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Summary

This paper investigates the existence of, and provides a theoretical basis for, an 'announcement effect' (AE) following a decision to impose an environmental tax. An AE is defined as an action taken to reduce the environmental impact that is the target of the tax, between the time of the announcement of the tax and its implementation, when this action would not have been taken if the tax had not been announced.

The term 'announcement effect' has been used a number of times in the environmental policy literature. Although the most well known cases are the sulphur dioxide (SO_2) tax and the nitrogen oxides (NO_x) charge in Sweden, the term was first used in the case of the German water effluent tax. The paper briefly presents the evidence for an AE in these three cases.

The existence of an AE is potentially problematic in a neo-classical economic context, in which actors are possessed of perfect information and are on a optimal technological path before the tax is announced. However, the paper constructs several models to show how the AE can be theoretically explained. The seven simple models distinguish between capital and operating costs and benefits. They show that an AE is theoretically possible even under neo-classical assumptions, although it becomes more likely when the assumption of perfect information is relaxed, and most likely when abatement actions open up opportunities for innovation or entry into new markets.

The models are then applied to the three taxes and charges discussed earlier. It is shown that they can explain the evidence of an AE in the SO_2 and NO_x cases, but that its existence in the case of the German effluent charge is more questionable. It seems that the evidence for an AE is more likely to have been the result of the introduction of new maximum emission standards coupled with subsides, rather than due to an AE as such.

1 Introduction

The purpose of this paper is to investigate the existence of, and provide a theoretical basis for, an 'announcement effect' (AE) following a decision to impose an environmental tax. An AE is defined as an action taken to reduce the environmental impact that is the target of the tax, between the time of the announcement of the tax and its implementation, when this action would not have been taken if the tax had not been announced (i.e. the action is additional to any abatement taken under business-as-usual).

The next section is a short survey of the occasions an AE has been associated with an environmental tax. Section 3 then introduces some theoretical arguments as to why an AE might come about under different assumptions. Section 4 relates the theoretical arguments to the three cases that have been briefly examined in Section 2. Section 5 provides some conclusions des.

2 Evidence Of The Announcement Effect

The term "Announcement Effect" (AE) has been used a number of times in the environmental policy literature. Although the most well known cases are the sulphur dioxide

(SO_2) tax and the nitrogen oxides (NO_x) charge in Sweden, the term was first used in the case of the German water effluent tax.

2.1 The Swedish Charge on Nitrogen Oxides.

Emissions of NO_X, together with sulphur dioxide, are the main causes of acidification in forests and lakes. In addition, nitrogen oxides contribute to the formation of ground-level ozone, which has negative effects on vegetation and human health. They are also a main cause of eutrophication in forestland and seabeds (SEPA, 2000).

As part of its strategy on NO_X emissions reduction, the Swedish Parliament passed a law in June 1990 introducing a charge to be levied from 1 January 1992. The charge was imposed on emissions of nitrogen oxides from boilers, stationary combustion engines and gas turbines with a useful energy production of at least 50 gigawatt hours (GWh) per year. The NO_X charge was based on actual emissions and imposed irrespective of the fuel used. The charge was levied at a rate of SEK[1] 40 per kg of emitted NO_X and has remained constant in nominal terms since. Before the imposition of the charge the abatement cost to reduce NO_X was found to be between 3 and 84 SEK/kg (SEPA, 1997). Because of the high monitoring costs needed at each pollution source, the charge was initially imposed only on big polluters, but due to the effectiveness of the charge and to the simultaneously falling monitoring costs, the policy was extended in 1996 to boilers producing at least 40 GWh per year and in 1997 to boilers producing at least 25 GWh per year (SEPA, 1997).

To avoid distorting competition between the plants subjected to the payment of the charge and those which are not, total revenues, not including administrative costs, are returned to polluters in proportion to the NO_X-efficiency of their energy production process. As shown by Cansier and Krumm (1997), the NO_X charge paid by the polluter i can be formalised as:

$$T_i = te_i - \beta_i \sum_{i=1}^{n} te_i \quad (1)$$

where e_i are its emissions, t the rate of the charge and β_i the fraction of the energy produced by the i-th polluter of the total energy produced by all taxable plants[2]. The i-th polluter is a net payer only if the efficiency of its production process is lower than the average firm[3]:

$$T_i \begin{Bmatrix} > \\ < \end{Bmatrix} 0 \Leftrightarrow \frac{e_i}{x_i} \begin{Bmatrix} > \\ < \end{Bmatrix} \frac{E}{X} \quad (2),$$

where E and X indicate the sum of individual firms' emissions and energy output.

The Swedish NO_X charge is considered a successful application of marked-based economic instruments in environmental policy (SEPA, 2000). On average, the plants

[1] This corresponds to Euro 4.36 or GBP 2.74 using the 2002 annual exchange rates provided by the Bank of England (1 SEK = Euro 0.1091 and 1 SEK = GDP 0.0686).

[2] $\beta_i = x_i / \sum x_i$ where x indicates energy.

[3] Indeed $T_i = te_i - \frac{x_i}{\sum_{i=1}^{n} x_i} \sum_{i=1}^{n} te_i > 0$ if $\frac{te_i}{x_i} - \frac{\sum_{i=1}^{n} te_i}{\sum_{i=1}^{n} x_i} > 0$ which gives (2).

originally targeted have reduced emissions per unit of energy input by about 60 per cent since the announcement of the tax, as shown in Figure 1. The rise in the emissions in 1996 and 1997 is due to the expansion of the system that brought about 100 new boilers into the scheme.

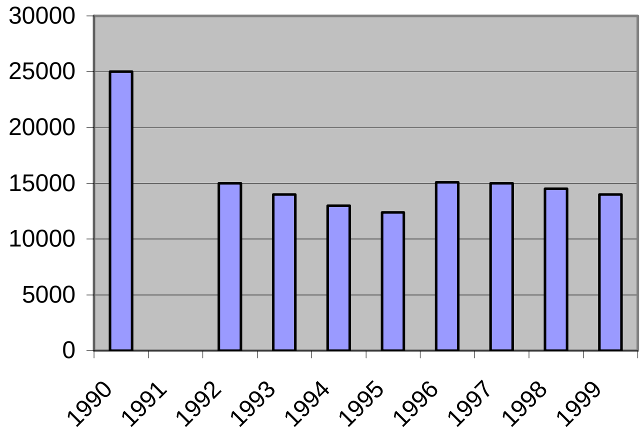

Figure 1. NO_X emissions from boilers subject to the NO_X charge between 1992 and 1999 and estimated emissions form these boilers in 1990. Source: SEPA (2000), p.10.

As shown in Figure 1, there was most likely a conspicuous reduction of NO_X before the tax was enforced in 1992 but it is difficult to discern an AE, as reliable data have been collected only since the introduction of the charge, when expensive measurement mechanisms were installed. The 1990 value is estimated using the average specific emissions of that year and 1992 energy output. Furthermore, it is difficult to separate the role of the charge from that of other instruments applied to the boilers. SEPA (1997) provides some figures but unfortunately the methodology and the data used to obtain them are not made explicit; according to Hoeglund (2000) 50 per cent of the abatement measures between 1990 and 1992 were due to the introduction of the charge. Because of the huge difference between the NO_X emissions in 1990 and 1992 it is concluded that an AE occurred even if its exact dimension remains uncertain.

2.2 The Swedish Tax on Sulphur Dioxide

Sulphur dioxide (SO_2) is the principal pollutant associated with acid deposition, usually after oxidation to sulphuric acid. As already mentioned, emissions of sulphur dioxide are damaging to whole ecosystems and in particular to forests and lakes. In addition, SO_2 has a well-established negative effect on human health (SEPA, 1997).

In the spring of 1990 the Swedish Parliament passed a law containing a tax on SO_2 emissions to be introduced on 1 January 1991. The tax is levied on the sulphur content of coal fuel, peat fuel, motor fuel and heating oil; exemptions are granted for fuels used in shipping, fuel production and in some industrial processes (i.e. metallurgical processes and recovery boilers). The tax rate at the introduction of the law was SEK 30[4] per kg sulphur and has since remained constant in nominal terms. Analogously to the NO_X charge, the SO_2 tax rate was based on the estimated emission abatement costs[5] (SEPA, 1997). Unlike the NO_X charge, the revenues from the SO_2 tax are not reimbursed to emitters, and can therefore only be avoided to the extent that polluters avoid SO_2 emissions by undertaking abatement measures.

[4] This corresponds to Euro 3.27 or GBP 2.06 using the 2002 annual exchange rates provided by the Bank of England (1 SEK = Euro 0.1091 and 1 SEK = GDP 0.0686).

[5] Abatement costs consisted of the price difference for oil with low sulphur levels and costs of technical emission reduction (Cansier and Krumm, 1997).

The Swedish SO_2 tax is regarded in the literature as another successful application of environmental taxes. However, the evaluation of the effect of the SO_2 tax is complicated because of the interaction between this tax and other instruments regulating the same pollutants (i.e. standards on the maximum sulphur content of fuels) and other taxes like the CO_2 tax, the Energy tax and the NOx charge. Furthermore, the data, on which the evaluations are based, are reliable only since the implementation of the tax . Despite these limitations, some qualitative conclusions can be drawn in the case of fuel oil. The tax rate on oil is SEK 27[6] per cubic metre for each tenth of a per cent by weight of sulphur in the oil; no tax is payable if the sulphur content is less than 0.1 per cent by weight (SEPA, 1997). The actual sulphur content in these fuels and the maximum value allowed by other environmental standards are shown in Table 1. In 1990, when it was announced that oil with less than 0.1% sulphur content would be exempt from the tax, it was thought that this threshold could give a strong incentive to the industry. In 1991 light heating oil was completely exempt from the tax. Although, as already mentioned, the data before the implementation of the tax is highly unreliable, Table 1 shows that the sulphur content in 1989 was above the tax exemption threshold. Also in the case of heavy oil a big decrease was observed. As these fuels are not affected by any other instrument, it seems likely that this is another example of the AE.

		Light heating oil	Heavy oil
Estimated	1989	0.2	0.6-0-7
	1990	?	?
	1991	0.08	0.5
	1992	0.076	0.45
	1993	0.056	0.45
	1994	0.058	0.45
	1995	0.076	0.35
Maximum permissible	1989 –1995	0.2	0.8

Table 1*. Sulphur concentrations in oil from 1989 to 1995 in per cent by weight. The particularly low sulphur concentrations in light heating oil in 1993 – 1994 were due to the rules at that time on environmental classification of oil. Source: SEPA (1997).*

2.3 The German Water Effluent Charge

Charges on emissions to surface water can be split into charges for sewerage and sewage treatment and wastewater effluent charges. While the former are a payment for the service of providing sewerage and sewage treatment, the latter are levied on all wastewater effluent (OECD, 1994).

The German water effluent charge, first proposed in 1974, was introduced by the Waste Water Levy Act in 1976 and came into effect in the majority of Länder[7] in 1981. The initial rate of the levy was DM 12 per damage unit but it was gradually increased to DM 40[8] per damage unit between 1981 and 1986; since 1997 the tax rate has been 36 EUR[9]. Although the revenues are earmarked and generally employed for water-related schemes, their particular use varies among the Länder.

According to Andersen (1994), the most important change in the German water policy in 1976 was the Water Household Act, which enabled federal authorities to prescribe maximum

[6] This corresponds to Euro 2.946 or GBP 1.852 using the 2002 annual exchange rates provided by the Bank of England (1 SEK = Euro 0.1091 and 1 SEK = GDP 0.0686).
[7] Länder are the regional states members of the German Federal Republic and of Germany after 1989.
[8] This means Euro 6.1356 or GBP 3.8568 and Euro 20.452 or GBP 12.856 using the 2002 annual exchange rates provided by the Bank of England (1 DM = 0.5113 Euro and 1 DM = 0.3214 GBP).
[9] This means 22.630 GBP.

emission standards for each industrial sector. The German water effluent charge has always strongly interacted with these licences but it has been considered a supplementary measure to the standards. This was highlighted in 1986 when the sector emissions standards, initially set with reference to the principle of the generally accepted technological standard, became based on the best available technology (BAT). This revision was considered a downgrading of the tax: since 1986 the main purpose of the tax has been to make polluters comply with the sector standards and therefore the German Water Effluent Charge can be considered a penalty tax[10] (EU, 2001). The tax is reduced when standards are adhered to, and further reduced if dischargers manage to keep their effluent at a quality level that exceeds the one set in the regulations. This further reduction is conditional upon improved performance being set in advance and subsequently verified.

In 1983, two years after the tax came into effect, water direct emissions were substantially lower than in 1981. Furthermore, in 1981 a remarkable reduction occurred in effluent not being treated (no treat in Table 2), although the amount of effluent discharged through own sewage treatment plants (wSTP in the table) declined only slightly.

	1977	1979	1981	1983	1987	1991	1995
Direct	100	107	101	83	80	95	76
- no treat	100	100	90	72	60	64	66
- wSTP	100	111	108	90	92	114	83
Net production	100	107	106	103	114	(*)	(*)

Table 2. *Index for direct discharges of production specific wastewater from industries as compared to net production index. The net production index refers to the economic activity (*) reunification effect: break in time series. Source: EU, 2001, p. 327.*

According to OECD (1994) in the case of the German water effluent charge "there are indications of an 'AE', as there had been a steep increase in abatement investments in the years immediately preceding the introduction of the charge" (p.69). This could be explained by the long time span between the announcement of the tax (1976) and its implementation (1981-82): firms had been given plenty of time to implement the most profitable strategy in response to the introduction of the tax before the legislation was enforced.

3 Theoretical Explanations Of The Announcement Effect

In the conventional neo-classical model, actors (in this case assumed to be firms) possess perfect information. In particular, they are assumed to know the cost and abatement implications of all relevant technologies. They are therefore assumed to be on an optimal technological path before the tax is announced, and to be able to calculate the optimal technological path thereafter. The discussion below explores the possibility of there being an AE mainly under these circumstances, as well as under the perhaps more realistic situation in which the assumption of perfect information is relaxed.

Perfect Information

Under perfect information, when the tax is announced the firm knows that its current technological path is not going to be optimal once the tax is introduced. Considering only operating costs and benefits, which are assumed to be currently optimal, and which may be assumed to be changed instantaneously, an AE can only occur if the announcement of the

[10] In 1986 the rate of the levy was reduced by 80 per cent if a firm complied with the BAT while municipal authorities extending or constructing sewage works were eligible for three years' exemption from the levy, provided that the new plants were able to meet the guidelines. The effect of the tax for public sewage treatment plants which did not comply with the BAT was to increase costs by up to 10% of total operating costs. For plants that complied the cost share of the tax was only about 2% (EU, 2001, p.86).

policy influences other economic variables and if these changes make abatement measures more profitable than they were previously (case 1-B).

With regard to capital equipment, the firm is assumed to know the new technologies needed from the date of the implementation of the tax (either because they are optimal or because they have been prescribed by the regulator). Several considerations may make the early installation of these technologies, and hence the early abatement of pollution, rational, as shown in Section 3.3.

Imperfect Information

When the firm does not have perfect information about its technological opportunities, the announcement of the tax may provide a stimulus to the firm to search for information and therefore to make changes in its capital or operating arrangements. If these changes result in reduced environmental impacts (as is likely) then they would show up as an AE. Such situations are discussed in Section 3.2 in relation to operating costs and benefits and in Section 3.3 in relation to capital costs and benefits.

3.1 A Simple Model

This section introduces a simple model describing the behaviour of a rational agent – a firm, F, polluting the environment – in response to the introduction of an environmental tax. The behaviour of the firm is rational in the sense that it maximises its profits after observing the values of the exogenous variables E[11] and the policy set P, fixed by the market regulator. In this framework an environmental tax announced by the market regulator in t_0 (announcement date) and enforced in t_1 (enforcement date) corresponds to a change in the policy set P[12] observed by the firm. It is worth underlining that the set P changes only in $t = t_1$, as in $t = t_0$ the environmental tax is announced but not implemented.

Initially the firm's behaviour is subject to the following assumptions:

a) The representative firm in t_0 has perfect information on the implementation date and on all details of the environmental tax.

b) Between the announcement and the enforcement date there are no changes in the policy as announced in t_0[13].

c) There is no strategic interaction between F and the market regulator.

d) Penalties imposed by the market regulator for firms which are not complying are so high that any attempt to deceive the market regulator in $t > t_1$ is profit-damaging.

e) The costs and benefits accruing to the firm after the enforcement date are not influenced by the firm's behaviour in $t \in [t_0, t_1)$.

Assumptions a) and b) imply that the time span between the announcement date and the enforcement date can be interpreted as an adjustment period granted to the firm by the market regulator, as in t_0 F has all the information needed to decide its response to the future change

[11] As the representative firm cannot affect the value of these variables we use the terms variables and parameters interchangeably. Examples of the variables in E are the interest rate and the level of prices.

[12] A change in the policy set can influence **x** – the variable, whose value is determined by the firm in order to maximise profits - either constraining its value (e.g. fixing a limit to the amount of pollution) or through a change in the exogenous variables E.

[13] Needless to say, if this assumption does not hold, the AE is less likely. It is worth pointing out that while in Sweden political uncertainty has not played a big role, in Germany industries went to court to stop the introduction of the tax and the Land of Bavaria repeatedly questioned the federal competence to establish this levy.

in P. Assumption c) implies that before the enforcement date the firm can influence neither the general contents of the policy nor any details regarding its implementation. When facing a tax F has two options: to pay the tax or to abate emissions. In particular, the firm will abate to the extent that the marginal abatement cost is smaller than the tax: this ensures that the resulting resource allocation is socially Pareto-optimal. But this only occurs if the firm abides by the policy, which is guaranteed by assumption d). The firm's decision to abide by the law can be the result of the maximisation of the expected utility using subjective weights on the likelihood of being caught red-handed or the result of less complicated rules of thumb. Finally, because of assumption e) the firm faces two independent problems: its response to the tax between t_0 and t_1 and its response after the enforcement date. Because of assumption d) and because of the incentives linked to the tax, the firm will reach the socially Pareto-efficient combination of abatement measures and pollution emission in $t \geq t_1$; what remains to be seen is whether the firm will change its behaviour in $t \in [t_0, t_1)$. Whether assumption e) holds depends on the detail of the tax being announced. As discussed in Section 4.1, the NO_X charge in Sweden is an example where this assumption does not hold.

The set of variables, whose value is determined by the profit-maximisation behaviour of the firm is shown here as **x.** Since F revises its optimisation process after every change in P and E, because of the structure of the problem the optimal values of **x** will be[14]

$$\mathbf{x}^* = \begin{cases} \mathbf{x}_0^* \; before \quad t_0 \\ \mathbf{x}_1^* \; \; after \quad t_1 \end{cases} \qquad (3).$$

From now onwards the term 'implementation date' indicates the time when F starts responding to the change in P. Changes in **x*** can be regarded as an important but not, as it will be shown, an unambiguous indicators to detect the implementation date. In order to analyse some of the considerations, making the AE plausible, assume that the effect of F responding to the announcement of the tax can be determined separately in respect of operating costs and benefits, and of capital costs and benefits.

3.2 Effects on Operating Costs and Benefits

Case 1-A

The operating costs arising from an environmental tax can be split into:

a) financial costs (FC) linked to the payment of the tax.
b) penalties (P) imposed when the firm does not abide by the policy in $t \geq t_1$.
c) abatement costs (AC) due to changes in the firm's organisational structure to carry out the abatement measures. Examples of these kinds of costs are wages of new personnel or allocation of equipment already owned by the firm.

Operating benefits, B, are linked to the increase in the efficiency of the production process of the firm. Porter (1990, pp.647-648) has hypothesised that environmental policy, by stimulating greater innovation and efficiency, may be good for economic competitiveness. This 'win-win' hypothesis of the economic, as well as environmental, benefits of environmental policy runs clearly counter to economists' normal assumptions of efficient, competitive markets. It has been attacked as being at best a marginal phenomenon with regard to the costs of environmental regulation as a whole. Palmer et al. (1995, pp.127-128) estimate that Porter's "innovation offsets" amount to only a few percent of the total costs of conforming to environmental regulations, which in the US have been estimated by the EPA at $135 billion in

[14] The enforcement of an environmental tax implies a change in the optimal values of x because it changes the relative prices.

1992. They contend that the vast majority of these costs conform to the standard economic trade-off model, whereby environmental benefits are gained at the expense of growth and competitiveness. While noting that this issue is not definitively resolved, it will not be pursued any further in this paper.

As neither the penalties nor the payment of the tax can be imposed before t_1, the net benefits of responding in $t \in [t_0, t_1)$ to the environmental tax can be written as:

$$NB(t_i, x^*) = B(t_i, x^*) - AC(t_i, x^*) \quad (4)$$

where t_i is the implementation date maximising the identity above, AC the abatement costs, and B the benefits of the policy. The variables in (4) describe the sum, discounted in t_0, of the instant benefits and costs from the implementation date onwards: in the case of the abatement cost variables $AC(t_i, x_1^*) = e^{-\delta(t_i - t_0)} \int_{t_i}^{t_1} ac(x^*) e^{-\delta t} dt$, where δ is the rate of discount, and analogously for the benefits. It is worth noting that the quantities in (4) are functions of two variables, t_i and **x***, as before the enforcement date the firm can choose both which abatement measures it wants to implement and when to carry them out. The optimal response in $t \in [t_0, t_1)$ obviously differs from that after t_1 as the change in the relative prices has not occurred yet.

Consider for example that the change in P does not affect in $t \in [t_0, t_1)$ any of the economic variables contained in E. At first sight, as environmental taxes affect relative prices only after they are introduced, this setting seems to be the most suited for the analysis of the AE. However, even if the tax-induced change in relative prices occurs only in t_1, the profitability of the firm's current production process is affected by the announcement of the tax. If F enjoys a certain degree of freedom in the intertemporal allocation of its production plan, anticipating part of the production of goods causing the emissions, which will be taxed from $t = t_1$, makes the firm better off. Paradoxically, the change in P does not affect the variables in E before t_1 only if the firm cannot exploit the benefits arising from the intertemporal substitution process described above.

The decision problem faced by F in t_0 will be to choose a set of values for (t_i, **x***) such that the net benefits are maximised:

$$\max_{t_i \; x^*} NB = \max_{t_i \; x^*} \; e^{-\delta(t_i - t_0)} \left[\int_{t_i}^{t_1} b(x^*) e^{-\delta t} dt - \int_{t_i}^{t_1} ac(x^*) e^{-\delta t} dt \right] \quad (5)$$

[s.t. $t_i \in [t_0, t_1)$

If the outcome of (5) is $\mathbf{x}^* = \mathbf{x}_0^*$ for every $t \in [t_0, t_1)$, any abatement measure is profit-damaging for F, given the current relative prices. Responding to the environmental tax as late as possible is the cost-minimising strategy. Because of the change in the relative price and of the penalties being switched on in t_1 the implementation and the enforcement date coincide.

If the outcome of (5) is $\mathbf{x}^* \neq \mathbf{x}_0^*$ for some $t \in [t_0, t_1)$, the firm abates emissions before the enforcement date. Given the instantaneous ability of the firm to alter the optimal **x** (because only operating costs and benefits are considered) and given the fact that E and P in $t \in [t_0, t_1)$ have not changed, values of **x*** different from $\mathbf{x}_0^*$ can be only due to the AE. When the change in P does not affect in $t \in [t_0, t_1)$ any of the economic variables contained in E, like in this case, anticipating some abatement measures can only be explained through bounded rationality[15]: $\mathbf{x}_0^*$ was the local optimum given the set I_0 containing the firm's information on the policy set, the economic variables, the technological and organisational space and about the transaction and measurement costs associated with abatement. If the announcement of the policy changes the firm's information set in t_0, the optimum value of $\mathbf{X}$ could change accordingly and some abatement measures may be revealed to be privately Pareto-superior for some $t \in [t_0, t_1)$. In the terms of (4), the value of B is positive and big enough to compensate for positive values of AC. The implementation date and the abatement measures carried out will be influenced by the variables in (5) and especially by the functional forms of the benefits and costs (i.e. their rate of change), by the discount rate and by the interaction between the implementation date and the benefits and costs arising from the abatement measures. In summary, under the current assumption early abatement measures can be profit-enhancing only because of bounded rationality. Furthermore, the change of **x*** in $t \in [t_0, t_1)$ results in lower emissions before t_1 and is a clear manifestation of the AE.

Case 1-B

Now consider that the announcement of the environmental tax influences in $t \in [t_0, t_1)$ the value of the variables E. If the profit-maximising firm does not change the values of **x***, profits are sub-optimal and the difference between the optimal level and those gained by the firm can be called induced losses (IL). An example of this, as mentioned in the previous section, is the reduced profitability linked to not changing the schedule of production after the tax announcement. As F is profit maximising, it will adjust **x*** but whether this effect is in the direction expected by the market regulator depends on the link between the abatement measures and the factors responsible for the induced losses. If they are negatively correlated, an increase in the emissions may be observed, while if they are positively correlated, implementing abatement measures, which were profit-damaging in $t < t_0$, becomes economically rational in $t \in [t_0, t_1)$ if the IL are bigger than the damage inflicted by an earlier reduction of emissions. In this case the AE occurs.

A particular example of this case is when a mechanism changing the cost-benefit structure (e.g. a subsidy) is part of the policy. If the market regulator grants a subsidy to firms implementing some abatement measures in $t_i \in [t_2, t_3]$ with $t < t_2 < t_3 < t_1$, the firm will solve the following

$$\max_{t_i \; x^*} NB = \max_{t_i \; x^*} e^{-\delta(t_i - t_0)} \left[\int_{t_i}^{t_1} b(x^*) e^{-\delta t} dt - \int_{t_i}^{t_1} ac(x^*) e^{-\delta t} dt \right] + S e^{-\delta(t_i - t_0)} \quad (6),$$

$$\text{s.t} \quad t_i \in [t_2, t_3]$$

and compare the outcome with the pay-off in (5). If the pay-off from (6) is bigger than that from (5) and positive, the firm will take the subsidy and implement abatement measures before the enforcement date. When the subsidy is paid proportionally to the difference between the implementation date t_i and t_1, the logic underlying the problem is the same and equation (6) becomes

$$\max_{t_i \; x^*} NB = \max_{t_i \; x^*} e^{-\delta(t_i - t_0)} \left[\int_{t_i}^{t_1} b(x^*) e^{-\delta t} dt - \int_{t_i}^{t_1} ac(x^*) e^{-\delta t} dt + \int_{t_i}^{t_1} s e^{-\delta t} dt \right] \quad (7)$$

[15] The term bounded rationality is used to designate rational choice that takes into account the cognitive limitations of both knowledge and cognitive capacity and that is based on the relaxation of one or more assumptions of standard expected utility theory. Due to the many different ways of weakening the ideal requirements, prospects of finding a single "right" theory of bounded rationality are limited.

$$\text{s.t.} \quad t_i \in [t_2, t_3]$$

In summary, when the announcement of the environmental tax influences in $t \in [t_0, t_1)$ the value of the variables E, the AE is theoretically possible without requiring a change in the information set, if the firm is "punished" through the induced losses for not responding to the policy before the enforcement date. Unlike in the case 1A, a change in the value of **x*** is not a clear manifestation of the AE. Indeed, if abatement measures and the factors responsible for the induced losses are negatively correlated, the value of **x*** will change but emissions may increase.

3.3 Effects on Capital Costs and Benefits

Analysing the likelihood of the AE when an environmental tax implies capital costs[16] and "capital benefits"[17] becomes slightly more complicated. The firm faces two linked, but independent problems: the purchase of the capital and the reduction of emissions. These issues are linked in the sense that if F wants to implement some abatement measures in $t \in [t_0, t_1)$, it has to own the capital; at the same time they are independent because after the new equipment has been bought, the firm is not bound to implement the abatement measures until the enforcement date.

The results from the literature on the optimal planning of investments are useful to analyse the likelihood of the AE. Hartl (1992) analyses a firm bound to acquire a certain stock of capital before a given date t_1 and shows that under reasonable assumptions on the cost function (concave before a certain level of investment I_t and convex afterwards) the optimal investment path monotonically increases after the announcement date provided that the discount rate, the depreciation rate and technological progress rate are bigger than zero. Because of these three factors a firm prefers to acquire the capital as late as possible while because of the convexity of the cost function, the firm prefers to spread the investment expenditure over a bigger time span. The result, being a compromise between these opposite forces, implies that the optimal investment path starts at a low level and increases in the whole maximisation period.

In the case discussed in this paper, implementing an accelerated investment path in order to have the equipment ready to be run in t_1 gains the firm what can be called "safety benefits". If F is ready to abate emissions in $t \in [t_0, t_1)$, it will have some time to fix unexpected problems occurring during the completion of the investment, which, if not fixed, oblige F to pay an inefficient level of environmental tax from t_1. It is relevant to point out that these benefits are a function of the expected length of the delay, the amount of the environmental tax, the firm's degree of unfamiliarity with the new equipment and, up to a certain extent, of the implementation date itself.

To discuss the likelihood of the AE in the presence of capital costs, the case when the decision on the capital is left to the firm has to be distinguished from when the market regulator fixes some limitations about the equipment being installed.

Case 2A

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[16] Lump-sum organisational costs (for example, consultancy fees for the implementation of the policy) can be considered part of the capital expenditure. Indeed, the material or immaterial nature of these costs is not relevant here.

[17] They could be new production possibilities (new products or new markets) or issues related to its reputation. The reputation of the firm is simply a form of immaterial capital and a proactive emission abatement practice can be advertised as a sign of the commitment to social and environmental issues.

If the market regulator leaves the decision on the equipment to the firm, implementing an accelerated investment path will increase capital costs due to the discount, depreciation and technological progress rate and due to the convexity[18] of the cost function: AI in (8), whose magnitude is positively correlated to the time between t_i and t_1, indicates these further costs. On the other hand, it is very likely that abatement measures implemented before t_1 provide information on how the new equipment operates and on the set of abatement measures. The magnitude of these information benefits, IB in (8), depends on the amount of the environmental tax, the firm's degree of unfamiliarity with the new equipment, the amount of the learning involved[19] and, to a certain extent, on the implementation date itself.

The firm's maximisation problem in t_0 becomes:

$$\max_{t_i \; x^*} NB = \max_{t_i \; x^*} \; e^{-\delta(t_i - t_0)} \left[\int_{t_i}^{t_1} b(x^*) e^{-\delta t} dt - \int_{t_i}^{t_1} ac(x^*) e^{-\delta t} dt - AI(\bullet) + IB(\bullet) \right] \quad (8),$$

s.t. $t_i \in [t_0, t_1)$.

In this setting the firm may be willing to abate emissions before the enforcement date due to the fact that abatement measures need investments to be carried out. As the change in the relative prices in t_1 shifts the boundary between profit-enhancing and profit-damaging abatement measures, some of the abatement measures becoming profit-enhancing in t_1 could give a positive pay-off also in $t \in [t_0, t_1)$. The cost of the capital, which is the factor making some of these policies profit damaging in $t < t_0$, is not one of the variables in (8): only the cost of an accelerated investment path is considered, as the equipment will be needed regardless, from the enforcement date onwards.

It is worth pointing out that so far it has been assumed that the firm faces a binary choice: to implement the whole set of measures before t_1 or to implement none. However, if this assumption does not hold, the logic of the maximisation problem is unchanged. The firm will have to simply maximise (8) not for the whole set of measures (and capital) but for the subset of measures (and related capital), which can be carried out independently.

Therefore to summarise, under the current assumptions the AE is theoretically possible because of the information benefits and because of the boundary shift in the set of abatement measures. The safety benefits are not part of (8) because they do not affect the decision on the abatement measures but only the decision on the investment path; indeed, the firm can choose to install the equipment but not to abate emissions. Unlike the case 1A, a change in the value of **x*** is not conclusive evidence of the AE, as it could be due to the implementation of the optimal investment path.

Case 2B

Now consider that the decision on the equipment purchase is not completely left to the firm: the relation between the prescribed capital and the equipment already owned by the firm becomes important for judging the likelihood of the AE. If the emission reductions, which are carried out with the equipment imposed by the market regulator, cannot be implemented by the equipment already owned by the firm, the previous case applies: constraints on the firm's choice do not make any difference in (8).

[18] As mentioned above, the convexity of the cost function implies that concentrating the investments in a short period increases the costs of investments. For this reason, if the firm wants to anticipate abatement measures, it has to bear increased capital costs. The increase of capital costs due to the depreciation, technological progress and discount rate is identical to Hartl (1992), as discussed above.

[19] The firm's degree of unfamiliarity with the emission abatement practice can be considered a good proxy for the amount of learning involved.

In the opposite case, (8) has to be modified to take into account the value of the old equipment to be substituted. Its present value decreases the longer it is used because the compound discount factor becomes smaller and because the residual value of the equipment decreases as its technological services are progressively depleted (depreciation). The difference between the value of the old equipment when substituted in t_1 and when substituted in t_i is indicated by SK in (9). It is not unlikely that the prescribed investments are technologically advanced compared to those already owned by the firm. If there are cost savings or other benefits arising from the utilisation of the new equipment, these factors are part of the operating benefits in (9).

The firm's maximisation problem becomes:

$$\max_{t_i \; x^*} NB = \max_{t_i \; x^*} \; e^{-\delta(t_i - t_0)} \left[\int_{t_i}^{t_1} b(x^*) e^{-\delta t} dt - \int_{t_i}^{t_1} ac(x^*) e^{-\delta t} dt - AI(\bullet) + IB(\bullet) - SK(\bullet) \right] \tag{9}$$

s.t. $t_i \in [t_0, t_1)$.

As the value of SK is positively correlated to the time between t_i and t_1, it will be more likely compared to the case 2A that the firm does not want to anticipate the abatement measures. As in the previous case the assumption that any abatement measure needs the whole set of capital can easily be dropped and does not change the logical structure of the problem.

As an example, consider there are two technologies: A with big start-up costs and low operational costs and B with very low start-up costs but bigger operational costs. Suppose that F is locked-in into the use of B because switching to technology A is profit damaging due to its high start-up costs. If the market regulator prescribes the use of technology A in t_1, the rational firm has to weigh only the costs of anticipating those investments against the benefits arising from the new technology. If the latter are bigger than the former, F wants to adopt A as soon as possible and not wait until t_1.

Case 2C

A positive contribution to the likelihood of observing an AE can be found in the case of "lumpy" investments replacing existing equipment, whose value becomes zero in $t \in [t_0, t_1)$. In this case there are no costs related to the substitution of the equipment already owned by the firm - SK in (9) - and to the implementation of accelerated investment path - AI in (9). Anticipating the implementation date enables the firm to avoid the costs of having to substitute capital later if it buys the old kind of equipment in $t \in [t_0, t_1)$ - the term AK in (10). Because AK may be very big, an AE is very likely to be observed.

$$\max_{t_i \; x^*} NB = \max_{t_i \; x^*} e^{-\delta(t_i - t_0)} \left[\int_{t_i}^{t_1} b(x^*) e^{-\delta t} dt - \int_{t_i}^{t_1} ac(x^*) e^{-\delta t} dt + IB(\bullet) + AK(\bullet) \right] \quad (10),$$

$$\text{s.t.} \quad t_i \in [t_0, t_1).$$

Case 3

In the case of capital benefits, while it is undeniable that accurately quantifying these factors is certainly difficult, their influence on the likelihood of the AE can be judged much more easily. If abatement of emissions can open up environmentally conscious markets or if it is a condition for the production of a "green" product, it is very plausible that the expected profits from anticipating these production possibilities will be bigger than the costs arising from the early reductions. Analogously, anticipating the market regulator's requests could enable the representative firm to exploit reputation issues in the form of increased prices commanded by its products. Either way it could make economic sense to bear increased costs between the implementation date and t_1.

Case	Assumptions	Outcome
1A	a) Environmental tax does NOT affect in $t \in [t_0, t_1)$ the variables contained in E b) Only operating costs and benefits	The AE can occur only in case of a change in the information set. A change in x* in $t \in [t_0, t_1)$ is a clear manifestation of the AE
1B	a) Environmental tax DOES affect in $t \in [t_0, t_1)$ the variable contained in E b) Only operating costs and benefits	The AE can occur because of induced losses. A change in x* in $t \in [t_0, t_1)$ is a manifestation of the AE only when abatement measures are positively correlated to induced losses
2A	a) Environmental tax does NOT affect in $t \in [t_0, t_1)$ the variables contained in E. b) Investments are needed to curb emissions. c) The choice of the equipment is left to the firm	The AE can occur due to a change in the information set and to the shift in the boundary between profit-enhancing and profit-damaging abatement measures. A change in x* can be due either to the AE or to the implementation of the optimal investment path
2B	a) Like in 2A except that the choice of the equipment is NOT left to the firm	The AE is less likely, compared to the case 2A, if capital has to be substituted but it is still possible. Like in 2A a change in x* can be due either to the AE or to the implementation of the optimal investment path
2C	a) Like in 2B except that by chance the firm would substitute the old equipment anyway in $t \in [t_0,t_1)$	The AE is more likely compared to the case 2A and 2B because of the further costs for firms not anticipating the policy implementation. A change in x* can be due either to the AE or to the implementation of the optimal investment path
3	a) Environmental tax does NOT affect in $t \in [t_0, t_1)$ the variables contained in E b) Capital benefits can be gained from an early emission reduction	AE is more likely to happen compared to 1A because the effect of these benefits is very likely to be substantial.

Table 3. Summary of the cases presented in this section.

4. Analysis Of The Announcement Effect

In this section the explanations for the AE of the environmental taxes, discussed in section 2, are suggested using the insights from section 3.

4.1 The Swedish Charge on Nitrogen Oxides

In the case of the NO_X charge the options to reduce emissions and the structure of the charge help explain why an AE occurred. There are three methods to reduce NO_X emissions: combustion measures, flue gas cleaning and fuel switch.

As the NO_X emitted depends on the conditions at which the combustion takes place and only to a lesser extent on the nitrogen content of the fuel (SEPA, 1997), NO_X emissions can be reduced by implementing measures increasing the NO_X-efficiency of the combustion (e.g. introducing flue gas re-circulation, or trimming, which means choosing the temperature, oxygen rate and other combustion parameters in order to optimise combustion efficiency, see SEPA, 2000).

Unlike combustion measures, in the case of flue gas cleaning some equipment needs to be installed in order to abate emissions but as in the previous case large reductions are possible at a zero or very low cost (SEPA, 2000). When the tax was introduced, the regulator thought there were several opportunities to reduce NO_X emissions using relatively inexpensive means. The introduction of the charge has therefore unlocked unutilised opportunities.

In the case of fuel switching the emission reduction is due to a changeover from coal to biomass fuels and from oil to natural gas (SEPA, 1997). The interaction with other instruments makes the estimate of the contribution of the NO_X charge to this process very uncertain.

In terms of the model in Section 3, the NO_X emission cut at a negative cost in $t \in [t_0, t_1)$ corresponds to the cases 1A and 2A. For emission cuts in $t \in [t_0, t_1)$ not requiring investments bounded rationality can explain the AE. Indeed, these abatement measures are not more profitable than they were before the tax announcement, as the change in the relative prices has yet to occur. This is confirmed by SEPA (2000), which states that the charge intensified the scrutiny of the boilers and their functions. During this process, efficiency-improving and cost-saving measures have been discovered and consequently implemented. This is exactly an example of a change in the information set due to a policy announcement.

Emission cuts in $t \in [t_0, t_1)$ requiring investments to be carried out are theoretically plausible in the context of the case 2A. If the change in the relative prices requires investments to cut emissions not later than t_1, some of these abatement measures may be economically rational also in $t \in [t_0,t_1)$. These opportunities were not exploited in $t < t_0$ as the investment required outweighed the benefits, but after the tax announcement the benefits in $t \in [t_0,t_1)$ have to be compared only with the cost of anticipating the investment, as pointed out in (8), and not with the whole investment costs. This logic may have been the reason behind the restructuring of the salary scheme at one site, where IISD (1994) finds that bonuses for employees were paid if emissions were low[20].

So far only emission cuts with a negative or null cost in $t \in [t_0, t_1)$ have been justified. The structure of the charge provides an explanation of the AE for emission cuts with a

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[20] Before the announcement of the tax there were not many reasons to incur the fixed costs due to the restructuring of the salary scheme but after the announcement of the tax the firm knows that this organisational change will make sense after t_1. However, as the anticipation of this change is unlikely to considerably increase its costs, any economic benefit in $t \in [t_0, t_1)$ will be almost free to the firm.

positive cost. Unfortunately, as the tax refund is paid according to the firms' relative NO_X-efficiency, see section 2.1, the assumption e) of the model in Section 3.1 is violated in the sense that the benefits after the enforcement date depend on the firm's behaviour in $t \in [t_0,t_1)$. Indeed, the more emissions the firm cuts before t_1, the more NO_X-efficient it will be when the tax refund is paid and the more it will be rewarded. However, the logic of case 1B can be applied to this setting, as the refund foregone by the firm in $t \geq t_1$ if it does not abate in $t \in [t_0,t_1)$ can be considered an induced loss (IL). In case 1B the plausibility of the AE depends on the link between the factors responsible for IL and those responsible for the abatement measures. As in the case of the NO_X charge, the abatement measures influence the size of the IL - the more NO_X is abated, the smaller the IL are[21] - abatement measures which were profit-damaging in $t < t_0$ are less damaging or profit-enhancing after the announcement of the tax, as the tax refund has to be taken into account.

It is interesting to point out that the firm's benefits after t_1 depend also on other firms' behaviour. As the refund is paid on the relative performance, given a certain amount of abatement measures carried out by F, the firm will be the better off, the less other firms have cut their emissions. In other words, there is an incentive to cut emissions as soon as possible. As the average costs of abatement measures at the introduction of the tax were SEK 7.5 per kg of NO_X while the charge was SEK 40 per kg (SEPA, 1997), an early reduction of emissions gives the firms a substantial cash flow. In summary, because the structure of the tax makes the firms compete for the refund, an earlier response by the firm (AE) is economically rational and rewarding.

This point of view is confirmed by data on investments. The energy sector, which started to invest in NOX abatement measures at an earlier stage and at a higher annual cost than other sectors has always been a net receiver of the charge (SEPA, 2000 and Hoeglund, 2000). Clearly, the energy sector seized a competitive advantage on the pulp and paper and chemical sectors because of its early response to the scheme.

4. 2 The Swedish Tax on Sulphur Dioxide

The results from Hammar and Loefgren (2001) are useful in judging the likelihood of an AE in the case of the Swedish tax on SO_2. Using a structural decomposition analysis[22], the author quantify the SO_2 emission reductions (D_{tot}) due to the changes in the sulphur content in the fuels (D_{sul}), to changes in the structure of the economy (D_{str}), to the substitution between light and heavy fuel oil (D_{fsh}), to the decrease in energy intensity (D_{int}), to the substitution between oil and other energy sources (D_{sub}) and to changes in GDP (D_{prod}).

As can be seen from the first column in Table 4, in the year when the SO_2 tax was announced (1990) the sulphur emissions decreased 1.61 kilotons compared to the previous year. But if the AE is the only cause of the decrease in 1990, it is not really clear how the reductions in 1988 and 1989 (Δ88/87 and Δ89/88 in Table 4) can be explained. While not denying the rationale of an AE, the data in Table 4 raise some issues about the empirical difficulties in detecting this phenomenon.

The first is related to the choice of the date at which the AE could start to be measured. The day when the law is approved by the parliament could provide a good choice but alternatively, the public debate preceding the promulgation of the law can provide enough

[21] As the firm is interested only in the emission-energy ratio, see (section 2.1), the introduction of the charge could have caused an increase in the emissions: combustion measures increasing the emissions but decreasing the ratio are perfectly rational from the firm's point of view. The fact that this has not happened is due either to the physical link between emissions and energy or that these kinds of measures were profit damaging after considering the energy price.

[22] The structural decomposition analysis is a tool able to disentangle the effect of multiple causes occurring at the same time. Hammar and Loefgren (2001) provide a brief survey of the methodology.

information for the firm to start acting. Theoretically, the best date would be when there is a discontinuous change in the quantity and quality of information made available to the industry (e.g. when the details of the policy like the list of affected sectors, discounts and exemptions are made public). However this information threshold is very difficult to measure in practice. In addition, the information relevant to one sector of the industry could be completely irrelevant to another, and information relevant to different sectors could be released on different dates. It is possible that there could be several AEs happening simultaneously but starting at different dates: in the extreme case one for every different sector (or interest group) involved by the policy.

The other difficulty relates to the methodology and data available. Even if detecting a "weighted" AE in the way mentioned above is theoretically possible, limitations in the data or in the methodology used could make it empirically not feasible or certain to distinguish the AE from the many others influencing the SO_2 emissions, like other policy instruments, the price of gas, oil and electricity and the expectations on each of these factors.

Change in sulphur emissions	D_{tot}	D_{sul}	D_{str}	D_{fsh}	D_{int}	D_{sub}	D_{prod}	D_{res}
Δ77/76	-2.40	0.00	-0.08	0.04	-0.53	-0.02	-1.81	0.00
Δ78/77	-2.23	0.00	0.83	-0.20	-1.12	-1.60	-0.14	0.00
Δ79/78	-0.44	0.00	0.13	-0.16	-1.89	-0.79	2.28	0.00
Δ80/79	-2.60	0.00	-0.11	0.10	-1.42	-1.16	-0.02	0.00
Δ81/80	-4.71	0.00	-0.38	0.13	-1.52	-2.42	-0.53	0.01
Δ82/81	-4.92	0.00	0.01	-0.23	-1.88	-2.46	-0.38	0.02
Δ83/82	-3.66	0.00	-0.02	0.03	-0.90	-3.56	0.79	0.01
Δ84/83	-1.05	0.00	-0.15	-0.10	-0.72	-1.29	1.22	0.00
Δ85/84	-0.79	0.00	-0.26	-0.27	0.00	-0.72	0.46	0.00
Δ86/85	-1.20	0.00	-0.10	-0.17	-0.31	-0.73	0.12	0.00
Δ87/86	-1.22	0.00	0.0	-0.17	-0.32	-1.27	0.45	0.00
Δ88/87	-2.06	0.00	-0.04	-0.23	-0.09	-1.88	0.18	0.01
Δ89/88	-2.67	-1.25	-0.16	-0.07	-0.31	-1.28	0.39	0.02
Δ90/89	-1.61	0.00	-0.20	-0.04	-0.24	-1.20	0.07	0.01
Δ91/90	-3.14	-2.12	0.01	-0.15	0.02	-0.68	-0.30	0.09
Δ92/91	-0.89	-0.37	0.00	-0.01	-0.21	-0.24	-0.07	0.01
Δ93/92	0.65	-0.05	0.05	0.11	0.00	0.55	-0.01	0.00
Δ94/93	0.76	-0.01	-0.12	0.01	-0.21	0.61	0.46	0.00
Δ95/94	-1.01	-0.92	-0.31	-0.03	-0.02	-0.13	0.39	0.00
Total Δ95/76	-35.19	-4.70	-0.82	-1.41	-11.68	-20.26	3.55	0.18

Table 4. Decomposition results for 1976-1995 expressed in kilotons of sulphur. 1 kiloton = 1000 thousand tons. D_{res} indicates the residual. Source: Hammar and Loefgren (2001), p. 120.

Hammar and Loefgren (2001) did not detect an AE where it is said to have happened: reduced emissions due to lower sulphur content in the oil (D_{sul} in Table 4). Before the imposition of the tax there was a high potential for a supply-side reduction of sulphur that remained unexploited because the demand for low-content sulphur oils was weak. On the demand side buying oil with a lower sulphur content implies only operating costs but there are almost no benefits for users to do it. On the supply side, as some investments are needed to produce oil with a lower content of sulphur, the optimal investment path would ideally be completed at the enforcement date when the demand for environment-friendly oil would increase. However, as selling oil with lower sulphur content before the implementation date could have influenced the long-term structure of the market (case 3), it is unlikely that these benefits would outweigh the costs of an accelerated investment path. If this is the case, the AE is theoretically plausible. This point of view is corroborated by a big reduction of the sulphur emission coefficient in 1989. The absence of an AE in 1990 could be due to an anomaly of the data or simply confirm that 1990 is not the best choice as announcement date.

Nowadays, the tax is not considered very effective as the light heating oil is already below the threshold, while the heavy oil needs major investments in oil refineries to achieve lower sulphur content. As one oil company has already marketed light oil containing less than 0.05% sulphur, lowering the exemption threshold would help the diffusion of this lower sulphur light oil. In the market of heavy oil the effects of the threshold decrease depend on the investments needed to decrease the percentage of sulphur content and therefore are more difficult to predict.

4.3 The German Water Effluent Charge

In the case of the German water effluent charge, it is questionable as to whether there has been an AE. The statement from OECD (1994) mentioned at the end of section 2 can be easily criticised because, as shown in section 3, using investment data to judge the existence of the AE is unjustified. If a firm invests before the enforcement date, this does not automatically mean that it is anticipating the implementation of the policy[23], as the firm's action could be simply due to technological constraints or to the firm's investment costs function.

Andersen (1994) quotes a study carried out by the Financial Research Institute in Cologne to support the existence of the AE. "In 1978, 60 per cent of the surveyed communities planned to improve their sewage treatment to standards exceeding the national guidelines; 46 per cent of the industrial direct dischargers were considering additional initiatives. […] At the beginning of 1980, 66 per cent of the industrial direct dischargers were found to have implemented better treatment."
Unfortunately, this claim cannot be verified, as data on the water pollution control investments of the manufacturing sector are only available from 1980. From 1980 to 1995 the investments in water pollution control have not been very reactive to big changes in the nominal level of the tax and in the regulatory standards imposed on the industry[24]. If investments in the period 1976-1981 were prompted by the implementation of the charge, it would be the only time the total level of investments had been reactive to the tax level.

However, data on emissions in Table 2 shows that an AE occurred. This phenomenon can be explained by considering the role of investments, as introduced in section 3.3 The case 2A could apply to the period 1976-81 when constraints on the capital choice of the firm were unlikely to cause widespread capital substitution (in the sense of case 2B) because the regulation was based on the principle of the generally accepted technological standard and because equipment to control water emissions was not very common among German firms. In the case 2A the AE is due to the information benefits gained by firms exploring the set of abatement measures and to the boundary shift due to the change in relative prices. The latter is likely not to be very important in this context because of the low rate at which the tax was introduced. The information benefits are likely to have been more relevant because German firms had at that time scarce knowledge of abatement measures.

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[23] IISD (1994) quotes the increase between 1990 and 1992 in the number of combustion plant undertaking investments as an evidence of the AE in the NO_X charge. However, in this case the plausibility of being an AE has been shown discussing data on emissions.
[24] According to data presented by EU (2001), the investments for water pollution control in 1980-1995 have fluctuated around 1.5% of the total level of investments of the industry (p. 338).

It might be that the AE observed in Germany was not due to the German water effluent charge but rather to the maximum emission standards being approved in 1980 after a four-year long bargaining process. According to Andersen (1994), the most important instruments in German surface water policy have been the sector guidelines and the issued permits (command-and-control approach) while the charge has always been used as a supplementary tool.

Finally, as in the period 1976-88 municipalities received subsidies amounting to approximately 24 percent of total investments, it could be plausible that the increased level of investments after the tax announcement was due to the subsidies, which are apparently independent from the tax.

In the 1986 revision of the German water effluent charge, firms willing to qualify for the partial exemption (80%) from the tax had to invest in the most advanced technology currently on the market. As shown in the case 2B, when the firm's choice is constrained by the market regulator, the AE is particularly unlikely to occur because of the costs linked to premature capital substitution. The generous tax reduction granted to firms complying with the best available technology standard implies that safety benefits are very much important but, as mentioned in section 3, they justify an accelerated investment path not an AE. Case 2C may also be relevant in this setting as many firms already implemented abatement measures of emissions to water in the mid eighties. However, an AE for the 1986 revision has never been mentioned in literature.

5 Conclusions

The literature has identified an "Announcement Effect" (AE) in a number of cases of implementation of an environmental tax or charge. This paper has attempted to present an introductory microeconomic explanation of the possible occurrence of the AE in the context of a profit-maximising neoclassical economic agent. This analysis has shown that in each case several factors can make an AE plausible.

In the case of the Swedish NO_X charge, the AE seems mainly due to the change in the information set and to the structure of the tax, which made the firms compete for tax refunds based on the relative NO_X-efficiency of polluters.

In the case of Swedish SO_2 tax, the AE is likely to have been due to the interaction between the supply and demand of fuel oils with lower sulphur contents. Problems related to the choice of the announcement date and to the methodology used in the case studies have been briefly discussed.

Finally, in the case of the German water effluent charge, remarks on there having been an AE has been criticised on the basis that they are based on data on the investments for pollution control. However, setting up investments does not mean that firms will abate emissions before the implementation of the policy. Other data supporting the occurrence of the AE have been presented but it is not clear if the AE has been caused by the tax, emission standards or subsidies handed out by the government.

Because environmental taxes are usually introduced with a refund scheme attached, this study points out that the Swedish NO_X tax is an interesting example of how a refund scheme can be designed to increase the environmental and economic effect of an environmental tax.

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