Implementation of Policy Instruments for Chlorinated Solvents

A Comparison of Design Standards, Bans, and Taxes to Phase Out Trichloroethylene

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September 2001 • Discussion Paper 01–32

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Abstract

This paper studies the Swedish prohibition of the hazardous solvent Trichloroethylene (TCE). Sweden is alone in completely prohibiting its use. The ban has been at best a partial success and illustrates the dilemmas of policymaking. Use has declined but not stopped, largely because the decision to ban TCE was challenged in the courts. Recently, the EU Court of Justice decided in favor of Sweden's right to have a ban. This article analyzes abatement cost data to show that the cost of replacing TCE is low for most plants, although there appear to be a few firms for which it may be quite high. A cross-country comparison indicates that the Swedish ban was less effective than the very strict technical requirements in Germany or the tax used in Norway. A tax (or deposit refund scheme) would be a good mechanism to achieve a swift phaseout.

Key Words: hazardous chemicals, regulation, environmental tax, solvents,

JEL Classification Numbers: D62, L50, Q28, K32

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Introduction[1]

Chlorinated (or halogenated) hydrocarbons are chemicals with very useful characteristics, particularly as solvents. Ever since a number of associated environmental problems and health hazards have been discovered, however, they have become increasingly controversial. Many of these compounds are suspected of being hazardous or toxic either directly or indirectly (after transformation). Among the examples cited are the formations of dioxins, which are extremely toxic and may be formed, for instance, when waste containing chlorinated hydrocarbons is burned. Another example is the effect of chlorofluorocarbons (CFCs) on the ozone layer. Yet other examples are such persistent and bioaccumulating chemicals as DDT and PCB.

This article evaluates the Swedish policy of banning trichloroethylene (TCE) and compares it with the policies used for both TCE and perchloroethylene (PER) in Sweden and some other European countries, particularly Norway and Germany.

Background

Metal cleaning and degreasing have constituted the dominant use of chlorinated solvents in Sweden and most other countries. Metal degreasing is a common process in the metal

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[1] The authors are grateful to Suzi Kerr for comments on an early draft and to the participants of two seminars in Gothenburg, one on policy instruments in 1997 and one specifically on trichloroethylene in Gothenburg, May 9, 2000. Particular thanks to G. Bengtsson of the Swedish Chemicals Inspectorate; Gunnar Ahlborg, Environmental Medicine, University of Gothenburg; Stefan Rubenson, the Swedish Ministry of Environment; Kenny Kvarnström, Mechanical Industries Association; Henrik H. Eriksen, Ministry of Environment, Norway; Herr Josef Lerrach, Bundesministerium des Umwelt, Germany; and Ulf Andersson, Chief Environmental Officer, SKF; all participated in the May 9, 2000, seminar on trichloroethylene at the University of Gothenburg, Sweden. Thanks also to an anonymous referee for valuable suggestions and comments.

industry. As soon as a metal object is cut or processed, the fresh surface is in danger of becoming corroded. To prevent this and permit storage, the object is covered in oil or grease. When the piece is to be soldered or processed in some other way, the grease has to be removed. Similarly, for lacquering, assembling, and delivery goods must be clean and dry. Surface fats, oils, wax, or soil must be removed. Chlorinated solvents have been popular in metal degreasing because they can be applied on different kinds of materials and effectively remove fats and oils. The high volatility of chlorinated solvents assures that the goods dry fast after degreasing. In the workplace these solvents are superior to certain other volatile solvents, like benzene, which are not only toxic but highly flammable and explosive as well.

Table 1 lists the main uses and some important environmental and health effects of the most commonly used solvents.

Table 1. Chlorinated Solvents

Solvent	*Main use*	*Environmental and health effects*
111-trichloroethane ($C_2H_3Cl_3$)	Metal cleaning and degreasing	Ozone depleting
CFC-113 ($C_2CL_3F_3$)	Degreasing in electronics industry, dry-cleaning	Ozone depleting
Carbon tetrachloride (CCl_4)	Laboratory	Ozone depleting, carcinogenic
Trichloroethylene (C_2HCl_3) (TCE)	Metal degreasing	Toxic, likely carcinogenic
Perchloroethylene (C_2Cl_4) (PER)	Dry-cleaning	Toxic, likely carcinogenic
Methylene chloride (CH_3Cl)	Laboratory	Toxic, likely carcinogenic

Health and environmental issues related to these chemicals are complex, and priorities change with knowledge. Before damage to the ozone layer was discovered, a number of ozone-depleting substances (ODS), such as the CFCs, were introduced as substitutes for other chlorinated solvents because they were less hazardous to human health. TCE, in fact, was once used as an anaesthetic. It should be noted, however, that all these solvents are hazardous to human health because they tend to pass easily through skin and membranes and they dissolve fats, such as those surrounding nerves and other vital organs. Some of these chemicals may be extremely hazardous depending on how they are used. In the early days of degreasing, several workers died when welding metals that were still contaminated by TCE, which may form phosgene ($COCl_2$, a lethal chemical gas used in some chemical weapons) upon combustion. Following the debate on the ozone layer, ODS solvents were phased out and some users tried alternatives to chlorinated solvents in metal degreasing, such as water-alkaline processes and

low-aromatic mineral oils. There was a lot of experimentation with, for instance, lemon peels, which are clearly "natural" but contain very strong and quite toxic aromatic compounds. Other users, however, reverted to TCE, PER, and methylene chloride. It was the risk of this type of substitution that was one of the driving forces behind the Swedish ban on TCE. Decisionmakers wanted to avoid creating new workplace health hazards as a by-product of addressing environmental problems, such as the ozone layer.

A number of international treaties bear on chlorinated solvents. The Montreal protocol of 1987 led to the phaseout of the worst ozone-depleting substances(ODS) (a number of so-called HCFCs, which have some but less ozone-depletion effect, are still permitted). Following the Montreal protocol, the Swedish parliament adopted a plan to abolish the use of ODS in Sweden. The main policy instruments used were import restrictions and total bans on ODS use. The ozone-depleting chlorinated solvents were regulated as follows.

Substance	*Prohibition*
CFC-113	January 1991
111-trichloroethane	January 1995
Carbon tetrachloride	Professional use, January 1993; all uses, January 1996

Between 1988 and 1994 the use of ODS decreased by 93% (Östman et al. 1995). The Swedish strategy to regulate ODS was thus quite successful, but because of fear that it would lead to greater use of other hazardous solvents, TCE was prohibited.

Perchloroethylene, which is chemically close to TCE, is used mainly in dry-cleaning but also, to some extent, in the printing and metals industries. The only regulation of PER in Sweden[2] is a maximum exposure limit in the working environment of 10 parts per million (ppm). Although there is no ban on the professional use of PER, its use decreased from 1,600 tons in 1988 to 250 tons in 1995. The decrease is due mainly to a modernization of the machinery used in dry-cleaning, from open to closed systems (Naturvårdsverket 1997).

Despite that decrease and the stringent ambient standard, a number of old PER machines are still around. Some of these are open systems and, in a recent report by the Swedish environmental protection agency (Naturvårdsverket 4725), many were described as poorly maintained and having insufficient reporting routines, high emissions, and other problems. Only

[2] In Germany, by comparison, regulators treat PER at least as stringently as TCE.

20% of the open machines and 55% of the closed ones have carbon filters. According to the report, considerable reductions could be achieved by forbidding open systems and requiring other technical improvements at a cost of 23 to 47 SEK/kg[3]. It was earlier believed there were no technical alternatives, but it is now clear that alternatives are becoming more common. Because many dry-cleaners are small enterprises located in the midst of apartment blocks and other housing and commercial areas, the risk of unintended exposure is relatively high. It might be considered a paradox that TCE should be forbidden but not PER.

Selection and Design of Policy Instruments

Some people think environmental policymaking is either "command and control" or economic policy instruments—that is, taxes—but the spectrum of choices is much more subtle. Market-based instruments range from taxes, charges, and deposit refunds to tradable permit schemes for fishery management and pollution control. Information provision, ecolabeling, liability, refunded emissions payments, subsidies, voluntary agreements, and many other schemes show that there is, in fact, a menu of policies.

The choice of policy instruments depends on both the ecological and economic conditions and the selection criteria (see Sterner 2001). With several goals, such as efficiency, incentive compatibility, fairness in the distribution of costs, and political feasibility, one would expect to find different combinations of policy instruments for different tasks.

The criteria also turn out to be of varying importance, depending on the conditions that characterize the issue. For environmental problems with moderate abatement costs in an economy with an even distribution of income, equity issues may be less important and efficiency paramount. Conversely, for issues that affect health and ultimately life in countries with large income disparities, distributional concerns and fairness may be more important than efficiency. In markets characterized by powerful monopolies or marked information asymmetries, the issues of incentive compatibility may well dominate. In other cases, it may be the complexity of the ecosystem that determines the design of the instrument. If there is a risk of serious and irreversible damages, then precaution may dictate the use of some very direct instruments, like prohibitions. But if the prohibitions are not effective and lead to lobbying rather than research

[3] 10 SEK ≈ 1 USD.

into new technologies, then market-based instruments that encourage such research may be more efficient.

A question that particularly interests us is whether bans are good policy instruments in the case of TCE. Traditional environmental economic analysis (Weitzman 1974) suggests that if the marginal cost of abatement is very steep or close to the zero limit (and the environmental damage curve is not so steep), then taxes (or some other price instrument) would appear better. If technical progress is expected to be fast but unevenly distributed among specific application areas, this preference for taxes would be strengthened by considerations of dynamic efficiency.

Under asymmetric information the choice of instrument is more complex. When an environmental protection agency imposes regulation, a company has an obvious incentive to overestimate abatement costs to get a "generous" emissions concession. When taxes are the instrument, the company does not have an incentive to overestimate abatement costs, since that would imply that the equilibrium tax necessary is high, too. One might think the firm has an incentive to underestimate, but this incentive is likely to be weak because it amounts to acknowledging that abatement is easy. Hence the tax instrument is likely to lead to fairly truthful reporting. This is an example of the "revelation principle" used to deal with policymaking under asymmetric information. Furthermore, the tax promotes rapid technological change: if a company has a 10-year concession, it has little incentive to develop or even adopt new technology, but if taxes are used, the incentive is to adopt new technology as soon as possible.

It is also important to focus on competition as well as on the politics and economics of firms' behavior with respect to environmental policy. There are, as pointed out by Albrecht (1998), contradictory hypotheses. The "industrial flight and pollution haven" hypothesis states that strict regulation will lead to industrial relocation. This is, in principle, what most economists would expect based on comparative advantage, although the effect is likely to be very small and the empirical evidence is not clear. We also have the Porter hypothesis, formulated by Harvard management guru Michael Porter, who suggests that environmental regulation will increase productivity through the secondary effects of innovation.

The logic of the Porter hypothesis has been criticized by economists who argue that if the productivity opportunities are real, they will be exploited irrespective of legislation (Oates et al. 1994). As the critics recognize, however, it is possible to construct models with some other market or regulatory imperfection that could lead to the existence of a Porter effect; see, for instance, Bonato and Schmutzler (2000). The model by Xepapadeas and de Zeeuw (1999)

confirms the logical impossibility of the pure Porter effect but points to a number of mechanisms implying that the cost of compliance with regulation may be very low.

The issue of compliance has also received considerable attention; it is sometimes thought to be a paradox that firms comply even if monitoring and enforcement are far from perfect. Various explanations have been offered for this so-called Harrington paradox, including the notion that compliance confers benefits, such as market advantages related to image (Arora and Gangopadhyay 1995; Harrington 1988; Arora and Cason 1996). Heyes has written extensively on monitoring and regulation, and Heyes and Liston-Heyes (1999) conclude that many business executives agree with Porter and then through lobbying build a model for regulation to show that the regulating agency should take account of Porter's views even if it considers them wrong and misguided.

The Ban on Trichloroethylene

In 1991 the Swedish Parliament passed a law prohibiting the professional use of TCE and methylene chloride, effective January 1, 1996. The use of TCE in consumer products was banned in 1993. A complete prohibition on all use might seem to be a very strong policy instrument, but it has not been wholly effective. The reason appears to be that the very strength of the instrument is in some sense its weakness: the ban is so absolute that it creates strong opposition among some users, who either find it particularly difficult to replace TCE or simply disapprove of the timing or policy method. The Swedish experience has shown that some firms spend a great deal of effort and resources in appealing and lobbying against the ban and gather support from industry associations and others. To some extent they hoped to get support from European Union (EU) institutions on the grounds that the ban might hinder the free mobility of goods.

The impetus for the ban was TEC's detrimental health and environmental effects, mentioned earlier. These consequences have been challenged, however, and, in fact, the environmental damage of TCE does not appear to be as serious as that from CFCs or even HCFCs. If the health effects are no worse than for certain other solvents, perhaps restrictions on maximum exposure in the working environment would have been enough. Sweden does have a stringent exposure limit of 10 ppm, compared with 100 ppm in the United States (eight-hour time-weighted average). Only Germany has a stricter standard: a limit of 20 ppm, which, combined with additional technical and workplace requirements, including completely closed systems for operation and even storage and transport, reduces ambient levels to 1 ppm or less

(Lerrach 2000), with the result that a number of degreasing units currently operating in Sweden would not be able to operate in Germany.

Those comparisons are particularly relevant because TCE was brought in as a replacement when other solvents, such as highly aromatic hydrocarbons and CFCs, were phased out for health or environmental reasons. This was, for instance, the case at the SKF factory in Gothenburg, which, in the early 1980s, used around 3,000 to 4,000 tons of TCE per year (almost half Sweden's consumption at the time). The firm introduced TCE as a replacement for both CFCs and highly aromatic nafta products.

Reducing Use of TCE—The First Phase

Figure 1 shows the use of TCE in Sweden to 1996, when it was first to have been phased out. Quite clearly, the ban did not cause the phaseout of TCE; perhaps it might be considered the logical last step in a phase out, or the only instrument capable of stopping the residual applications after other policies had reduced its use. By the time the decision to ban TCE was made, consumption had already fallen from about 9,000 tons per year to 3,000 tons. The decision to ban was followed by a period of fairly stable use: It seems that industries did little or nothing between 1991 and 1995 to prepare for the ban and, in fact, many executives have said in interviews that they did not think the authorities were serious about this ban, especially since TCE had a long history and no other countries were banning it. At the same time, Sweden was preparing for entry into the EU, where it was not banned, and TCE became a fairly important item in the negotiations.

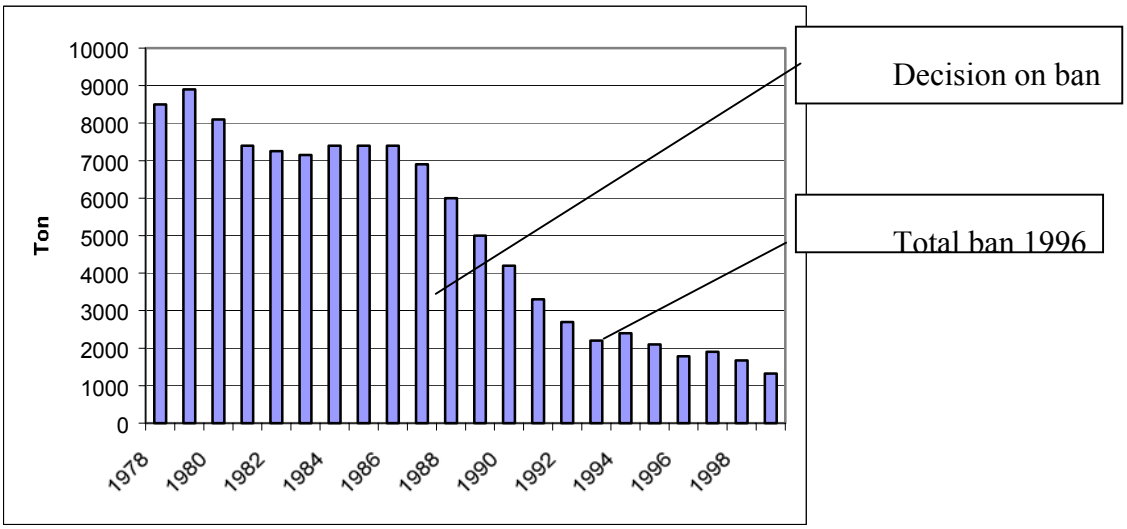

Figure 1. Use of TCE in Sweden 1978—1999.

Source: Naturvårdsverket (the Swedish environmental protection agency).

During the second half of the 1980s, large industries faced emissions standards and tighter exposure limits that forced them to reduce their use of TCE or phase it out completely. The standards and regulations led either to the use of other technologies and other solvents or, more commonly, to the adoption of closed systems with carbon filters, which allowed a drastic reduction. As an example, we may look at the case of SKF, which accounted for a large share of consumption. SKF used TCE for three purposes:

- ordinary degreasing;
- as a solvent for fats used as antioxidants; and
- dewatering of sensitive components.

SKF is an interesting case not only because of its size but also because the demands are unusually exacting. Ball bearing components must be dried within 30 seconds, after which corrosion becomes unacceptable. Moreover, the size and shape of the product makes substitution more difficult than in many other types of manufacturing, where, for instance, large sheets of metal need degreasing before they are welded. Thus, although one could argue that SKF has more resources and thus can more easily accommodate to environmental restrictions, at least technically one might argue the opposite: if SKF can eliminate TCE, then many other industries should find it fairly easy.[4]

Reduction in use of TCE at SKF was driven by two factors: the trade union demands on working environment and the environmental requirements for reduced emissions. When use was at its peak, SKF was emitting 250 tons per year into the air. In its 1983 permit SKF was ordered to reduce annual emissions to a maximum of 15 tons. Installing active carbon filters led to a two-thirds reduction, to about 80 tons per year, but further reductions required changes in processes. New degreasing processes that used water and (low-aromatic) oils and new packaging and storage routines were combined with the use of lighter oils for conservation of ball bearings instead of wax, whose removal required TCE as a solvent.

Finally, only very small amounts of TCE were being used, and the costs of maintaining the handling, storage, and filter facilities became disproportionate. Furthermore, SKF discovered it could gain in good will and environmental image by exceeding the requirements instead of

[4] For cases where TCE elimination may be particularly difficult, see below.

reacting passively to them. The company therefore decided to phase out all use of TCE. This decision applied to all SKF plants abroad, even if local authorities did not require it, for two reasons: environmental image, and uniformity of standards and processes to ensure homogeneous product quality.

The Ban and the Ensuing Legal Battles

SKF is one case; in some other companies the ban on TCE led to bitter opposition and protests. Many petitions and articles were written and a number of companies decided to fight the legislation[5], threatened to close down or leave the country, and have appealed to the courts. Leading points of contention are that the industries disapprove of the prohibition as a method, its timing, and a number of its consequences, which we discuss below. Here we briefly recapitulate some of the more salient points. In 1994, 39 industries published an open letter to Prime Minister Ingvar Carlsson as an advertisement in a leading Swedish newspaper (Dagens Industri 1994), saying that the prohibition was poorly motivated and prepared and should be withdrawn. They contended that their viability was threatened and that more than half of them would have to move abroad if the prohibition was enforced.

The letter was strongly worded—even excessive, as several executives admitted later in interviews—but its tone was indicative of industry's strong resentment of the regulation. Although some companies did phase out TCE rather than move abroad, others applied for waivers. Originally the ban was to take effect on January 1, 1996. Because a number of companies had difficulties and there was considerable resistance, the Chemicals Inspectorate issued a general exemption for any companies that could report difficulties. In the first year (1996) some 500 companies were given waivers, effectively postponing the ban until January 1, 1997. After that date only companies that could show that they had made a serious effort to substitute for TCE and had a plan for doing so would be granted (a temporary) exemption. These companies would also pay an exemption fee of 150 SEK/kg—a fee intended not so much as an environmental tax as a way to remove any disadvantage that a complying company might suffer vis-à-vis competitors that had not yet invested in TCE substitution.

[5] Although this is very common in the United States, it is extremely rare for Swedish legislation to be challenged in this way.

Of the 283 companies that applied for exemptions for 1997, 137 were granted waivers, and 60 of the companies whose applications were rejected appealed the decision. The Stockholm County Administrative Court revoked the decisions made by the Chemicals Inspectorate, and there have been several further rounds of appeal to higher courts. When Sweden joined the EU in 1994, Holland, the U.K., and the EU Commission were very critical of the ban, largely because Sweden does not produce TCE and had imported the chemical, and thus the ban would be a barrier to trade. However, Sweden fiercely defended the ban by citing politicians' pledge during the EU campaign that membership would not compromise the country's environmental goals. The ban thus became a symbol and as such the subject of a fight with considerable prestige.

Meanwhile, Sweden's Chemicals Inspectorate modified its rules for exemption, dropping the requirement that the firm present a plan for the phaseout of TCE and modifying the fee structure. The new requirements were as follows:

- the company is actively researching other alternatives;
- no suitable alternative is readily accessible for the company's needs; and
- no harmful exposure results from the use of TCE.

The exemption fee was later withdrawn entirely, since the EU Commission considered it "out of proportion" to the environmental damage. Of the 220 companies that applied for waivers to continue using TCE after 1997, all were granted, along with 121 waivers in 1998 and roughly 150 in 1999. The case of one company, Toolex Alpha, was referred to the European Court of Justice (by a Swedish court) to determine whether the Swedish prohibition was in accordance with the free movement of goods (case C-473/98).

A number of interesting general principles of European law underlie the legal struggle. First, the prohibition must be in the public interest and not a hidden trade restriction. Second, it must be necessary and nondiscriminatory. Third, the law should be proportional—that is, not unreasonably harsh in comparison with its goal. On July 11, 2000, the European Court of Justice ruled that the Swedish prohibition did not run counter to EU legislation on the free movement of goods, reasoning that

- the basis for the prohibition was concern for health and the environment;
- the EU has classified TCE as toxic and carcinogenic;

- Member countries have the right to stricter environmental legislation[6]
- there is no basis to assume the prohibition was motivated by an attempt to stop trade; and
- there are reasonable possibilities of getting a waiver.

The last point was important: It appears that an absolute phaseout with no exceptions would have been considered disproportionate. Hence, one might with some exaggeration say that the prohibition was accepted because it was watered down by the greater likelihood of obtaining a waiver. Considering the sensitive issue of national sovereignty in environmental decisionmaking and the relatively skeptical attitude of the Swedish electorate vis-à-vis the EU, it seems wise that Sweden has been allowed to keep its independent (and at least in some sense more radical) national policy on this issue. There remains, however, the broader question of whether prohibition as such is a good policy instrument in this case. Recall that Sweden is alone in prohibiting TCE, and that TCE and methylene chloride are the only chlorinated solvents for which Sweden has chosen this rather drastic measure.

Marginal Costs of Abatement or TCE Substitution

To study the marginal cost of abatement, we looked at the applications for exemption from the 1996 ban, which were required to contain information on the economic consequences of a substitution—that is, the marginal cost of substitution. Although these figures may reasonably be assumed to be biased estimates, since their very purpose is to provide the basis for an exemption, we also have data from other sources: detailed interviews with a number of companies on their use of TCE and the actual costs of substitution, and other studies, including one by the Swedish Chemicals Inspectorate that includes figures on the cost of substituting for TCE. The data cover the whole range of companies, from SKF to some very small workshops, and represent different sectors of industry; they also include companies that both have and have not made the required investments (see Slunge 1997).

[6] The fact that regulations and laws governing the use of TCE were, in fact, not harmonized within the union was an important factor in favor of allowing Sweden's regulations. In areas of law where there is explicit harmonization—for example, pesticides or vehicles, (the mercury content of which Sweden wants to phase out)—it would be much more difficult for one nation to have separate legislation.

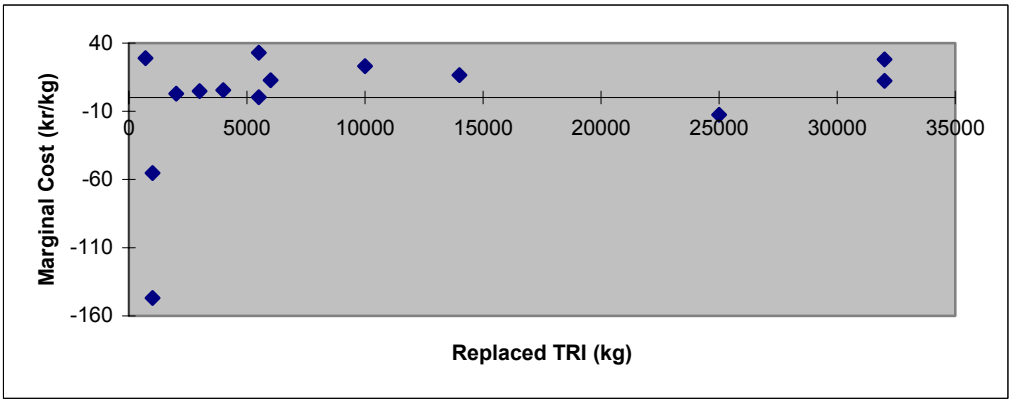

Figure 2 MC of abatement for companies that had replaced TCE
Source Slunge (1997)

We have standardized assumptions concerning the real rate of interest (4%) and the useful life of capital equipment (15 years) as well as made reasonable assumptions in each case about investment costs and (what turned out to be more difficult) operating costs. We found that the cost estimates were not only higher but also much more uncertain (i.e., the estimates had a higher variance) for companies that had not carried out the investments. This reflects true uncertainty and, presumably, is also an element of tactical reporting.

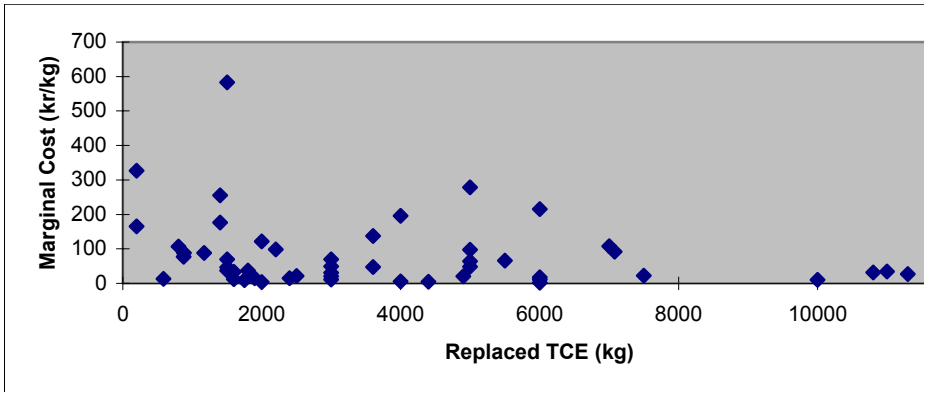

Figure 3. Estimated Marginal Cost of Abatement for Companies That Had Not Yet Replaced TCE. Source: Slunge (1997).

Figures 2 and 3 present the marginal costs for a number of companies and illustrate the effects of either uncertainty or tactical estimates by companies that do not want to comply with the ban. The companies that had phased out TCE incurred an average and median cost of 6 SEK/kg TCE. Those that had not phased out TCE calculated much higher costs, a median of 48

but an average of 84 SEK/kg TCE, due to some very high (maybe protest) estimates. To cast some light on which of these factors is most important, we looked in greater detail at those companies for which we have the best data and examined the marginal costs of abatement for different steps in phasing out TCE. As in the case of SKF, the first reductions in quantity were sometimes very easy, since they mainly required closing systems and installing carbon filters, which (at least in large-scale use) were inexpensive. However, the next step in abatement actions turned out to be much more difficult and expensive.

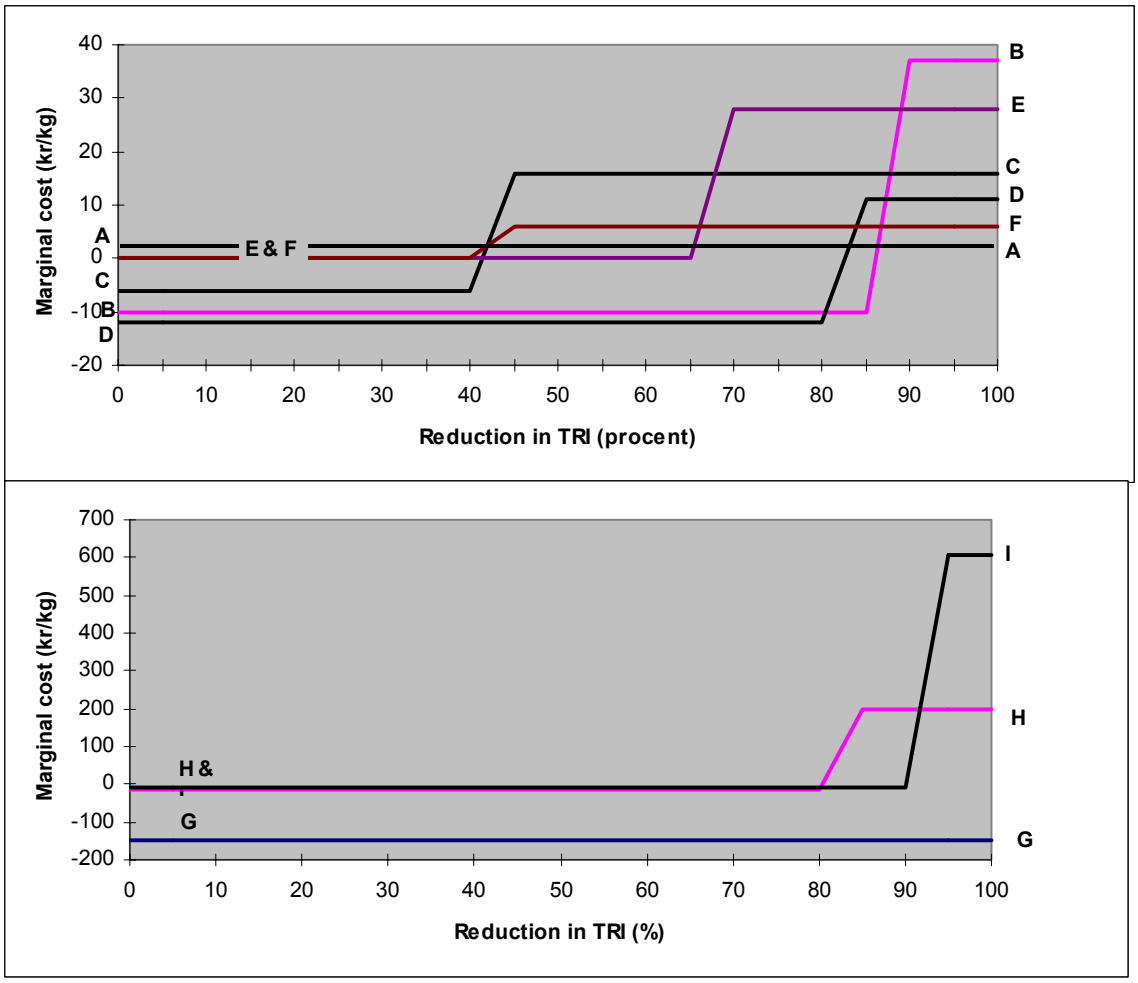

Figure 4. Marginal Cost of Abatement in Nine Companies.
Source: Slunge (1997).

Figure 4 has been split into two because of scale: One company reported that the last 10% was so expensive (marginal cost = 600 SEK/kg) that most of the other variation reported (generally, marginal costs between –10 and 40 SEK/kg) would have been invisible on a scale required to capture the extreme cases (600 to –150 SEK/kg).

Most evidence we have shows that in most cases substitution of other chemicals for TCE is relatively if not very cheap. There remains some evidence that it might be very expensive in some special cases, but it is difficult to judge whether this is due to tactical exaggeration or lack of knowledge by the individual firms, or a reflection of special needs or circumstances of an individual firm.[7] For example, the residues may be very difficult to remove, or the demands on cleanliness very high, or the technical specifications are in some other way exacting. More commonly, a company may have recently invested in expensive, closed-cycle TCE degreasing equipment and cannot afford in the short run to throw out this equipment and install new degreasers. Some companies are small and lack either space (the water-based equipment is typically larger) or time (they may be temporarily overloaded with work or understaffed). There are also firms that have special financial situations and cannot borrow money for this type of investment. A small company whose owner is the only technical expert may find that closing the plant to install new equipment could well be prohibitively costly.If a small company is working overtime to expand in a new direction or struggling to catch up with orders, a management distraction of even a week or two on "side issues" like degreasing may carry a very considerable cost: the opportunity cost of management. This type of cost is hard to quantify and not included in our material, but it is reflected in the strong statements some small companies have made about the prohibition.

In many instances companies facing tougher environmental restrictions have initially reacted by saying that the new requirements are impossible to meet and will force plant closure. It is not uncommon that after a couple of years, they find it was much easier than anticipated, and there is even anecdotal evidence that new processes turn out to cost less or improve product quality. This is a version of the Porter hypothesis—that efficiency is enhanced by tough environmental standards. However, some such cases may be due to a coincidence of technological progress, and it is not easy to distinguish the companies that may be bluffing from the ones that face true difficulties.

[7] If there is such a variation in abatement costs, we would expect to find the firms with higher costs in the group of companies that have not yet carried out abatement. Uncertainty, tactical reporting, and selection thus all pull in the same direction and cannot easily be distinguished.

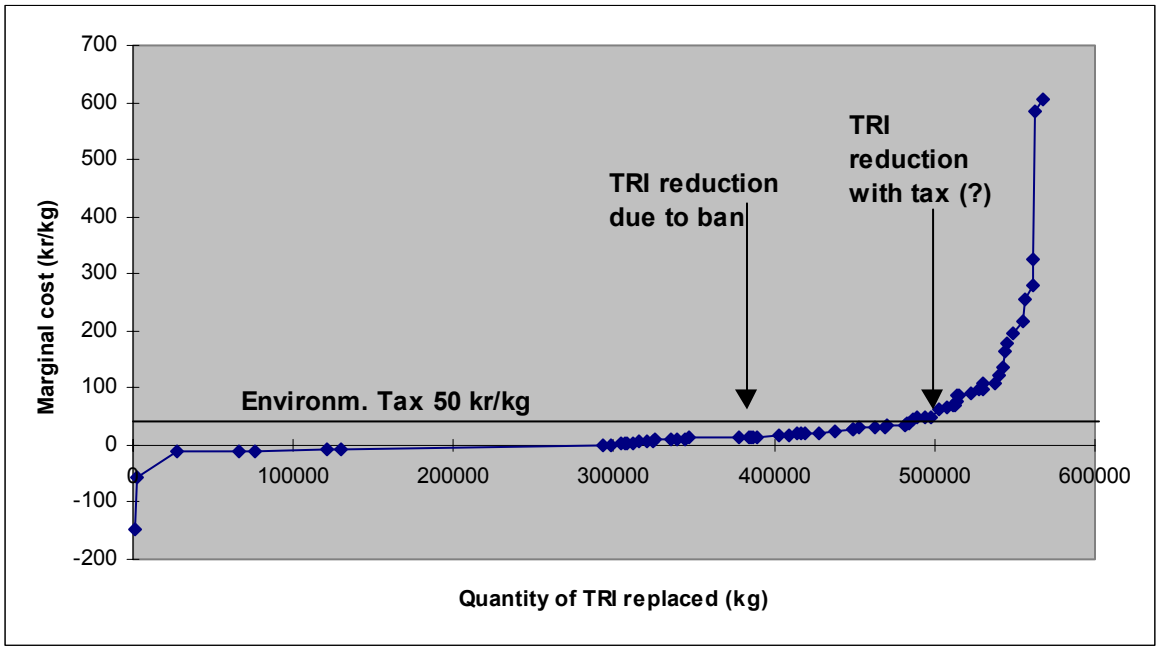

Figure 5. Marginal Abatement Cost and Effects of Tax Compared with Ban.
Source: Slunge (1997).

Figure 5 shows the *reported marginal costs* of abatement for 46 companies applying for exemption from the Chemicals Inspectorate ban, with the *actual marginal costs* for 19 other companies, from their databases and our interviews. This is in no way a representative sample of companies. A very large share of emissions carries a low marginal cost of abatement, and an environmental tax or fee of 50 SEK/kg would probably have sufficed to effect most (around 90%) of the abatement. A higher fee would incidentally not appear to have much of an effect on this figure if the costs of abatement rise as dramatically at the end as they appear to in Figure 5. As we have pointed out, these cost estimates may be exaggerated, but neither the regulator nor the researcher can know for certain. Although there are environmentally reasonable and technologically viable solutions to degreasing without TCE, the compliance costs for an individual firm may yet be high, particularly if the firm is required to comply very fast and not given time to adapt.

Alternative Policies: Taxes, Technology Standards, and Deposit Refunds

Policy alternatives worth considering in this context are taxes, stricter emissions requirements, and a deposit refund (DR) scheme or special environmental fees, as distinct from taxes. The DR is particularly useful when the effluents or emissions are small or hard to monitor. The environmental tax is levied at purchase (i.e., it is a deposit) and the burden of proof is then

on the polluter. If the polluter does not emit and can prove this by handing back the appropriate amount of the substance, the tax is refunded. This sort of refund has the advantage of reducing net payments from the industry to the environmental authorities or to the state budget, which reduces political resistance. DRs have the added advantage of specifically targeting emissions, rather than use, which makes good closed systems more attractive. Since it is the emissions that entail health and environmental problems, the firm pays at the margin only for the TCE that is not recycled.

Targeted emissions fees would be like taxes on TCE except that the proceeds would not go to the government's treasury but instead fund some program in which the concerned industry has an interest—research into alternative degreasing technologies, for example, or loans on favorable terms for special cases.[8] This runs counter to the usual public economics arguments against earmarking, but we are concerned here with very minor funds of a transient nature. The interest for the treasury is minutethe politically important aspect is gaining some support or understanding and preferably partnership with the industry to avoid the kind of confrontation that has characterized the Swedish prohibition.

Norway has recently implemented a tax per kilo on both TCE and PER of 50 Norwegian crowns(roughly equivalent to the Swedish ones) that combines elements of both tax and DR, since firms have the right to reclaim half the tax paid on delivery of TCE sludge delivered to special treatment plants or authorized recyclers. Considering that the market price of TCE is 10 to 15 crowns, a tax of 50 crowns may be expected to have a significant impact, and that in fact is what our firm-level inquiries suggest. The main alternative policy considered in Norway was a prohibition. Industry reactions to the tax have not been enthusiastic; nevertheless, there appears to be an appreciation of the fact that the tax allows firms much more flexibility than an outright ban.

Germany has employed very tough technical requirements concerning emissions that apply to both PER and TCE. When PER from dry-cleaners was found in adjacent apartments in both air and foodstuffs, regulations were imposed, calling for completely closed systems for PER; that policy was then expanded to TCE. As a result, PER and TCE (as well as 111-

[8] Another possibility is simply to refund the payments to the industries concerned. This is done with fees on NO_x emissions in Sweden (see Sterner and Höglund 2000). These refunded emission payments (REPs) are paid back in proportion to output. The charge is rather like grandfathered emissions permits, or a "competition" in which the "dirtier-than-average" plants in an industry pay emissions fees not to the regulator but to the cleaner plants.

trichloroethane and dichloromethane) have all been drastically reduced—roughly by a factor ten in 15 years (more than 50% from 1986 to 1991, when the unification of Germany creates a break in the figures, and then another 80% from 1991 to 2000). These figures show a decline that is somewhat faster decline than in Sweden or Norway (see Figure 6) and considerably faster than in the EU as a whole. Comparing EU and German figures, it is clear that for 1993–1998 Germany alone accounts for half the reduction (and thus 10% of use in 1993 but only 5% in 1998). For PER, Germany accounts for 9 of the total 11 kilotonnes of EU reduction. It would seem that the German focus on health issues and thus the joint emphasis on TCE and PER make good sense. At the same time the industrial policies, which were worked out in close cooperation with industry, also focus on workers' health and on technological improvement. This has had the added advantage of being an incentive for the machine industry, and Germany is now the main exporter of high-quality closed-loop degreasing equipment.

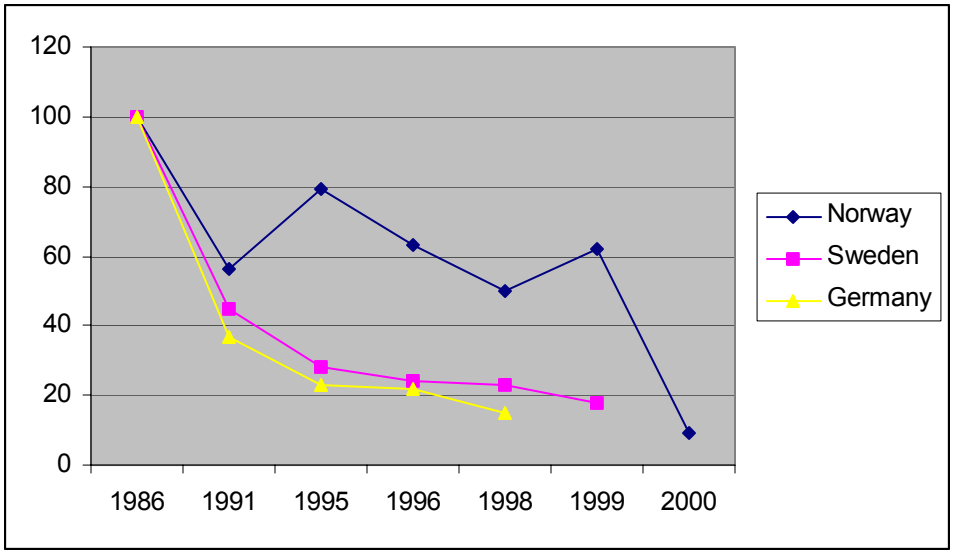

Figure 6. Relative Rates of Reduction of TCE in Sweden, Germany, and Norway.

The Norwegian tax took effect in 2000 and thus it is too early to fully evaluate its effects. As Norwegian data show, there was hardly any decrease in Norwegian demand before 2000, and in fact the 25% increase during 1999 might be attributed to pretax hoarding. According to the Eriksen (2000, 2001), the tax has been very effective, and preliminary figures show that purchases of TCE have fallen from more than 500 tons in 1999 to 82 tons in 2000. For PER the figures show a reduction from 270 tons in 1999 to 26 tons in 2000. Even if the 1999 purchases included some buildup of stockpiles, it is clear from the size of the reductions that the use of TCE and PER is far below pretax levels. All in all, we see that the Swedish policy was more

effective than the pre-1999 Norwegian policy (which was fairly lax), but it seems to be less effective than the Norwegian tax.

Compliance Incentives and the Reputation of Regulators

The Swedish policy has also led to reduced use of TCE, but as shown in Figure 1, the ban has not been entirely effective. Many companies with seemingly moderate abatement costs have chosen to fight the ban rather than abate. The threat of sanctions was apparently not credible. The risk of formal sanctions was reduced when a large number of firms coordinated their efforts; they appeared to think the Swedish authorities had a weak case. As for informal, market sanctions, it is noteworthy that larger companies, such as SKF, quickly eliminated their use of TCE. Small companies, in contrast, may not have been concerned about their image, perhaps because of their size or because they did not sell consumer products and did not think their corporate customers would be sensitive to this issue. In this case, the logic was clear: Fighting the ban costs little more than the effort of writing the letters, and companies facing regulatory instruments have an incentive to exaggerate the costs of abatement.

Even though the ban has survived legal challenge (it would have been extremely embarrassing to the Chemicals Inspectorate had it been struck down), implementation has been an uphill battle. Might this process have shown, once and for all, the legal powers of the national authorities and thus strengthened the likelihood that prohibitions would be used in similar future cases? We think that is an unlikely interpretation. In our view, the ban survived because it was watered down by the generous exemptions; the legal and media battles were exhausting but ultimately non- or even counterproductive. Prohibition will no doubt be used again, but the authorities will restrict it to more clearcut cases, as when health or environmental damage is more dramatic or international opinion more coordinated. Prohibitions that are, like this ban, not immediately successful portend problems for the policymaker:

- The planned environmental improvement is, after all, not (immediately) achieved.
- A greater improvement could perhaps have been achieved, at lower cost.
- The regulating agency suffers a loss of prestige (this is possibly one goal of the companies that fight the legislation), and the energy and confidence needed to enforce other regulations vis-à-vis the noncomplying companies may be weakened. In Sweden, these companies now have less incentive to comply with future regulations or initiatives from the Chemicals Inspectorate.

- The regulating agency also suffers loss of prestige vis-à-vis the complying companies. Companies that in good faith followed the regulations and invested in new equipment (in some cases at great expense) found that their efforts had been "unnecessary" and their competitors did not even have to pay environmental fines or compensatory fees. Several companies have brought this kind of complaint, and their experience may reduce the incentive for compliance with future regulations or initiatives.
- The regulating agency must rules on polluters' applications for waivers. Besides wasting inspectors' time, this opens up the possibility of arbitrary decisions and, in theory, even corruption.
- The uncertainty caused by a proposed ban may discourage investment in new technology. For many years the Swedish industry was hesitant, and anecdotal evidence has it that unsuitable temporary methods (such as manual degreasing in petrol in open air) were used because of the uncertainty. It is perhaps an irony that half a dozen Swedish companies have now ordered German closed-loop degreasing machines. They are convinced the machines are good (giving some credit to German policy) but do not know whether they can run them on TCE in Sweden—but if not, they can always use PER instead!

Conclusions

It is always risky to draw conclusions based on the partial experience of just a few countries. Observed results are due to a combination of policies and other factors, and it is hard to disentangle the effect of any one of them. The Norwegian policy is so new that we have only one year of data. The German case is complicated and consists of many different elements. For Sweden, a tentative conclusion—drawn with the benefit of hindsight—is that the authorities would have been more successful implementing harsh technical requirements and a monetary instrument applied over a somewhat broader range of chemicals than outright banning just one chemical, TCE. Thus, for instance, a fee on the use of a wide spectrum of chlorinated hydrocarbons, including both TCE and PER (as well as some other similar substances) might have provoked less resistance and achieved the same reduction we have seen—and maybe more. Exemptions could have been made for a few types of use where the costs of abatement were high and the health risk was low. If the fees had been earmarked for environmental collaboration with the industry association, the results might even have been enhanced.

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