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THE SWEDISH TAX ON NITROGEN OXIDE EMISSIONS

LESSONS IN ENVIRONMENTAL POLICY REFORM

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The Swedish Tax on Nitrogen Oxide Emissions

Lessons in Environmental Policy Reform



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The Swedish Tax on Nitrogen Oxide Emissions

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KEY FINDINGS

The problem

Sweden was facing a serious soil acidification and water eutrophication problem caused partly by emissions of nitrogen oxides (NO_x) from combustion processes in transport, industry and power.

The policy response

In 1992, Sweden introduced a high tax on NO_x emissions from large combustion sources (e.g. power plants, industrial plants, waste incinerators). The tax was accompanied by a refund according to the amount of energy generated. This ensures that facilities with low NO_x emission intensitites are net beneficiaries of the scheme. Continuous monitoring of emissions was also made mandatory. The tax was designed to accelerate and stimulate investment in advanced combustion and pollution-abatement technologies and as a supplement to existing regulatory measures.

The impact

A 35% reduction in NO_x emissions from facilities covered by the tax within 20 months after the implementation of the tax; industry was encouraged to develop cheaper, more efficient technologies; and emission intensities of energy production have been cut by half.

Key messages

A high emission tax rate can be made politically acceptable by: (1) refunding revenues earned back to the firms affected; and (2) ensuring the policy is well designed.

1. See http://en.wikipedia.org/wiki/NOx.

2. Only about 20% on average of nitrogen deposition occurring in Sweden stems from pollution sources within the country itself. Most comes from emissions from Central Europe and the United Kingdom. However, it was nevertheless felt necessary to limit domestic emissions while also working through international co-operation to control emissions in other countries (SEPA, 2003).



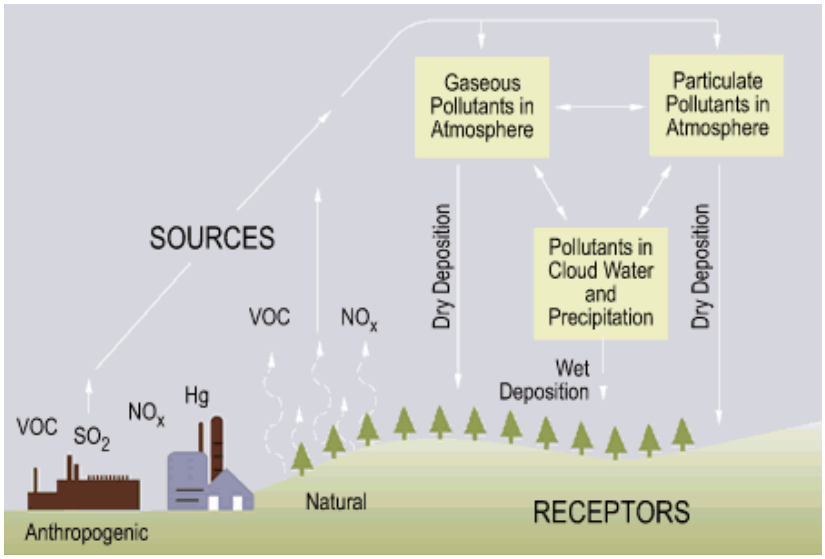
1 The environmental problem

Soil acidification has been a major political issue in Sweden since the 1980s. With its already naturally acidic soil, Sweden is more sensitive to acid deposition than most other countries. It is therefore one of the countries that has been most affected by acid rain, causing negative impacts to lake and forest ecosystems.

One of the families of gases contributing to acid rain is nitrogen oxides (NO_x): a term used to cover nitric oxide (NO) and nitrogen dioxide (NO_2). These gases are produced from a reaction between nitrogen and oxygen in the air during combustion, especially at high temperatures – such as in engines or power station boilers. NO_x emissions form nitric acid when dissolved in atmospheric moisture, and this is a component of acid rain (Figure 1).[1] In addition, nitrogen oxides contribute to the formation of ground-level ozone (smog), which has adverse effects on vegetation and human health (respiratory and cardiovascular problems).

Sweden has taken an aggressive – and largely successful – approach to tackling all the pollutants produced within its borders which contribute to acid rain (mainly sulphur and nitrogen).[2] This case study describes the approach taken to reduce NO_x emissions from combustion plants, the challenges encountered and the social, environmental and economic impacts. It concludes by discussing the wider lessons that are raised for other governments seeking to develop similar policy responses.

Figure 1 | **Origins of acid rain**



Source: Wikimedia commons, downloaded originally from US EPA website: www.epa.gov/acidrain/images/origins.gif



2 The policy challenge: Curbing NO_x emissions in Sweden

The strong political attention given to environmental problems caused by NO_x emissions prompted the Swedish Parliament to adopt a strategy in 1985 to reduce overall domestic NO_x emissions by 30% by 1995, compared to 1980 levels. The law on environmental protection established NO_x emission limits as of 1988 for stationary[3] combustion plants using permits that were non-tradable. However, it soon became clear that these limits would not reduce emissions quickly enough, and in addition the guidelines for how the permits ought to be formulated were not legally binding. The question was how to achieve these large reductions cost effectively and without damaging the competitive basis of the industries involved.

The Swedish Environmental Charges Commission was set up in the late 1980s, tasked with designing effective policies to tackle a range of environmental problems (Box 1). They consulted widely in order to design a politically feasible solution which addressed a number of challenges. The policy chosen for reducing NO_x from combustion plants was influenced by a number of factors:

- Unlike CO_2 and SO_2 emissions, which depend to a large extent on the carbon and sulphur content of the fuels combusted, most NO_x emissions are produced through reactions with nitrogen present in the air (Box 2). This means that while it is possible to tax the carbon and sulphur content of fuels to limit CO_2 and SO_2 emissions, other means are needed to tackle NO_x emissions, and emissions will vary significantly depending on the combustion technology employed and the maintenance of the combustion equipment (Box 2) (Sterner and Höglund-Isaksson, 2006).

- The costs of reducing NO_x emissions vary significantly across producers, and economies of scale and rapid development meant that the flexibility of a market-based instrument was needed.

3. Stationary or point sources of emissions are usually plants or facilities, while mobile sources of emissions generally refer to vehicles.

- To be an effective deterrent, a high tax rate was needed, but there was likely to be much opposition and lobbying against it by the affected industries; there was also a concern that it would put Swedish firms at a competitive disadvantage compared to foreign producers.

- Given the complexities of NO_x formation, it is crucial to have direct, continuous monitoring at the plant in order to assess emissions (Box 2). This can be expensive for smaller plants. A tax on all point sources of airborne NO_x emissions was not feasible because monitoring was too expensive for small units.[4] But if small units were exempted because of the high monitoring cost, then a high tax levied only on large units could have perverse effects, favouring the operation of small, and usually less efficient units over big ones (Sterner and Höglund-Isaksson, 2006).

Box 1 | Policy by design: the Swedish Environmental Charges Commission

The Environmental Charges Commission (ECC) was appointed in 1987 and its reports resulted in the introduction of a number of new economic instruments as part of Swedish environmental policy (SOU, 1989). The ECC included representatives from all parliamentary parties, the most relevant ministries, and civil society. The ECC's proposal for the tax on NO_x emissions was presented for broad public consultation, and a large number of public and private stakeholders expressed their views, mainly in support of the main lines of the proposal. The commission also proposed several other economic instruments, including CO_2 and SO_2 taxes.

4. It was estimated that continuous measuring of NO_x emissions would cost each plant about SEK 350 000 (about EUR 37 000) every year. These high costs made it necessary to limit the tax to relatively large plants. The very largest energy producers were, however, already obliged to have equipment for continuous emission measurements installed, so the NO_x tax did not imply any additional measurement costs.

The design solution: the Swedish NO_x emissions tax and refund system

The policy, voted in by the Swedish Parliament on 1 January 1992, was to impose a high tax on emissions of nitrogen oxides from energy generation at combustion plants. The tax[5] was set at a rate of 40 SEK[6] for every kilogramme of NO_x emitted from any stationary combustion plant producing at least 50 megawatt hours (MWh) of useful[7] energy per year. This corresponds to 6 000 USD/tonne, much higher than the hundreds of dollars usual in the US programmes for NO_x permits (Sterner and Höglund-Isaksson, 2006).

The most innovative feature of this tax, however, was that all the revenue raised (except administration costs)[8] would be returned to the participating plants in proportion to their production of useful energy. This means that firms emitting low volumes of NO_x per unit of energy produced are net beneficiaries of the scheme – only firms with large NO_x emissions per energy unit are net tax payers. This feature of the system encourages the targeted plants to reduce their emissions of nitrogen oxides per unit of energy to the lowest possible level and avoids distorting the pattern of competition between those plants subject to the NO_x tax and those that are not (SEPA, 2006). Another important feature of the tax was that it was based on mandatory continuous monitoring of emissions.

Initially, about 200 plants producing more than 50 GWh of usable energy per year were regulated by this tax. In the following three years, average emissions per unit of useful energy produced fell by 40% among these plants. Its effectiveness, coupled with falling monitoring costs, led to extensions of the system, first in 1996 to about 270 plants producing at least 40 MWh of useful energy per year; and then from 1997 onwards, to about 400 plants producing at least 25 MWh of useful energy per year.[9] Today, all stationary combustion plants producing more than 25 MWh – whether for power and heat production, chemical production, waste incineration, metal manufacturing, pulp and paper, food and wood industry – are subject to the NO_x tax.

5. This levy is often referred to as a "charge", but according to OECD definitions, it is actually a tax; i.e. an "unrequited payment to general government" (OECD Glossary of Tax Terms, available at www.oecd.org/ctp/glossaryoftaxterms.htm).

6. This tax rate was based on an estimate of the marginal costs of abatement measures that were expected to trigger an emission reduction of some 5 000-7 000 tonnes NO_x per year – the amount necessary to reduce NO_x emissions by 30% between 1980 and 1995.

7. "Useful energy produced" has been accepted as a relevant and neutral yardstick for measuring output from this heterogeneous group of industries since the main goal is to affect combustion technologies. For power plants and district heating plants it is equal to the energy sold. For other industries, the energy is defined as steam, hot water or electricity produced in the boiler and used in production processes or heating of factory buildings (Sterner and Höglund-Isaksson, 2006).

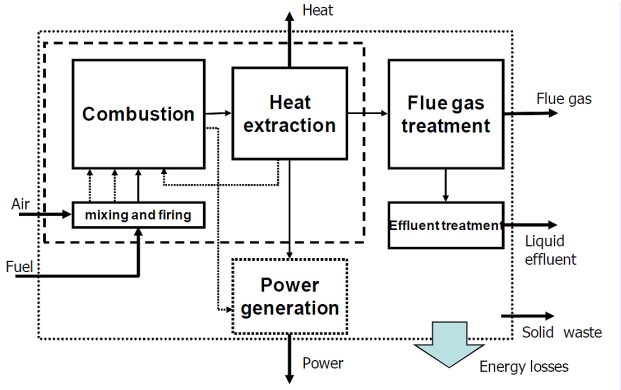
8. SEPA, the administrator of the scheme, stated that the administrative costs were about 0.7% of the total tax revenue (SEPA, 2003).

9. The *EU Directive on Large Combustion Plants* specifies emission limits for several air pollutants and a requirement to continuously monitor concentrations of SO_2, dust and NO_x in flue gases. All combustion plants with a thermal input of more than 100 MW have been subject to continuous emission monitoring since November 2002. For Sweden, the Directive has no real implications for NO_x emissions since most plants affected are already regulated by the NO_x tax.

Box 2 | **What causes NO_x emissions?**

Combustion uses fuel to produce heat. Heat extraction and conversion are the primary functions of combustion units. It is during these steps that the energy is converted into a useful form: piped steam, hot water, hot oil, and/or electricity. Heat requires fuel and an oxidising agent, generally air. Fuel and air are fed, mixed and fired to create a flame, which is propagated throughout the combustion chamber, whose shape, size and materials all can affect NO_x formation and overall efficiency. A conflict may appear between energy-efficiency and NO_x formation, as one way of increasing combustion efficiency is to raise temperature and pressure, which considerably increases the formation of NO_x. Fluidised bed combustors partly overcome this limitation and allow simultaneous efficiency gains and cleaner flue gases. The relationship between combustion parameters and NO_x formation is highly non-linear and complex. The exhaust gases leave the combustion chamber and may go to post-combustion processes intended to reduce air pollutants (e.g., NO_x, SO_2, CO and PM). These pollutants can be transformed, precipitated and washed in liquids or deposited as sludge, depending on their nature and concentrations.

Figure 2. **Scheme of the main steps in a combustion process**



Source: Sterner, T. and B. Turnheim (2008), "Innovation and Diffusion of Environmental Technology", *Discussion Paper* 2008:02, Resources for the Future, Washington, DC, available at www.rff.org/RFF/Documents/RFF-DP-08-02.pdf.

The cement and lime industry, coke production, and much of the mining industry, refineries, blast-furnaces, glass and isolation material industry, wood board production and processing of biofuels are exempt from the tax, due to concerns about unfeasibly high costs.

From 1 January 2008, the tax rate was increased to SEK 50 (EUR 5.5) per kg of NO_x, partly in order to maintain a strong abatement incentive. In 1992, the first year the tax applied, the total revenues were SEK 612 million (SEPA, 2003). In 2011 they amounted to SEK 794 million – about EUR 88 million.

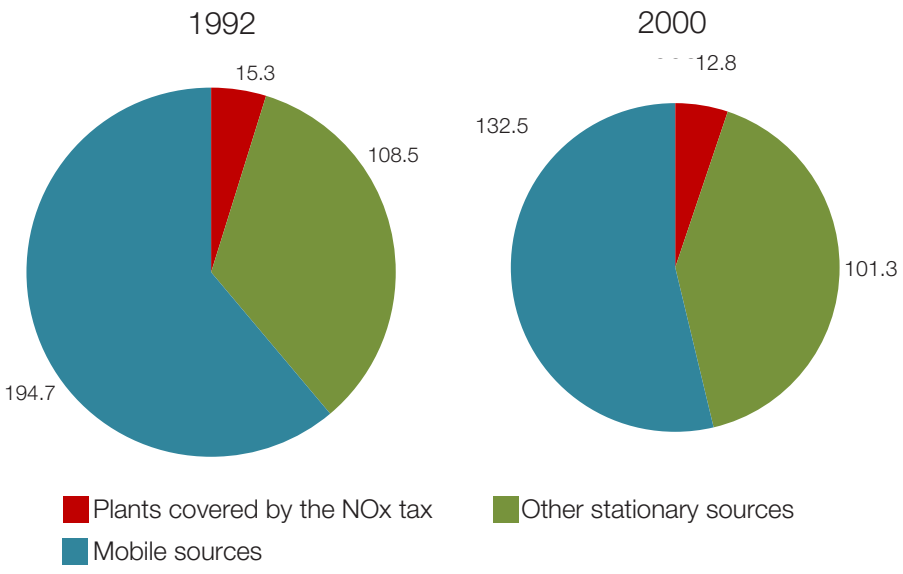


3 Environmental, social and economic impacts

Reducing emissions

In 1980, total emissions of NO_x in Sweden amounted to about 450 kilotonnes. By 2000 they had fallen to just over 240 kilotonnes (Figure 3). The NO_x tax is aimed at a relatively small proportion of Sweden's total NO_x emissions, given that in 2000, 54% of emissions were from the transport sector, which is not covered by the tax. But while emissions from transport were reduced by about 13% between 1980 and 1997, emissions from stationary sources were reduced by over 50% on average (Statistics Sweden, 1998, cited in UCD, 2008). Between 1992 and 2000, total NO_x emissions from all sources decreased by 23% (Figure 3).

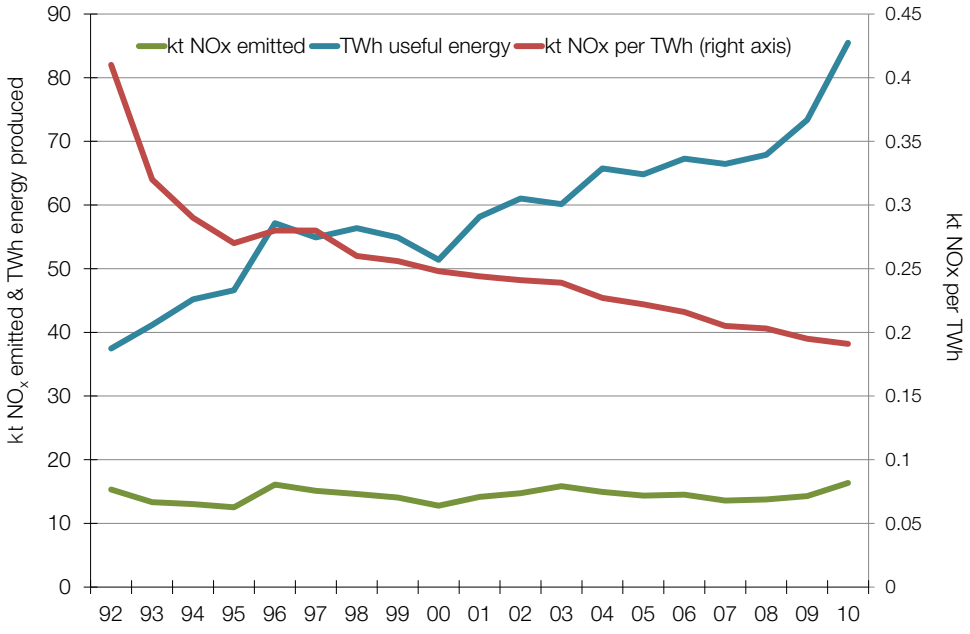
Figure 3 | **Emissions of nitrogen oxides in Sweden by sector, kilotonnes**



Source: SEPA (Swedish Environmental Protection Agency) (2003), *Kväveoxidavgiften – ett effektivt styrmedel. Utvärdering av NO_x-avgiften* (Reducing NO_x Emissions. An Evaluation of the NO_x Tax). In Swedish, with an English Summary. Rapport 5335, SEPA, Stockholm, available at www.naturvardsverket.se/Documents/publikationer/620-5335-3.pdf.

Many companies started NO_x-reducing projects as soon as the tax was proposed to parliament in 1990, in order to have as low emissions as possible when the tax came into force in January 1992. From 1992 to 2010, NO_x emissions per unit of energy produced fell by more than 50% (the red line in Figure 4). The figure also shows how the combined NO_x emissions from all the plants covered by the tax remained relatively stable over this period, even though the amount of energy produced by these plants more than doubled – partly because of the lowering of the threshold for tax inclusion mentioned above, meaning that more firms became covered by the tax.

Figure 4 | **More energy but lower NO_x emissions from taxed plants**

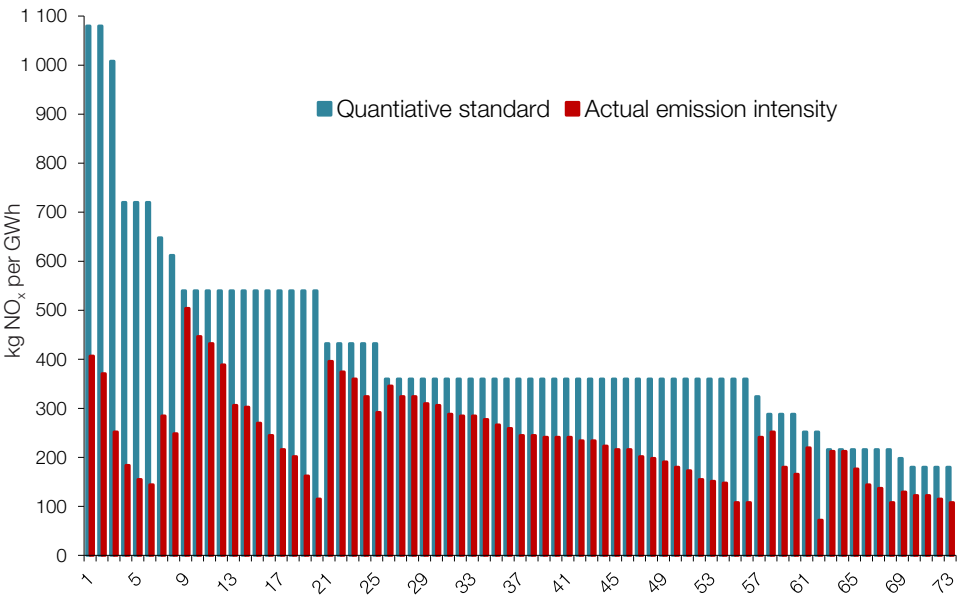


Note: TWh – tera watt hour; kt = kilotonne, i.e. 1 000 tonnes

Source: Swedish Environment Protection Agency.

The management and the operators at the plants have become more focused on reducing NO_x. At one plant the operators are given a salary bonus if NO_x emissions are low (IISD, undated). The tax seems to have been more effective in reducing emissions intensity than the overlapping regulatory emission standards. Figure 5 shows that by 2001, not only had all the plants complied with their emission limits,[10] but the NO_x tax appears to have provided strong incentives for most of the surveyed plants to lower emission intensities well below the limits of the quantitative standards.[11] This is based on information collected by SEPA (2003) on emission standards and actual emission intensities for 73 plants that were regulated by the NO_x tax both in 1997 and 2001. The actual emission intensity levels were on average 40% below the limits specified by the quantitative standards for these plants. Also, actual emission intensities for plants with very generous standards were comparable with emission intensities in plants with considerably stricter limits (OECD, 2010a).

Figure 5 | **Allowed and actual emission intensity for individual plants**



Note: The bars show individual plants regulated in 1997 and 2001, with emissions specified in mg NO_x per megajoule (MJ).

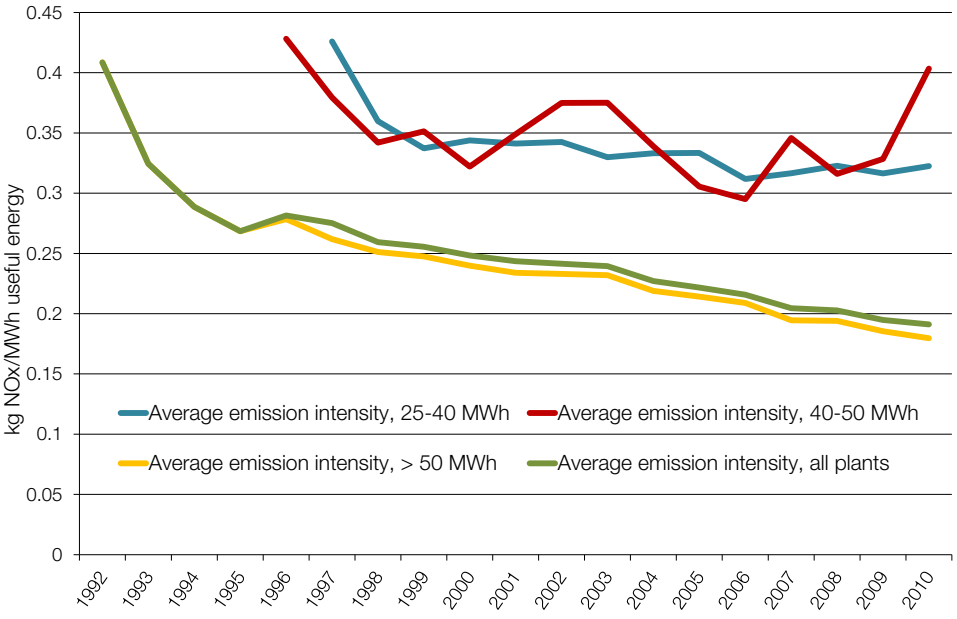
Source: SEPA (Swedish Environmental Protection Agency) (2003).

10. Forty per cent of all firms included in Figure 5 had a permit to emit 100 mg NO_x for every megajoule (MJ) of energy they produced.

11. The emission intensity is the average emission rate of a given pollutant from a given source relative to the intensity of a specific activity; for example milligrams of NO_x released per megajoule of energy produced.

Figure 6 indicates that the improvements in NO_x emissions per unit have been most important in the firms with an energy production larger than 50 GWh per year. For the firms with lower energy production, the emission intensity did decrease significantly the first year after taxation was introduced, but emissions since then have been more varied.

Figure 6 | **How NO_x emissions per energy unit vary for firms of different sizes**



Source: Swedish Environment Protection Agency.

What's driving emission reductions?

The reduction in emissions of NO_X cannot solely be ascribed to the effect of the NO_X tax system. A large number of boilers are also subject to specific regulations stipulated in the plants' operating permits under the Environmental Code (SEPA, 2006). They must also comply with parallel quantitative standards both for NO_X and other pollutants, and emissions may also have fallen through cost-effectiveness activities unrelated to NO_X reduction (Sterner and Höglund, 2005).

Lena Höglund-Isaksson and Thomas Sterner analysed 626 combustion plants that were regulated by the NO_X tax for at least one year between 1992 and 2007 (OECD, 2010a). In Figure 7, the plants have been plotted in order of increasing emission intensities against the cumulative energy output of the plants. This illustrates how emission intensities in later years are considerably lower than in 1992 when the tax was introduced. For example, in 1992, the plants were producing 3 000 Gigawatt hours (GWh) of energy while emitting around 550 kg NO_X per GWh. Sixteen years later, in 2007, the plants were able to produce the same amount of energy while emitting less than 181 kg NO_X per GWh – an improvement of 67%. There are three main explanations for this:

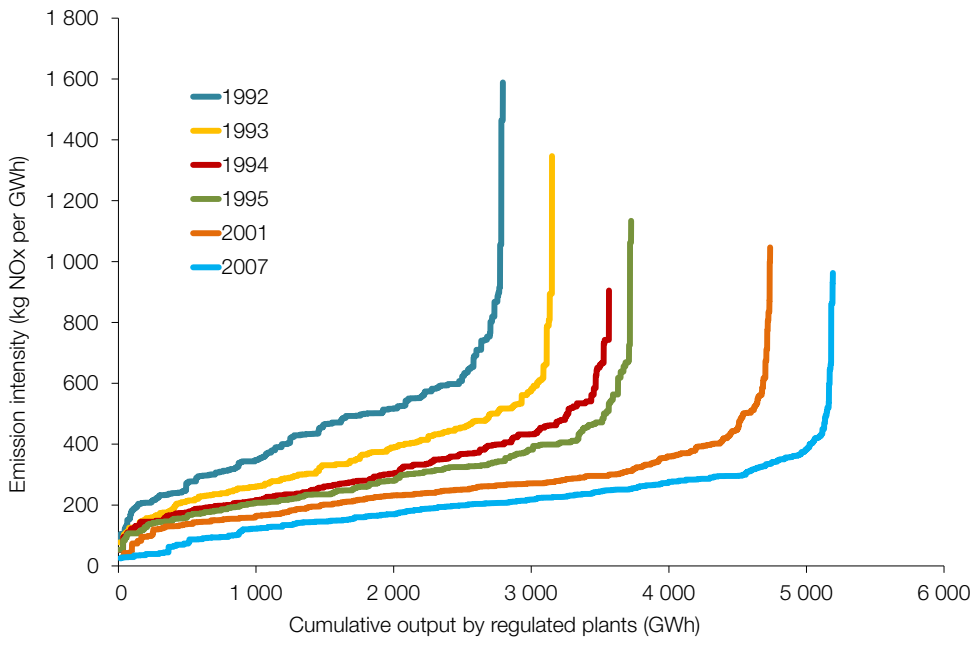
- Cumulative energy output produced by the plants increased by 74% over the period. The expansion in output mostly took place in plants that were relatively emission-efficient.
- Regulated plants invested in NO_x mitigation and were therefore able to produce more energy output with fewer emissions.
- Innovations in mitigation technology made it possible to reach even lower emission intensity levels for the same output level.

Some of these explanations are explored further below.

Stimulating innovation

The design of the Swedish NO_x tax has stimulated demand for new technologies. It has done so through: (1) the refund system, which promotes competition to achieve the lowest NO_x emissions per unit of energy produced; and (2) its requirement to install equipment to monitor NO_x emissions on a continuous basis. This has driven demand for several new technologies for pre-combustion, combustion, post-combustion and monitoring, as well as energy efficiency (OECD, 2010a).

Figure 7 | **How emission intensity has improved in plants covered by the NO_x tax**



Source: SEPA (Swedish Environmental Protection Agency) (2008), *Database of Information from Annual Surveys of Plants Regulated by the Swedish NO_x Charge*, SEPA, Östersund.

The impact of the tax on innovations for reducing NO_x emissions has been studied by the OECD (OECD, 2010a and 2010b). In 1992 – the year the tax was introduced – only 7% of the plants subject to the NO_x tax reported to the Swedish Environmental Protection Agency (SEPA) that they had NO_x abatement technologies installed. A year later, 62% of plants reported having some kind of NO_x abatement technology installed, and this share increased to 72% in 1995. An analysis of patents lodged for combustion and post-combustion technology shows that in Sweden there appears to have been continuous activity in this field since 1988, especially between 1988 and 1993. The intense activity during this particular period coincides with the introduction of quantitative standards for NO_x in 1988 and the NO_x charge in 1992.

> *With quantitative emission standards there is no cost saving to be made from reducing emissions further, once the standard has been met and, hence, there are no further incentives for innovations.*

In a survey of plants included in the first five years of the tax, Höglund-Isaksson (2005) found that the adoption of NO_x control technologies was a combined effect of the tax and the individual emission standards that the plants had been subject to since 1988. She found that out of 162 NO_x-reducing measures undertaken, 47% would not have been implemented without the introduction of the tax, 22% were undertaken primarily to meet the quantitative standards, and 31% primarily for other reasons, e.g. improved cost-effectiveness (unrelated to NO_x reductions) or compliance with emission standards for other pollutants than NO_x (predominantly SO_2). Thus, the NO_x tax appears to have been the most important, but not the only, factor for NO_x abatement adoption during this first phase of the NO_x tax and refund system.

However, while the NO_x tax clearly stimulated innovation, a regulated firm's willingness to share innovations with other regulated plants is hampered by the refund system, since a spread of the innovation to other regulated firms will reduce the innovating firm's own tax refund. On the other hand, for firms producing NO_x emission abatement equipment – who are not themselves directly affected by the NO_x tax – there are no such obstacles.

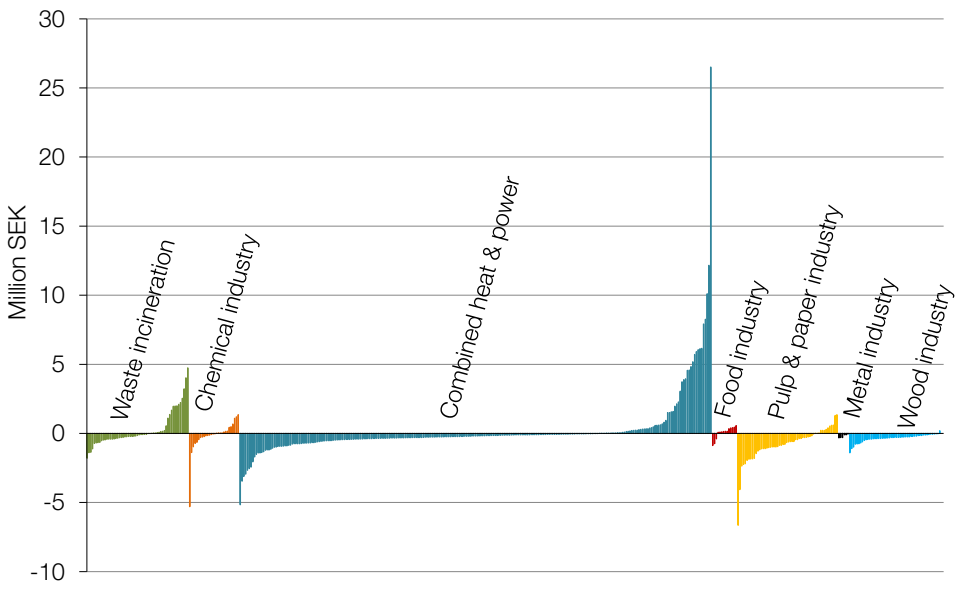
Economic impacts

> *"The introduction of the tax revealed abatement opportunities to pick the "low-hanging fruit".*

The net winners and losers among the firms in the different industrial sectors covered by the tax in 2010 are illustrated in Figure 8. Each vertical bar in the graph represents a separate firm. The bars showing positive values represent firms that receive more in refund than what they paid in taxes – the "winners" in the system. While there are "winners" and "losers" in all sectors, the "losers" are largely from the pulp-and paper[12] and wood industry – but the net tax payments per firm are relatively modest. There are a few large "winners" in the combined heat and power generation sector – with one plant receiving about SEK 27 million, or more than EUR 3 million in net refund.

12. Possibly for this reason, the pulp and paper sector at one stage suggested that the refund system should be changed, in such a way that each sector received a refund equal to the total tax payments from that sector (with a deduction for administrative costs). This proposal was, however, not adopted.

Figure 8 | **The Swedish NO_x tax: winners and losers by sector**



Source: Swedish Environment Protection Agency.

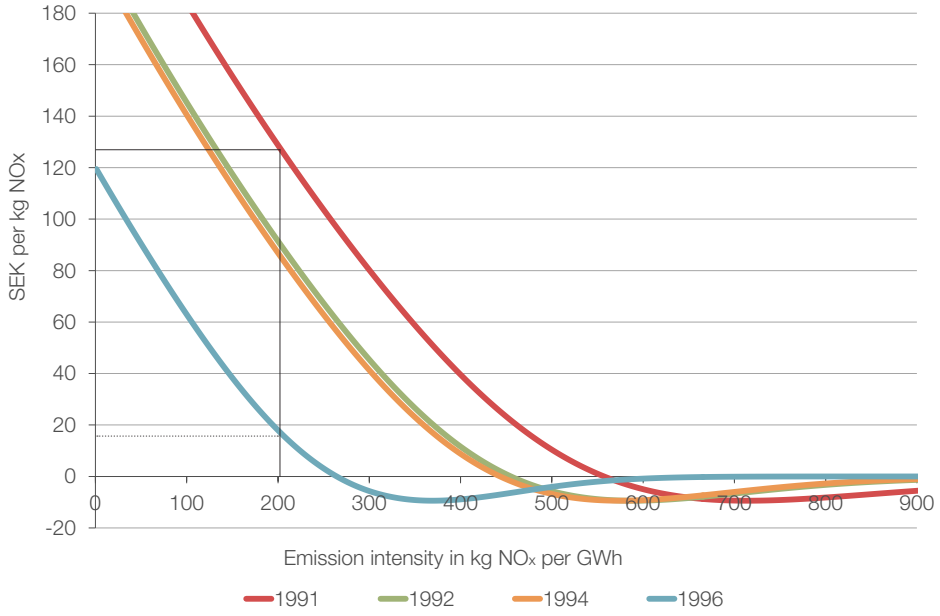
Costs of emission reduction for affected facilities

According to SEPA (2006), comparatively large NO_x emission reductions have been possible at zero or very low cost. In 1996, the average cost of measures to reduce emissions as a result of the NO_x tax was SEK 7.5 (about EUR 0.8) per kg of reduced NO_x. Reduced emissions at zero cost or even at a profit were reported for about 30% of boilers. One reason for this may be that the implementation of NO_x abatement measures has often been preceded by thorough scrutiny of the boilers and their functions, highlighting opportunities for efficiency-improving and cost-saving measures. The NO_x tax has also increased knowledge of abatement measures (SEPA, 2006).

Analysis of 114 plants regulated between 1992 and 1996 found that the emission intensity attainable at no extra cost decreased from 557 kg per GWh in 1991 to about 300 kg per GWh in 1996 (Figure 9; Höglund Isaksson, 2005). This shift likely comes from adoption of innovations in abatement technology, which made it possible to produce energy with less NO_x emissions but without increasing costs. To a large extent, the effects are referred to as trimming activities. Some of these opportunities also existed before the introduction of the tax; however, the tax's requirement to measure NO_x emissions continuously made it possible for the firms to discover and develop them to attain even lower emission intensity levels.

The figure also shows that for a firm with an emission intensity of 200 kg of NO_x per GWh in 1991, the cost of reducing emissions by one kg (i.e. the marginal abatement cost) was close to SEK 130 (about EUR 13.5). In 1996, this cost had fallen to less than SEK 20.

Figure 9 | **Falling NO_x abatement costs in the energy sector in Sweden**



Source: Höglund-Isaksson, L. (2005), "Abatement Costs in Response to the Swedish Charge on Nitrogen Oxide Emissions", *Journal of Environmental Economics and Management,* Vol. 50, pp. 102 120.

Economy-wide costs

Apart from the direct abatement cost for the plants, what are the wider costs of the tax? Based on a survey of 114 plants regulated by the NO_x tax between 1992 and 1996, Höglund (2000) estimated the average total cost to be between SEK 25 and 40 for every kilogramme of NO_x reduced. Splitting the total costs of the NO_x tax into detailed cost components (Table 1) revealed that abatement costs make up about 50% of total costs, or SEK 12 to 25 per kg of reduced NO_x emissions, depending on the assumed lifetime of fixed investments. Monitoring costs, including annual calibration of monitoring equipment, were estimated at 140 000 to 193 000 SEK per plant per year, or about 20% of total costs. Administration costs were found to be low. About 2% of total costs were spent on additional administration within plants and 1% on administration by SEPA, according to this study.

NO_x abatement often gives rise to increased emissions of other pollutants, like carbon oxide (CO), nitrous oxide (N_2O) and ammonia (NH_3), as by-products of the incomplete break-down of NO_x or residuals of additives used, depending on the abatement technology applied. Although estimating the damage costs of these pollutants to society is difficult, Höglund (2000) made an attempt using estimates by SEPA (1997). The cost to society of emission increases in these pollutants was found to represent about 23% of total costs to the Swedish economy. Finally, the refund mechanism gives rise to a welfare loss due to distortions in resource allocation (for further details, see Social Impacts section below), which was estimated at about SEK 1 per kg NO_x reduced, or 3% of total average costs. The cost components are summarised in Table 1.

Table 1 | **Relative contribution of different components to the total cost of the Swedish NO_x tax**

COST COMPONENT	
NO_x abatement	50%
Monitoring and compulsory calibration of monitoring equipment	20%
Plant administration	2%
Regulator administration	1%
Increased emissions of CO, VOC, N_2O and NH_3	23%
Distorted resource allocation due to refunding	3%
Total (25 to 40 SEK per kg NO_x reduced)	**100%**

Source: Höglund, L. (2000), *Essays on Environmental Regulation with Applications to Sweden*, Ph.D. thesis, Department of Economics, Gothenburg University, Sweden.

Competitiveness impacts

As mentioned above, the significant costs involved in continuous monitoring of NO_x emissions meant that authorities had to set an energy production threshold below which a firm was exempted from the tax. This was deemed to be important for the competitiveness of district heating compared to individual heating in homes and offices. This has been addressed by the refund system already described, but also by reducing the threshold value twice, from originally 50 MWh of useful energy per year to 25 MWh of useful energy per year – partly in response to the development of cheaper measurement technologies. The lower the threshold, the broader the coverage of the tax – and the smaller the competitiveness problems in relation to firms that are not covered.

Social impacts

Due to the refund mechanism, there was hardly any *net* cost increase for industry, and hence virtually no impacts on product prices. This in turn meant that there is no negative income distribution impact from the scheme.

However, this is also one of the disadvantages of a refunded tax: by having little impact on the relative prices of products whose production involved high emissions, it does not discourage demand for such products.[13] For the same reasons, it would be very difficult to achieve a fundamental decarbonisation of the economy if one only were to rely on taxes where for example electricity generators and other industries had their tax payments refunded in one way or another.

The main drawback with refunding is that it preserves an already distorted resource allocation. The refund resembles a subsidy from society to the producers. Polluters do not pay the full environmental cost of the pollution their production causes. This leads to a welfare loss to society since too much productive resources are allocated to polluting production relative to cleaner production. Hence, the polluter pays principle does not apply when emission charges are refunded to polluters (OECD, 2010a).

13. The tax and refund system applied in Sweden is very close in its impacts to an emission trading system with free allocation of permits, *based on current output levels*. For further discussion, see OECD (2008) and Sterner & Höglund-Isaksson (2006).

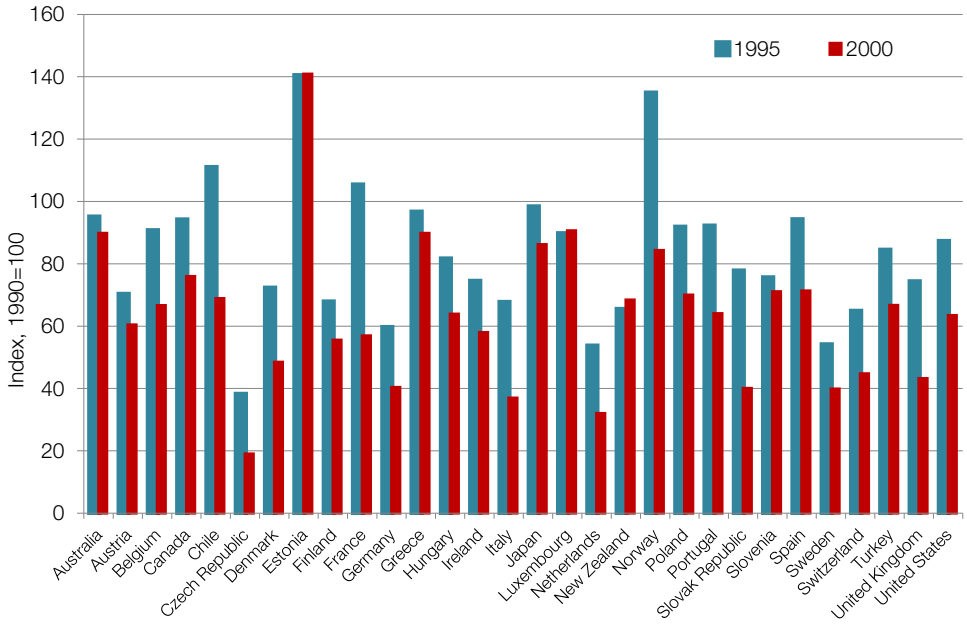


4 Comparison with other countries

How does the environmental effectiveness and economic efficiency of the Swedish NO_x tax compare with policy instruments applied in other countries?

Figure 10 shows how much NO_x was emitted per unit of electricity and heat produced by fuel combustion[14] in electricity generation and industry across OECD countries in 1995 and 2000 compared to 1990 levels. Sweden performs well in comparison to most OECD countries, especially when considering that the country's emissions per energy unit at the outset were already among the lowest.[15] Even starting from a strong position, the NO_x emissions per unit energy produced in 2000 were 40% of their 1990 levels.

Figure 10 | **OECD NO_x emissions per unit of electricity and heat generated**



Source: OECD Environment Compendium and IEA Energy Balances.

14. The comparison only includes electricity and heat produced by combusting fuels. Hence, electricity generated by hydro power or in nuclear power plants is excluded – as this would not generate any NO_x emissions.

15. A country like the Czech Republic started out with several times the NO_x emissions per energy units produced of Sweden, as their emission reductions across the 1990s were facilitated by the major economic restructuring the country went through in those years.

What is lacking in the comparison is information about the costs of the different policy measures. Unfortunately, the data necessary for a comprehensive comparison over the relevant years are not available, although there are some data for a few European countries (Box 3).

Box 3 | **What do other countries do?**

In 2007 and 2010, Norway and Denmark introduced taxes on NO_x emissions at rates of EUR 2.1 and EUR 0.7 per kg NO_x respectively. These had a broader sectoral coverage than in Sweden, but did not include a refund system. The Danish tax rate was increased to EUR 3.4 per kg NO_x in July 2012. The tax rate applied in Norway is based on an estimate of the value of the damage caused by one kg of NO_x emitted. However, strong industry opposition in Norway has led to exemptions for emission sources covered by environmental agreements with the state concerning the implementation of measures to reduce NO_x in accordance with a predetermined environmental target. Taxes on NO_x emissions have also been introduced in several other countries – such as France, Italy and Galicia in Spain – but in most cases, the tax rates are quite modest.

The French tax on NO_x emissions was introduced in 1990 as part of a combined package to reduce emissions of the air pollutants SO_2, NO_x and VOC from large combustion plants. Revenues from the charge were destined to subsidise investments in abatement technology in regulated plants and for research and development of abatement technology. Due to concerns about distortions in competitiveness, the tax rate was set very low – about 1% of the Swedish NO_x charge. There was also no requirement for continuous monitoring of emissions. Both factors are mentioned by Millock, Nauges and Sterner as important explanations for why the French NO_x tax did not have any measured effect on NO_x emissions (cited in OECD, 2010a).



5 Lessons learned

The Swedish case demonstrates clearly that well-designed economic instruments that provide significant economic abatement incentives can trigger important environmental improvements. It also demonstrates that such instruments can strongly encourage innovation – which helps to lower the costs over time of achieving ambitious environmental policy objectives. Lessons with wider applicability include:

- A high emissions tax rate can be made politically acceptable by refunding the money earned back to the sector: this strongly reduces the total cost to the affected polluters and hence the resources they will expend on lobbying to stop or lower the charge (Sterner and Höglund, 2006). The decision to exclude smaller plants was based partly on the high costs of metering which (together with abatement costs) were considered unreasonable for smaller plants. If a tax without refunds had been applied to only a subsection of some industry then this would have been unfair compared to other firms in the same industry. In this case, if the tax were applied only to the large plants, companies would have an incentive to set up several small combustion plants instead of one big one and this is typically not desirable (from any viewpoint including emissions of NO_x and other pollutants).

> *"With less resistance from polluters it becomes politically easier to set environmental taxes that are high enough to generate substantial environmental improvements.*

- Well-focussed environmental information to the public at large can play an important role. The introduction of the tax was also most likely helped by the good understanding by many Swedes of the environmental damage caused by NO_x emissions and of the potential benefits of using economic policy instruments in environmental policy.

- A policy designed with the involvement of all parliamentary parties – as was the case with Sweden's Environmental Charges Commission – is likely to contribute to broad support.

- Continuous (and correct) measurement of emissions is important for bringing attention to low-cost emission reductions that can be achieved simply by "trimming" production processes. In a number of countries, continuous measurement of a broad spectrum of pollutant emissions is now compulsory for many sources. This could form the basis for the more widespread use of economic instruments.

- Measures to abate NO_x emissions can increase emissions of other pollutants, such as CO, VOC, N_2O and NH_3. This phenomenon is not due to the use of a tax instrument as such, but could occur as a result of any measure taken in response to almost any type of policy instrument. While possible increases in other emissions in principle could be addressed via a number of policy instruments, a promising and consistent alternative would be to introduce a "price" on each of the linked pollutants, reflecting their relative damage to society.

This is one of the few OECD examples of a tax or charge that is refunded directly in this way, and offers an interesting alternative to permits, particularly when the regulator wants a price-type instrument but does not want to place the full cost burden on the polluters. For a small open economy in which trade-sensitivity is an issue, refunding makes political sense (Sterner and Höglund-Isaksson, 2006).

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