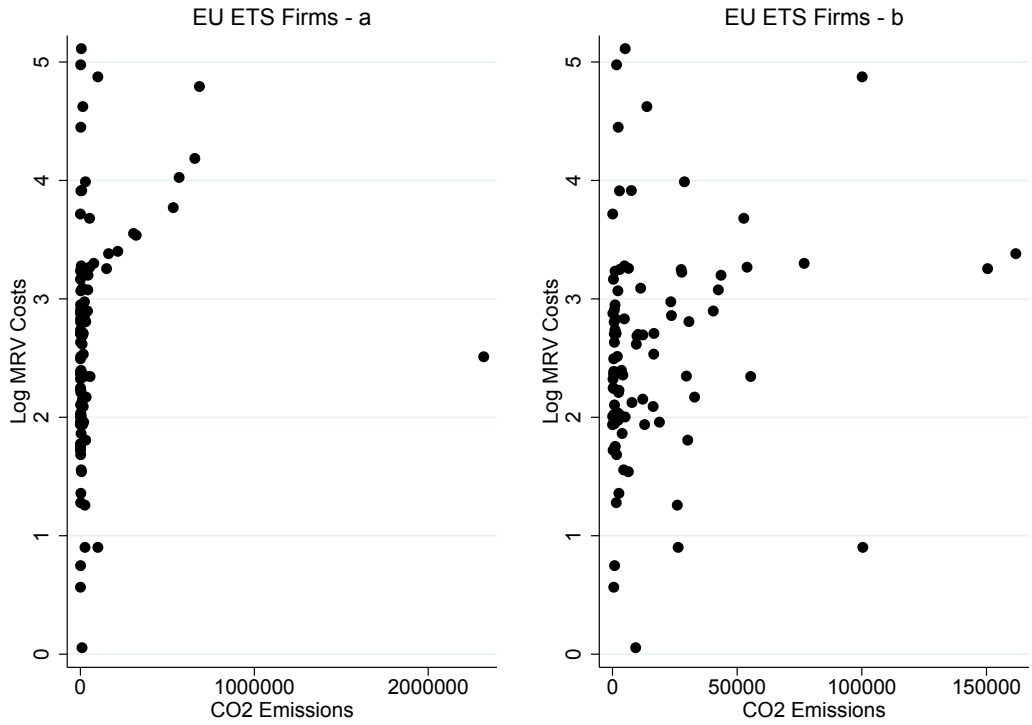

*Sources*: The survey and the authors' calculations. *Note*: The outside values are excluded.

Figure 3: The Scatter Plots of the Internal and External MRV Costs and $CO_2$ Emissions, $CO_2$ Tax Firms



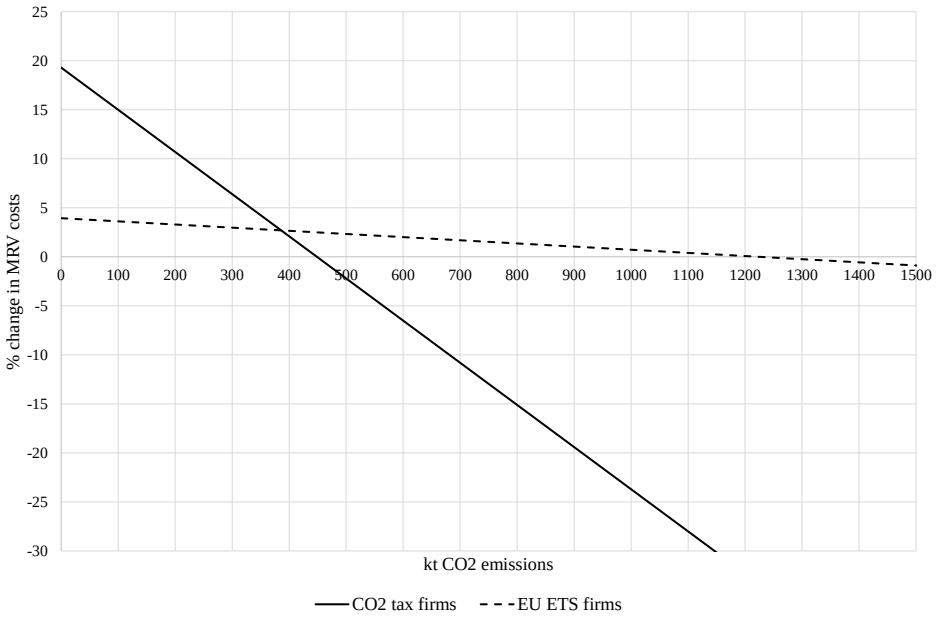

*Sources*: The survey and the authors' calculations. *Notes*: 1. Figure (a) includes all observations; Figure (b) excludes the outliers and firms with $CO_2$ emissions larger than 200 000 tones. 2. The MRV costs are in logs.

Figure 4: The Scatter Plots of the Internal and External MRV Costs and $CO_2$ Emissions, EU ETS Firms




*Sources*: The survey and the authors' calculations. *Notes*: 1. Figure (a) includes all observations; Figure (b) excludes the outliers and firms with $CO_2$ emissions larger than 200 000 tones. 2. The MRV costs are in logs.

Figure 5: The Marginal Effects of $CO_2$ Emissions on the MRV Costs




*Sources*: The survey and the authors' calculations. *Notes*: 1. The calculation of the marginal effects is based on Model 4 estimates. 2. This figure summarizes the percentage changes in the MRV costs when $CO_2$ emissions change by 10 kt$CO_2$.

# A The Results of the Non-Parametric Wilcoxon-Mann-Whitney Tests

Table A1: Comparing the MRV costs between $CO_2$ tax all firms and EU ETS all firms

| | *P*-value | No. of $CO_2$ tax firms | No. of ETS firms |
|---|---|---|---|
| Internal costs | 0.165 | 80 | 104 |
| Internal & external costs | 0.000 | 80 | 104 |
| Internal, external and capital costs | 0.000 | 80 | 104 |
| Internal costs per $tCO_2$ | 0.000 | 61 | 101 |
| Internal & external costs per $tCO_2$ | 0.000 | 61 | 101 |
| Internal, external and capital costs per $tCO_2$ | 0.000 | 61 | 101 |

Table A2: Comparing the MRV costs between $CO_2$ tax double regulation firms and EU ETS double regulation firms

| | *P*-value | No. of $CO_2$ tax firms | No. of ETS firms |
|---|---|---|---|
| Internal costs | 0.010 | 59 | 59 |
| Internal & external costs | 0.000 | 59 | 59 |
| Internal, external and capital costs | 0.000 | 59 | 59 |
| Internal costs per $tCO_2$ | 0.010 | 54 | 57 |
| Internal & external costs per $tCO_2$ | 0.000 | 54 | 57 |
| Internal, external and capital costs per $tCO_2$ | 0.000 | 54 | 57 |

Table A3: Comparing the MRV costs between $CO_2$ tax/EU ETS all firms and $CO_2$ tax/EU ETS double regulation firms

| | $P$-value | No. of all firms | No. of double regulation firms |
|---|---|---|---|
| *$CO_2$ tax firms* | | | |
| Internal costs | 0.935 | 80 | 59 |
| Internal & external costs | 0.873 | 80 | 59 |
| Internal, external and capital costs | 0.952 | 80 | 59 |
| Internal costs per $tCO_2$ | 0.818 | 61 | 54 |
| Internal & external costs per $tCO_2$ | 0.797 | 61 | 54 |
| Internal, external and capital costs per $tCO_2$ | 0.818 | 61 | 54 |
| *EU ETS firms* | | | |
| Internal costs | 0.074 | 104 | 59 |
| Internal & external costs | 0.145 | 104 | 59 |
| Internal, external and capital costs | 0.189 | 104 | 59 |
| Internal costs per $tCO_2$ | 0.217 | 101 | 57 |
| Internal & external costs per $tCO_2$ | 0.170 | 101 | 57 |
| Internal, external and capital costs per $tCO_2$ | 0.163 | 101 | 57 |

Table A4: Comparing the shares of the internal and total MRV costs between $CO_2$ tax double regulation firms and EU ETS double regulation firms

| | $P$-value | No. of $CO_2$ tax firms | No. of ETS firms |
|---|---|---|---|
| *Internal MRV cost breakdown* | | | |
| Monitoring cost share | 0.040 | 59 | 59 |
| Reporting cost share | 0.004 | 59 | 59 |
| Verification cost share | 0.000 | 59 | 59 |
| *Total MRV cost breakdown* | | | |
| Monitoring cost share | 0.057 | 56 | 58 |
| Reporting cost share | 0.002 | 56 | 58 |
| Verification cost share | 0.000 | 56 | 58 |

Table A5: Comparing the MRV costs between small and large firms *within* each regulation

| | $P$-value | No. of small firms | No. of large firms |
|---|---|---|---|
| $CO_2$ tax firms | | | |
| Internal costs | 0.133 | 37 | 26 |
| Internal & external costs | 0.468 | 37 | 26 |
| Internal, external and capital costs | 0.769 | 37 | 26 |
| Internal costs per $tCO_2$ | 0.000 | 36 | 26 |
| Internal & external costs per $tCO_2$ | 0.000 | 36 | 26 |
| Internal, external and capital costs per $tCO_2$ | 0.000 | 36 | 26 |
| EU ETS firms | | | |
| Internal costs | 0.001 | 72 | 31 |
| Internal & external costs | 0.001 | 72 | 31 |
| Internal, external and capital costs | 0.002 | 72 | 31 |
| Internal costs per $tCO_2$ | 0.000 | 70 | 31 |
| Internal & external costs per $tCO_2$ | 0.000 | 70 | 31 |
| Internal, external and capital costs per $tCO_2$ | 0.000 | 70 | 31 |

Table A6: Comparing the MRV costs of different size firms *across* the regulations

| | $P$-value | No. of $CO_2$ tax firms | No. of ETS firms |
|---|---|---|---|
| Small firms | | | |
| Internal costs | 0.5259 | 37 | 72 |
| Internal & external costs | 0.003 | 37 | 72 |
| Internal, external and capital costs | 0.008 | 37 | 72 |
| Internal costs per $tCO_2$ | 0.151 | 36 | 70 |
| Internal & external costs per $tCO_2$ | 0.011 | 36 | 70 |
| Internal, external and capital costs per $tCO_2$ | 0.027 | 36 | 70 |
| Large firms | | | |
| Internal costs | 0.111 | 26 | 31 |
| Internal & external costs | 0.002 | 26 | 31 |
| Internal, external and capital costs | 0.001 | 26 | 31 |
| Internal costs per $tCO_2$ | 0.532 | 26 | 31 |
| Internal & external costs per $tCO_2$ | 0.020 | 26 | 31 |
| Internal, external and capital costs per $tCO_2$ | 0.012 | 26 | 31 |

# B The conversion of fuel purchase into $CO_2$ emissions

## Survey on Transaction Costs of Climate Policies.

The purpose of this survey is to gather information and compare transaction costs incurred by Swedish firms covered under the Swedish $CO_2$ tax and/or the European Union Emissions Trading System (EU ETS). Transaction costs, for the purposes of this analysis, are grouped into costs of **monitoring**, **reporting** and **verification (MRV)**. Costs of monitoring include staff and management time spent for checking, observing and recording $CO_2$ emissions and/or fuel purchases, as well as purchases of equipment necessary to perform monitoring procedures. Costs of reporting include management and staff time spent on performing necessary paperwork, writing reports for the regulator of for internal purposes. Costs of verification include staff and management time spent for verification procedures, such as organizing verification process, contacting a verifier, preparing necessary information for a verifier.

This survey is conducted by Naturvårdsverket in collaboration with researchers at the Environmental Economics Unit (University of Gothenburg) and the Centre for Environmental and Resource Economics (Umeå University). It consists of short questions and should take no more than 30 minutes to complete.

The information you provide will be treated as strictly confidential. It will be used as an input into the evaluation of environmental policies. The results of data from this survey will be publicly available at aggregate level only.

We would be grateful if you could complete the survey before **May 23th 2013**.

Many thanks in advance for your help. Your answer is very valuable to us. If you have questions regarding the survey, please contact Jessica Coria (Jessica.Coria@economics.gu.se).

UNIVERSITY OF GOTHENBURG

UMEÅ UNIVERSITET

## GENERAL DETAILS

| Details of the person who led the completion of the questionnaire: **PLEASE COMPLETE ACROSS** | |
|---|---|
| Name | |
| Position | |
| Telephone number | |
| Fax number | |
| E-mail address | |

| | |
|---|---|
| Firm name | |
| Official registration number | |
| Number of employees | |
| Main economic activity | |
| NACE activity code (2 digit) | |
| If your firm is a part of a subsidiary, provide its name | |

**Unless otherwise stated please answer each question by marking X in the appropriate box(es).**

## Monitoring, reporting and verification (MRV) costs

**Most environmental regulations require regulated firms to monitor and report their emissions or fuel consumption on monthly or annual basis. In some cases, these reports might have to be verified by an accredited verifier.**

**In what follows, we would like to ask you a series of questions regarding the costs of monitoring, reporting and verifications (MRV) that were incurred by your firm as part of the compliance with the $CO_2$ tax and/or EU ETS.**

**We assume that MRV costs can be divided into four categories:**

- ***internal* costs, mainly management and staff time;**
- ***external* costs incurred in terms of consultancy services taken in to be MRV compliant;**
- ***capital* costs, meaning emissions/fuel measurement, monitoring, recording, and data storage equipment needed to comply.**
- ***other* costs not included in the above**

**IMPORTANT:**

**Most questions refer to the decisions or actions taken in 2012. Please, complete the questionnaire even if your firm opted out of the regulation in 2013.**

**If your firm paid $CO_2$ tax <u>and</u> participated in the EU ETS, please answer the questions presented in Section A, Section B and Section C**

**If your firm paid <u>only</u> the $CO_2$ tax (i.e. you firm is an authorised fuel warehouse keeper), please answer the questions presented in Section A and Section C.**

**If your firm participated <u>only</u> in the EU ETS, please answer the questions presented in Section B and Section C.**

## SECTION A MRV costs of $CO_2$ taxation

**The Swedish $CO_2$ tax was introduced in 1991. The tax is differentiated according to carbon content of fuels and energy sources. Around 300 companies are authorized to produce and hold energy products without tax being charged and declare the tax upon the delivery outside the suspension regime.**

**Authorised fuel warehouse keepers should report their fuel expenditure and use, and calculate the related emissions to Skatteverket on monthly basis.**

A0 Is your firm an **authorised fuel warehouse keeper** requested to report fuel purchase/use to Skatteverket?

| | | |
|---|---|---|
| | Yes | CONTINUE |
| | No | GO TO SECTION B |

**MONITORING**

A1 How frequently did your firm **monitor** (check/observe) its fuel purchase/use in the year **2012**?

| | |
|---|---|
| Daily | |
| Weekly | |
| Monthly | |
| Quarterly | |
| Semi-annually | |
| Annually | |
| Ad hoc (please specify) | |

A2 What is your estimate of the overall full-time working days spent in the year **2012** by your firm's staff on the **monitoring** procedures of the $CO_2$ tax? **PLEASE WRITE IN NUMBER – RECORD NONE AS '0000'.**

| | | | |
|---|---|---|---|
| | | | |

A3 Did your firm incur any **external** costs for the **monitoring** procedures of the $CO_2$ tax in the year **2012**?

| | | |
|---|---|---|
| | Yes | CONTINUE |
| | No | GO TO A5 |

A4 Please provide the estimated overall **external** costs in the year **2012** on the **monitoring** procedures **in 000s of SEK**.

| | | | |
|---|---|---|---|
| | | | |

A5 Has your firm incurred any **capital** costs necessary to perform the **monitoring** activities related to the $CO_2$ tax?

| | | |
|---|---|---|
| | Yes | CONTINUE |
| | No | GO TO A8 |

A6 What necessary equipment or technology has your firm purchased to perform **monitoring**?
**Please describe below.**

A7 Please provide the estimated overall acquisition costs of equipment or technology necessary to perform **monitoring** activities **in 000s of SEK.**

| | | | |
|---|---|---|---|
| | | | |

**REPORTING**

A8 How frequently did your firm **report** its fuel purchase/use in the year **2012**?

| | |
|---|---|
| Daily | |
| Weekly | |
| Monthly | |
| Quarterly | |
| Semi-annually | |
| Annually | |
| Ad hoc (please specify) | |

A9 What is your estimate of the overall full-time working days spent in the year **2012** by your firm's staff on the **reporting** procedures of the $CO_2$ tax? **PLEASE WRITE IN NUMBER – RECORD NONE AS '0000'.**

| | | | |
|---|---|---|---|
| | | | |

A10 Did your firm incur any **external** costs for the **reporting** procedures of the $CO_2$ tax in the year **2012**?

| | | |
|---|---|---|
| | Yes | CONTINUE |
| | No | GO TO A12 |

A11 Please provide the estimated overall **external** costs in the year **2012** on the **reporting** procedures **in 000s of SEK**.

| | | | |
|---|---|---|---|
| | | | |

**VERIFICATION**

A12 Were your firm's fuel purchase/use and $CO_2$ tax payments **verified** by the regulator in the year **2012**?

| | | |
|---|---|---|
| | Yes | CONTINUE |
| | No | GO TO A15 |

A13 Please describe below **the $CO_2$ tax verification process in you firm.**

| |
|---|
| |

A14 What is your estimate of the overall full-time working days spent in the year **2012** by your firm's staff on the **verification** procedures of the $CO_2$ tax? **PLEASE WRITE IN NUMBER – RECORD NONE AS '0000'.**

| | | | |
|---|---|---|---|
| | | | |

**GENERAL**

A15 Please provide a breakdown of your firm's total **MRV** costs of the $CO_2$ tax in the year **2012**.

| | |
|---|---|
| Monitoring | % |
| Reporting | % |
| Verification | % |
| **Total MRV** | **100%** |

A16 Are there any other relevant costs related to the compliance with the $CO_2$ tax? **Please describe below.**

| |
|---|
| |

A17 Have the costs **MRV** of $CO_2$ tax increased/decreased over time?. If yes, to what extent? **Please describe below.**

| |
|---|
| |

## SECTION B MRV costs in the EU ETS

**Installations in the EU ETS are required to monitor and report their annual emissions in accordance with legally binding guidelines adopted by the European Commission. Installations are required to have an approved monitoring plan, according to which they monitor and report their emissions during the year.**

**The data in the annual emission report must be verified before 31 March each year by an accredited verifier. Operators must surrender the equivalent number of allowances by 30 April of the same year.**

**This annual procedure of monitoring, reporting and verification, as well as all processes connected to these activities, are known as the "compliance cycle" of the EU ETS.**

**NOTES:**

1. **If your firm has several installations in the EU ETS, please provide your answers in such a way that they refer to all installations within your firm. If for some reasons it is difficult to do that, please indicate here**

   _____
   _____
   _____
   _____.

2. **If a question refers to the year 2012, please consider this year as EU ETS compliance year.**

**MONITORING**

B0 Is you firm regulated by the EU ETS?

| | | |
|---|---|---|
| | Yes | CONTINUE |
| | No | GO TO SECTION C |

B1 How frequently did your firm **monitor** (check/observe) its $CO_2$ emissions in the compliance year **2012**?

| | |
|---|---|
| Daily | |
| Weekly | |
| Monthly | |
| Quarterly | |
| Semi-annually | |
| Annually | |
| Ad hoc (please specify) | |

B2 What is your estimate of the overall full-time working days spent in the compliance year **2012** by your firm's staff on the **monitoring** procedures of the EU ETS? **PLEASE WRITE IN NUMBER – RECORD NONE AS '0000'.**

| | | | |
|---|---|---|---|
| | | | |

B3 Did your firm incur any **external** costs for the **monitoring** procedures of the EU ETS in the compliance year **2012**?

| | | |
|---|---|---|
| | Yes | CONTINUE |
| | No | GO TO B5 |

B4 Please provide the estimated overall **external** costs in the compliance year **2012** on the **monitoring** procedures **in 000s of SEK**.

| | | | |
|---|---|---|---|
| | | | |

B5 Has your firm incurred any **capital** costs necessary to perform the **monitoring** activities related to the EU ETS?

| | | |
|---|---|---|
| | Yes | CONTINUE |
| | No | GO TO B8 |

B6 What necessary equipment or technology has your firm purchased to perform **monitoring**?
**Please describe below.**

| |
|---|
| |

B7 Please provide the estimated overall acquisition costs of equipment or technology necessary to perform **monitoring** activities **in 000s of SEK.**

| | | | |
|---|---|---|---|
| | | | |

**REPORTING**

B8 How frequently did your firm **report** its $CO_2$ emissions in the compliance year **2012**?

| | |
|---|---|
| Daily | |
| Weekly | |
| Monthly | |
| Quarterly | |
| Semi-annually | |
| Annually | |
| Ad hoc (please specify) | |

B9 What is your estimate of the overall full-time working days spent in the compliance year **2012** by your firm's staff on the **reporting** procedures of the EU ETS? **PLEASE WRITE IN NUMBER – RECORD NONE AS '0000'.**

| | | | |
|---|---|---|---|
| | | | |

B10 Did your firm incur any **external** costs for the **reporting** procedures of the EU ETS in the compliance year **2012**?

| | | |
|---|---|---|
| | Yes | CONTINUE |
| | No | GO TO B12 |

B11 Please provide the estimated overall **external** costs in the compliance year **2012** on the **reporting** procedures **in 000s of SEK**.

| | | | |
|---|---|---|---|
| | | | |

**VERIFICATION**

B12 What is your estimate of the overall full-time working days spent in the compliance year **2012** by your firm's staff on the **verification** procedures of the EU ETS? **PLEASE WRITE IN NUMBER – RECORD NONE AS '0000'.**

| | | | |
|---|---|---|---|
| | | | |

B13 Did your firm incur any **external** costs for the **verification** procedures of the EU ETS in the compliance year 2012? **NOTE: THESE COSTS SHOULD ALSO INCLUDE THE COSTS OF AN EXTERNAL VERIFIER.**

| | | |
|---|---|---|
| | Yes | CONTINUE |
| | No | GO TO B15 |

B14 Please provide the estimated overall external costs in the compliance year **2012** on the **verification** procedures **in 000s of SEK**. **NOTE: THESE COSTS SHOULD INCLUDE THE COSTS OF AN EXTERNAL VERIFIER.**

| | | | |
|---|---|---|---|
| | | | |

**GENERAL**

B15 Please provide a breakdown of your firm's total **MRV** costs of the EU ETS in the compliance year 2012.

| | |
|---|---|
| Monitoring | % |
| Reporting | % |
| Verification | % |
| **Total MRV** | **100%** |

B16 Are there any other relevant costs related to the compliance with the EU ETS? **Please describe below.**

| |
|---|
| |

B17 Have the costs of **MRV** to the EU ETS increased/decreased since your firm joined the EU ETS. If yes, to what extent? **Please describe below.**

| |
|---|
| |

## SECTION C GENERAL QUESTIONS

**Please answer the below questions irrespectively by what environmental regulations your firm is regulated. When answering the questions below, please provide your own opinion rather than your firm's official position.**

C1 Please indicate to what extent you agree with the following statement: "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".

| | | | | |
|---|---|---|---|---|
| Strongly agree | Agree | Indifferent | Disagree | Strongly disagree |

C2 Please indicate to what extent you agree with the following statement: "The EU ETS provides stronger incentives for firms to reduce their $CO_2$ emissions than $CO_2$ tax".

| | | | | |
|---|---|---|---|---|
| Strongly agree | Agree | Indifferent | Disagree | Strongly disagree |

C3 Please indicate to what extent you agree with the following statement: "The volatility of the price of the allowances in the EU ETS has provided firm with strong incentives to reduce their $CO_2$ emissions".

| | | | | |
|---|---|---|---|---|
| Strongly agree | Agree | Indifferent | Disagree | Strongly disagree |

C4 Please indicate to what extent you agree with the following statement: "The EU ETS is too burdensome for small emitters". According to the EU ETS Directive (Article 27), small emitters are defined as having annual emissions that are less than 25,000 tones of $CO_2$ and a thermal capacity not exceeding 35MW per year.

| | | | | |
|---|---|---|---|---|
| Strongly agree | Agree | Indifferent | Disagree | Strongly disagree |