The crucial role of the environmental damage function in strategic trade models with pollution-intensive industries

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Abstract

In markets where governments act strategically in setting pollution taxes, it is very difficult to determine whether the pollution taxes are low in order to be more competitive on world markets at the expense of the environment and the welfare of trade partners, or if the taxes reflect the actual damages, or if information problems make it difficult to implement the appropriate environmental tax. This paper is a first attempt to shed light on this question by analyze the European valuation literature to see if there are obvious differences in preferences for environmental quality between countries, and evaluate the use of environmental valuation data and the damage function approach for setting pollution taxes in strategic trade models.
Introduction

The environmental damages resulting from different types of production activities are often difficult to identify. This fact has some implications for environmental taxes on pollution, which in some cases, also influence competitiveness.

In perfect markets, some pollution taxes are set at non-optimal levels (often too low) due to lack of information about marginal abatement and environmental damage costs, or to protect certain interest groups (i.e., producer groups) in the economy. Moreover, pollution taxes may vary across countries because the marginal damage costs varies. This could be due to different physical impacts of the pollutant due to differences in assimilative capacity of the environment, and values for environmental and health impacts might differ substantially between countries. The demand for environmental quality could vary between countries due to differences in income levels, preferences, demographics, cultural and institutional conditions, and size of the population affected by the impacts. Thus, the damage function for a specific pollutant could vary substantially between countries.

In perfect markets, the consequences of non-optimal pollution taxes mostly affects the polluting country itself, but could have consequences for other countries’ welfare in the case of global or transboundary pollution problems. Trade competitiveness consequences are usually not very substantial except in the very “large country case”, where the large country’s choice of environmental policy will affect the terms of trade (Krutilla, 1991).

In imperfect markets (where governments may act strategically in the choice of pollution taxes), it is very difficult to determine whether the level of pollution taxes is determined in order to be more competitive at world markets at the expense of the

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1 One example is how critical loads for airborne sulphur and nitrogen depositions with respect to acidification damages to ecosystems vary between countries; see Posch et al. (1995) for European results.
2 Estimation of the damage function can be divided into four main steps: (i) Mapping emissions of pollutants from the production activity, (ii) Mapping of emissions into changed concentrations of pollutants and other conditions by location, (iii) Calculating physical impacts by dose-response relationships and expert assessments, and (iv) Economic valuation of impacts using non-market valuation techniques to estimate damages (or benefits). This is the general damage function approach as described by e.g. Freeman (1993; 30-33).
environment, or if the pollution taxes reflect the actual marginal damages, or if the tax
is set at a more “random” level because the government does not have the expertise to
adopt and implement appropriate environmental policies.

All types of “optimal” pollution taxes derived from an optimization of a
country’s welfare, are dependent on knowledge of the damage function. In imperfect
markets, where we will show that taxes deviate from the standard Pigouvian level, the
strategic element and competition for market shares make one country’s choice of
pollution taxes more crucial for other countries’ welfare than in perfect markets. In
this paper, the purpose is to investigate the link between theory and practice in using
pollution taxes as indirect trade policy. Special emphasis will be on strategic trade,
since the interdependency of the countries’ environmental policies are shown to be
more crucial in imperfect markets. To avoid any confusion around the subject of links
between trade and pollution taxes, a small survey of optimality conditions for pollution
taxation in trade models with different market structures is presented. We then present
different theoretical cases where we vary important parameters of our strategic trade
model; including the marginal damage, production technology (and implicitly also
abatement technology) and the emission factor of the home and foreign country. We
proceed to discuss the applicability of these theoretical cases to the analysis of acid rain
damages from atmospheric emissions of sulphur and nitrogen in Europe and North
America. Finally, we assess the results of our analysis, and conclude with some
implication the results have for environmental and trade policy.
Trade and environmental taxation in different markets

When markets are perfectly competitive and a country is small, the conditions for optimal environmental taxes in some cases follow those that are derived for closed economies. In the case where pollution (negative externality) only affects the domestic country, the policy that would be efficient domestically, will also be efficient globally (Segerson, 1988). Traditionally, externalities are corrected for using Pigouvian taxes, which is a unit tax on polluting activities equal to the marginal social damage (Krutilla, 1991). The optimality conditions for a Pigouvian tax (or equivalent policies) depend upon traditional neo-classical assumptions about technology, consumer behavior, and market structure. Given that these conditions hold, the Pigouvian tax will be a first best policy, because this tax has as a tax base the emission or the environmental degradation itself (Lloyd, 1988; Førsund and Strøm, 1994). This result is derived from the theory of the second best which argues that when distortions exist, policies that attack the distortion directly are superior to those that indirectly corrects the distortion, or those that impose an additional distortion. The use of a trade policy (such as a tariff) to reduce pollution will, therefore, typically be a second best policy. This because tariffs introduce distortions in both production and consumption, while a Pigouvian tax corrects directly on the source of environmental degradation.

Many pollution problems involve transmission of pollutants across borders. Some of these problems are global (like depletion of the ozone layer), while others are more transnational in character (like acid rain). It is important to distinguish between these two categories of pollution, called global pollution, and transboundary pollution, respectively. Transboundary pollution is spillover effects from one country to another (Segerson, 1988; Snape, 1992). The main difference when looking at international externalities compared to domestic externalities, is that the polluting country no longer can guarantee global efficiency by correcting for domestic external effects. A polluting country will typically only consider pollution falling from its own borders (Lloyd, 1992; Segerson, 1988; Snape, 1992). Thus, there will be excess pollution from a global point of view (Mäler, 1990). To improve global efficiency, the other affected countries might be forced to take their own actions to reduce negative external effects.
In the case with transboundary or global pollution, the Pigouvian tax would still be the first best policy (Lloyd, 1992). The problem when more than one country is involved is how to enforce this tax. There is a growing literature discussing these questions which will not be the main focus in this paper.

When a country is large, a secondary factor of environmental taxation (on production) in open economies is the terms of trade effect. Krutilla (1991) discusses how the terms of trade effect influences the optimal environmental tax. Pollution is assumed to be local. Recall that the optimal environmental tax (on production) in an open economy under the small country assumption is equal to the standard Pigouvian tax rate. When a country is large, Krutilla shows that the optimal environmental tax will differ from the standard Pigouvian tax.

Recently, a few models have concentrated on environmental policy as indirect strategic trade policy (Conrad, 1993; Barrett, 1994b; Hung, 1994; Nannerup, 1995, Lothe, 1998). In quantity competition games (Cournot), these models show that it is optimal for governments to reduce the pollution taxes to levels beyond the standard Pigouvian tax where the tax equals marginal damage of pollution. Governments choose to use pollution taxes for dual purposes: to reduce pollution and to shift rents from foreign to domestic industries. The rent-seeking deduction from the pollution tax is analogous to the direct export subsidies in the well-known Brander-Spencer model (Brander and Spencer, 1985). The derivation of the optimal pollution tax in strategic trade models requires information on the marginal damage of pollution in addition to cost and demand parameters. This implies that the informational requirement for the derivation of optimal policy is larger than in standard strategic trade models where the industries are not pollutive.

\[^{3}\text{Barrett (1994a) and Hoel (1995) are examples from this literature.}\]
The damage function as a basis for policy choice in strategic trade models

In all the cases discussed above, the derivation of a set of optimal pollution taxes requires knowledge on the marginal damage of pollution. In the following, we want to concentrate on the use of pollution taxes as indirect strategic trade policy, and the crucial role of the environmental damage function in this aspect. An example of a strategic trade model with pollutive industries is presented. The model is based on Conrad (1993), Conrad (1995), and Lothe (1998).

The model presented is a third market Cournot duopoly model where the home and foreign firms produce for exports to a third market. This is a relatively simple model, and the third market model is chosen because it allows the strategic effects of pollution taxation as indirect trade policy to be analyzed in pure form (Brander, 1995). Production processes in both countries are pollutive, and the model can handle both local pollution or pollution with transboundary effects. Global pollution (like the global warming pollution problem) is not modeled. Trade and environmental policy is modeled as a multistage game. In the first stage, governments simultaneously choose the levels of pollution taxes. In the second stage, the production levels of firms are determined in a Cournot fashion (quantity game). The game is solved by backwards induction to find the sequential rational Nash equilibria. Let the domestic variables be denoted by lowercase letters and the foreign variables by capital letters, except for outputs, denoted by $y$ (home production) and $x$ (foreign production). The inverse demand function $P = P(\varphi)$, where $\varphi = x+y$, is assumed to be linear of the form $P = a - b(x+y)$, where the parameters $a > 0$ and $b > 0$. The domestic firm produces $y$ at variable cost $\gamma q(t)y$, where $q(t)$ is the total price of a polluting input (defined in (2) below). Other input prices than the total price of the pollutive input are omitted from the cost function (for simplicity). The firm does not have a flexible abatement technology, but the parameter $\gamma$ does reflect how efficient the firm is in the use of the pollutive input. The higher is $\gamma$, the more pollutive is the firm (for a given

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4 Alternative market structures could be a intra-industry trade model (reciprocal dumping model), or a model where both firms produce for the home market, or other oligopolistic market structures.
production level). The profit of the home firm is revenue minus variable costs and some fixed costs (f):

\[ \pi(x, y; t) = (a - b(x + y))y - \gamma q(t)y - f \]  

(1)

In addition, some sunk cost explains the imperfectly competitive market structure in this industry. The pollution tax is included in the total price of the input. With no abatement, the total emission price is

\[ q(t) = q_0 + te \]  

(2)

where \( q_0 \) is the base price of the input, \( e \) is emission per unit of input used, and \( t \) is the pollution tax. This way, both the cost parameter \( \gamma \) (cost efficiency in the use of the pollutive input) and the emission coefficient \( e \) (emission per unit of input used) determine how pollutive the firm is. The profit of the foreign firm is similarly given as

\[ \Pi(x, y; T) = (a - b(x + y))x - \Gamma Q(T)x - F \]  

(3)

with the total price of the pollutive input given by

\[ Q(T) = Q_0 + TE \]  

(4)

The outputs \( x \) and \( y \) are homogenous products, and the increase of output in one country results in a decrease in the marginal revenue of the firm in the other country (\( r \) and \( R \) are the revenues in the home and foreign country, respectively).

\[ r_x < 0; \ r_{yx} < 0; \ R_y < 0; \ R_{xy} < 0 \]  

(5)

A Cournot equilibrium must satisfy the following first-order conditions

\[ \pi_y = a - b(x + 2y) - \gamma (q_0 + te) = 0 \]  

(6)

\[ \Pi_x = a - b(y + 2x) - \Gamma (Q_0 + TE) = 0 \]  

(7)

and the corresponding second-order conditions

\[ \pi_{yy} < 0; \ \Pi_{xx} < 0 \]  

(8)

Uniqueness and global stability of the equilibrium is ensured if own effects of output on marginal profits dominate cross effects as stated in the following condition

\[ \Omega = \pi_{yy}\Pi_{xx} - \pi_{yx}\Pi_{xy} > 0 \]  

(9)

In general, condition (8) and (9) are satisfied for profit functions that are globally concave. In this model, demand is linear, and marginal costs are constant for any given level of the pollution tax. Condition (8) and (9) then hold globally, and the global
uniqueness of the Cournot equilibrium is ensured. Also, an interior solution is assumed, implying that both countries produce a positive amount of output. This implies that the differences in costs between the two firms are not too large.

The firms’ reaction functions are implicitly derived in (6) and (7). Changes in pollution taxes imply shifts in the reaction functions, and consequently, output and market shares change. Total differentiation of the first-order conditions results in the following comparative statics (the mathematical appendix contains more details):

\[
\frac{dy}{dt} = -\frac{2\gamma e}{3b} < 0
\]
\[
\frac{dy}{dT} = \frac{\Gamma E}{3b} > 0
\]
\[
\frac{dx}{dT} = -\frac{2\Gamma E}{3b} < 0
\]
\[
\frac{dx}{dt} = \frac{\gamma e}{3b} > 0
\]

All the comparative statics have the intuitively correct signs; the equilibrium output in the home country is decreasing in its own pollution tax and increasing the foreign pollution tax and vice versa for the foreign country.

The home and foreign governments maximize welfare in order to find the optimal pollution taxes. Welfare in both countries are given by the sum of profits, government revenue, and environmental damage. Pollution could be purely local, or with transboundary pollution effects. For simplicity, it is assumed that (possible) transboundary pollution effects only affect the two producing countries, and not the importing (third) country. To model this in a flexible way, consider the share of pollution staying in the country (from own production) to be 1 − s (0 ≤ s ≤ 1), and the share of pollution entering from the foreign country to be S (0 ≤ S ≤ 1). If both the home and foreign country just experienced local pollution problems, s and S would, respectively, be zero. A similar approach is used in Conrad (1995) in a model of intra-industry trade. Total pollution \( z \) in the home country is:

\[
z = (1 - s)\gamma e y + S\Gamma E x
\]

The intuition here is that total pollution in the home country is the share of pollution from

\(^5\) Condition (9) always holds if marginal cost is nondecreasing. Only if marginal cost falls more steeply than demand, condition (9) may be violated.

\(^6\) In such a case, the more competitive firm would capture the whole market.
home production, plus the amount of pollution entering from the foreign country. For the home country, the welfare function is then:

$$ w = (a - b(x + y))y - \gamma q(t)y - \int \gamma ey - d(z) $$

where the environmental damage function is assumed to be convex in the pollution level. A convex environmental damage function implicates that the marginal environmental damage increases with increased emissions. This functional form is commonly used in the literature (see for example Førstad and Strøm, 1994).

The welfare in the foreign country is similar to the welfare in the home country:

$$ W = (a - b(x + y))x - \Gamma Q(T)x - F + \Gamma EY - D(Z) $$

If none of the countries have a Stackelberg leader position in choosing pollution taxes, they will maximize welfare simultaneously, and this results in the following optimal pollution taxes for the home and foreign country, respectively (see the mathematical appendix for details):

$$ t = \left(1 - s\right)md(z) - \frac{by}{2\gamma e} - \frac{smd(z)\Gamma E}{2\gamma e} $$

Similar for the foreign country:

$$ T = \left(1 - S\right)MD(Z) - \frac{bx}{2\Gamma E} - \frac{sMD(Z)\gamma e}{2\Gamma E} $$

where md(z) and MD(Z) are the marginal damages of all pollution in the home and foreign country, respectively. In the Nash equilibrium of pollution taxes, each country’s belief about the other country’s choices must coincide with the actual choices the other country intends to make (Varian, 1992). Hence, full information of all the elements in both the welfare functions are needed for both countries in order to know the payoff (welfare) for your own country as well as for the other country. In many situations, this is not an appropriate assumption. The derivation of the optimal pollution tax in strategic trade models (as in (13) and (14)) requires information on the marginal damage cost of pollution in addition to production cost and demand parameters. In the following, we will discuss the implications for trade and competitiveness of including the marginal damage cost as an important factor in policy-making and furthermore analyze how well the theoretical results can be applied to some real world situations.
First, some intuitive explanations of the optimal taxes in (13) and (14) are given. With no transboundary pollution (s and S equal zero), the home and foreign country would use a pollution tax that is lower than the standard Pigouvian pollution tax. The pollution taxes are used for dual purposes, to reduce pollution and to shift rents. With transboundary pollution, the countries will still use a Pigouvian tax with rent seeking deductions, but now, the Pigouvian tax is reflecting the marginal damage from the production externality that is not leaving the borders (the first term in (13) and (14), respectively). Then, there is a rent seeking effect as for the local pollution problem (the middle term), and last, there is an extra rent seeking effect stemming from the transboundary pollution entering from the trade partner. What is the intuition behind this? In the welfare maximization problem, a country faces a trade off between pollution damage and profits. If high domestic pollution taxes makes a country less competitive and this results in increased production in the other country (and an increased spillover of pollution from this country), the domestic country might be better off by reducing pollution taxes in order to be more competitive, even if this increases pollution from own production.

Different types of equilibria can be described for all different combinations of parameter values and for different functional forms of the damage function. A selection of some of the relevant constellations is presented in the table below, and the applicability to real world pollution problems is discussed in the next session.

Table 1: Policy consequences of symmetries and asymmetries in parameter values and in the environmental damage function

<table>
<thead>
<tr>
<th>Case</th>
<th>Marginal environmental damage (for any given level of total pollution)</th>
<th>Parameters (entering the damage function)</th>
<th>Policy consequences: Consequences for size of Pigou taxes and rent-seeking effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$md(z) = MD(Z)$</td>
<td>$s = S, \gamma = \Gamma, e = E$</td>
<td>$t = (1 - s)md(z) - \frac{by}{2\gamma e} - \frac{Smd(z)}{2\gamma e} \Gamma E$ (13)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T = (1 - S)MD(Z) - \frac{bx}{2\gamma E} - \frac{sMD(z)}{2\gamma E} \gamma E$ (14)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Symmetric equilibrium in pollution taxes and in quantities. If $s = S = 0$, local pollution case (and less aggressive rent-seeking than for positive values of $S (= s)$. Pigou taxes higher the lower is $s = S$.</td>
</tr>
<tr>
<td>Case</td>
<td>Equation</td>
<td>Conditions</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>----------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>2</td>
<td>$md(z) = MD(Z)$</td>
<td>$s = 0, S &gt; 0, \gamma = \Gamma, e = E$</td>
<td>More aggressive rent-seeking in the home country relative to the foreign country the higher is $S$. High Pigou tax in the home country, lower Pigou tax in the foreign country the higher is $S$.</td>
</tr>
<tr>
<td>3</td>
<td>$md(z) = MD(Z)$</td>
<td>$s = 0, S &gt; 0, \gamma \neq \Gamma, e = E$</td>
<td>Less (more) aggressive rent-seeking in the home country relative to the foreign country the higher (lower) is $\gamma$ relative to $\Gamma$. High Pigou tax in the home country and lower Pigou tax in the foreign country, the higher is $S$.</td>
</tr>
<tr>
<td>4</td>
<td>$md(z) = MD(Z)$</td>
<td>$s = 0, S &gt; 0, \gamma = \Gamma, e \neq E$</td>
<td>Less (more) aggressive rent-seeking in the home country relative to the foreign country the higher (lower) is $e$ relative to $E$. High Pigou tax in the home country and lower Pigou tax in the foreign country, the higher is $S$.</td>
</tr>
<tr>
<td>5</td>
<td>$md(z) \neq MD(Z)$</td>
<td>$s = 0, S &gt; 0, \gamma = \Gamma, e = E$</td>
<td>Higher (lower) Pigou tax in the home country relative to the foreign country the higher (lower) is $md(z)$ relative to $MD(Z)$. More (less) aggressive rent-seeking in the home country relative to the foreign country, the higher (lower) is $Smd(z)$ relative to $MD(Z)$.</td>
</tr>
</tbody>
</table>

It is (of course) also possible to look at combinations of case 5 with the cases 2-4, and the policy implications can be seen from the information that is in the table.

By looking at the table, we observe that the domestic country would be more aggressive in rent-seeking the higher is the share of foreign pollution spillover, the higher is the domestic marginal damage of pollution, and the higher is the ratio of production cost parameters and emission coefficients between the foreign and the domestic country.

The table describes a “first-best world” where all relevant information is available to all the players of the game. This is hardly ever the case, and we will discuss both the asymmetries in parameters analyzed in the table and how different types of environmental damage are known with more or less certainty. Unilaterally, the lack of one or several of the informational requirements related to knowing the environmental damage, will result in two main effects. The pollution tax could be too low, and the marginal benefit of increased industry profit is then lower than the marginal cost of increased pollution and decreased pollution tax revenues. The pollution tax could be too high, and the marginal benefit of a cleaner environment and increased pollution tax revenues is then lower than the marginal cost from the decrease of industry profit.
Also, the table points out some incentives for misrepresenting information. There are several types of information asymmetries, but we will concentrate on the information asymmetry that could exist between countries. The domestic country would like to make the impression to the foreign country that the domestic industry is very competitive (or vice versa). In order to be more competitive, one country would have the incentive to claim (to the other country) that transboundary pollution effects from own production industry are low, and that the production process is not that pollutive (cost efficient and with low emissions, and with small impact on environmental damage).

**Applicability of the theoretical model to acid rain damages from pollutive industries**

Parameters entering the damage function

We will now discuss how the cases described in table 1 can be used to describe acidification damages from sulphur (S) and nitrogen (N) emissions in Europe and North America. We will also look at differences in S and N taxes in selected European countries, to see if these differences can be explained by the model.

Case 1 describes a situation where the home country “exports” the same amount of pollution as it “imports” from the foreign country, i.e., \( s = S \). In the “pure” case of no transboundary pollution, \( s = S = 0 \). This local pollution case does not apply to S and N emissions in Europe. However, the \( s = S \) situation could apply to neighbouring countries in Mid-Europe. A more typical situation for Norway (and Sweden and Finland) as the home country would be case 2, where only the foreign country exports pollution; i.e. \( s = 0, S > 0 \). Norway “exports” very little of its S emissions, but “imports” 95% and 86% of its S and N depositions, respectively. The main, identified “exporting” countries are the United Kingdom, Germany, France, Russia and Poland. Since we assume the pollution per unit of output to be the same in these two countries, this would probably best describe the situation with one of the first three countries as the foreign country. It is reasonable to assume that these

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7 Of course, information asymmetry between governments and firms could also be present.
Western European countries have the same production technology (and implicitly the
same abatement technology) as Norway. If a Central and Eastern European Country
(CEEC) was the foreign country, case 3 (with $\gamma < \Gamma$) would be more appropriate.
Norway has a more efficient production technology with lower emissions for a given
level of output than the older production technology of CEECs.

Case 4 illustrates a situation where the two countries have equal production
technology, but the quality of the input with regards to emissions of pollutants differs
(e.g. sulphur content in fuel oils, emissions from the electricity source used). This
could illustrate a case with Norway as the home country and e.g. Germany or the UK
as the foreign country, because the sulphur content in fuel oils used in the industry
could be higher in these countries, and the pollution from Norway’s main electricity
source for industrial production, hydro power, is much smaller than from coal fired
power plants in Germany and the UK (i.e., $e < E$).

A combination of case 3 and 4 would give a better description of the home and
foreign country if Norway was the home country and a CEEC was the foreign country,
since the CEECs would typically have more polluting production technologies and
inputs, i.e. $\gamma < \Gamma$ and $e < E$.

So far in table 1 we have assumed that the marginal damage function is the
same in the two countries, i.e. $md(z) = MD(Z)$. For acidification damages from S and
N emissions this would not be the case with Norway as the home country and any of
the countries we “import” the pollution from as the foreign country. There are two
main reasons for this: (i) The assimilative capacity of the ecosystems with respect to
acidification (i.e. buffering capacity of the soils) is much lower in Norway than the
foreign country; see Posch et al. (1995; 9). Thus, the same deposition of $S$ and $N$
causes a larger impact in Norway compared to e.g. France and the UK, (ii) The impact
is valued higher in Norway than the foreign country because Norwegians have higher
per capita income than the foreign country, more positive attitudes towards
environmental protection, etc. We will examine point (ii) in more detail in the next
section. Thus Case 5 with $md(z) > MD(Z)$ would be more appropriate in our
application. However, case 5 should be combined with $\gamma < \Gamma$ and $e < E$ to describe a
situation with a CEEC as the foreign country, and $\gamma = \Gamma$ and $e < E$ or $e = E$ for
Western European countries. To the extent imperfections in the markets above are
observed, strategic effects of the asymmetries in parameters can be analyzed by using strategic trade models. If markets are “more perfect”, general results from the theory of pollution taxation for perfect markets can be applied.

Empirical survey of pollution taxes in Europe

When it comes to types of pollution, our model is suitable for both emissions of both sulphur dioxide and nitrogen oxide. The emission of sulphur dioxide (SO$_2$) is mainly determined by the specific sulphur content of the single fuels and sulphur emissions from the source of electricity production, and one can, thus, tax potential emissions; i.e. input based taxation. Nitrogen oxide (NO$_x$) emissions must be taxed based on actual emissions (which is of course also a possibility for SO$_2$). In the following, we will concentrate on SO$_2$ emissions in Europe.

Cansier and Krumm (1997) compare the level, construction and structure of pollution taxes on SO$_2$, NO$_x$ and CO$_2$ in selected European countries. They review forerunners in environmental taxation policy, and note that these countries, due to competitive risks, have been concerned about protecting their national economies by means of an adequate technical design of the tax.

They conclude that the SO$_2$ tax in Sweden, Norway and Denmark rely on ecological and economic efficiency impacts, whereas the financing function of the tax is most important in France. SO$_2$ taxes in Sweden, Norway and Denmark are up to more than 200 times higher than in France. In Norway and Sweden the tax revenue from SO$_2$ taxes goes into the public budget without any earmarking. In France, however, a large proportion of the tax revenue is given back to the group of taxed polluters in order to subsidize emission abatement. In Denmark the SO$_2$ taxation scheme aims at removing the polluters’ income loss caused by the taxing of residual emissions. The taxes paid by the industry are completely reimbursed to this sector in one way or another - especially by diminishing the employers’ contribution to social insurance. Thus the “net” SO$_2$ tax paid by the industry in Sweden and Norway is much higher than in France and Denmark.\footnote{However, it seems doubtful that even the tax level in Sweden and Norway, -in comparison to the marginal abatement costs, will always be sufficient for realizing the the national emission goals set by the government (Cansier and Krumm 1997; 68)}
differences in impacts, since assimilative capacity of ecosystems in France and Denmark is much higher than in Norway and Sweden (Posch et al., 1995). The difference could also be due to that the Danish and French people value environmental and health impacts less than Norwegians and Swedes due to differences in e.g. preferences and income levels. A review of European valuation studies (Navrud, 1992) do not lend support to this hypothesis, but it is not unreasonable to assume that net “importers” of SO$_2$ have a higher WTP to avoid these damages than net “exporters” of SO$_2$. However, neither the national emission goals nor the level of the tax rates in France, do seem to be based on a damage cost approach. In the Scandinavian countries, however, this seems to be the case, at least partially. The large difference in pollution tax between France and the Scandinavian countries can probably not be explained by differences in national impacts alone (Posch et al., 1995). While impacts of SO$_2$ are well known, peoples’ valuation of these impacts are much more uncertain. This introduces an uncertainty in the damage function which makes it difficult for trade partners to evaluate whether low pollution taxes (as in France) are based on actual damages or strategic behavior. Since at least some of the branches with SO$_2$ pollution are described by imperfect competition structures (e.g., steel, chemicals, and coal), a better understanding of the strategic elements in trade are necessary in order to distinguish between rent seeking and effects from different valuation of impacts.

Is pollution impact valued differently in different countries?

We have already stressed that damages might vary between countries due to differences in impacts, and people’s different valuation of impacts. As we mentioned above, it can be shown that for acidification damages from SO$_2$, impacts are relatively well known, while empirical results for valuation of these impacts across countries, are scarce. In the following, we will discuss the main techniques for valuing environmental goods, and then go on to discuss whether the empirical studies can shed light on how factors that affect the demand for environmental quality vary between countries.

Two main approaches to value environmental and health impacts have been developed; stated preference (SP) and revealed preference (RP) approaches. Both approaches build on the welfare economic concept that social cost and benefit of a
marginal decrement / increment in environmental quality is the aggregate of all individuals’ willingness to pay (WTP) for an improvement in environmental quality.

The most popular of the SP approaches is the Contingent Valuation (CV) method. CV involves asking individuals in surveys (or experimental settings) to reveal their personal evaluation of a hypothetical change in the health or environmental risks or effects. In the survey the good or amenity is described, both the current level of provision and the proposed increment or decrement therein. They are also informed about the institutional structure under which the good is to be provided, the method of payment, and (implicitly or explicitly) the decision rule which determines whether to implement the offered program or not. One of the main challenges here is to convey to respondents what a policymaker wants them to take into account in a way that is both theoretically and technically correct, and at the same time understandable and plausible. The respondents are then asked to carefully consider his/her maximum WTP, or to vote yes or no to predetermined prices (i.e. discrete choice techniques), to get the increment or avoid the decrement in quantity/quality of the commodity. Mitchell & Carson (1989) give a thorough description of the method and its potential biases. Arrow et. al. (1993) provide a detailed list of guidelines for CV surveys to provide valid estimates of use and non-use values to be used in cost-benefit analyses, environmental costing and Natural Resource Damage Assessments.

The CV method, if properly designed, offers a unique possibility for finding the Total Economic Value (TEV), i.e. both use and non-use value, of environmental impacts. Other major advantages of the method include: it can be designed to value future changes (ex ante analysis) in public goods, the good being valued can be specified exactly to match e.g. the endpoint of a physical dose-response function, and the survey can be administered to a sample appropriate for the good being valued (whether representative of the general population or of some special group).

Among the revealed preference (RP) approaches, the Travel Cost (TC) method can only calculate the current use value of a recreational area, based on the existing behavior in the market for transport services to the area. The Hedonic Price (HP) method is also based on revealed preferences in a market connected to the environmental good in question. Observed differences in property prices have been used to value air quality and noise from air and road traffic, and differences in wages
have provided values for occupational health risks. Neither methods are suited for measuring the value of future environmental impacts. Both methods are based on observed behavior in existing markets for private goods that are connected to the environmental good in question. For this connection to hold several strict assumptions must be fulfilled. This is a main weakness of the RP approaches as opposed to the CV method that tries to construct a market for the environmental good directly, instead of going by an “indirect route”. The main advantage of the RP methods is that they are based on observed, not hypothetical, behavior.

To examine whether people in different countries value environmental damages differently, we have reviewed meta analyses of different environmental goods and health risks. Meta analysis has been used to synthesize research findings and improve the quality of literature reviews of valuation studies used to come up with adjusted unit values to be used in benefit transfer. In a meta analysis, original studies are analyzed as a group, where the results from each study are treated as a single observation in a new analysis of the combined data set. This allows us to evaluate the influence of the resources’ characteristics, the features of the samples used in each study (including characteristics of the “affected” population), and the modeling assumptions. Thus, meta analysis provide a structured way of testing whether preferences for the same environmental good vary between countries. However, the majority of existing meta analyses of valuation studies have looked at studies in one country only, mainly the US.

Smith and Karou’s (1990) meta-analysis of TC recreation demand models using both consumer surplus per unit and the own price elasticity of demand, and Walsh et. al’s (1990) summary of TC and CV studies for the US Forest Service’s resource planning program, were the first attempts to apply meta analysis to environmental valuation. Later there have been applications to HP models valuing air quality (Smith and Huang 1993), CV studies of both use and non-use values of water quality improvements (Magnussen 1993), CV studies of groundwater protection (Boyle et al 1994), TC studies of freshwater fishing (Sturtevant et al 1995), CV studies of woodland recreation using Geographical Information Systems (GIS) (Bateman et al 1995), CV studies of visibility changes at national parks (Smith and Osborne 1996), CV studies of morbidity using Quality of Life Years (QUALY) indexes (Johnson et
al., 1996), CV studies of environmental functions of wetlands (Brouwer et al. 1997), and HP studies of aircraft noise (Schipper et al., 1998). Only the last two studies can be considered to be international meta analyses, including both European and North American studies. Unfortunately, none of these meta analyses include variables for income and other characteristics of the local population, which could be used to test whether preferences for environmental goods vary between countries.

McConnell (1997) and Kristrom and Riera (1996) provide reviews of valuation studies that support the hypothesis that WTP increase as a function of income for both health risks and environmental goods, with the possible exceptions of local public goods and recreation (McConnell, 1997). Therefore, if Norway is the home country in our model and a CEEC is the foreign country, the much lower GDP per capita in the foreign country would mean a lower WTP to avoid environmental damage in the foreign country, and thus (all other things equal) a lower pollution tax.

It is still premature to conclude that other differences between countries than income levels affect valuation of environmental goods and health risks (from pollution). Thus, the same impact, will be valued differently depending on income levels and distribution in different countries. The total level of uncertainty in the damage function (both from uncertainties in identifying and valuing impacts and methods used), sometimes makes it difficult to apply theoretical models in which the damage function has a central role. For SO$_2$, the uncertainty in damage is smaller than for many other pollutants where both impacts and valuation are much more uncertain.

**Concluding remarks**

We have used a strategic trade model to illustrate some of the problems related to the crucial role of the damage function in theoretical models for optimal pollution taxation in trade models. Industries with acidification damages from S and N emissions illustrate how such a model can be used under different sets of assumptions regarding parameter values and differences in environmental damage. In order to apply this model (or similar models), knowledge on the damage function is crucial. We have identified a general lack of cross-country valuation studies of the same pollution
impacts using similar methods. Cross-country valuation studies are necessary in order to understand how the valuation of the same impact varies between countries. Because of this lack of empirical results, the aggregate uncertainty in damage functions is high, and this causes several problems. In imperfect markets, it can be difficult to distinguish between strategic behavior and other effects related to the uncertainty in damage. Current interpretations of the WTO rules on competitiveness, do not consider low pollution taxes to be implicit subsidies (Westin, 1997), but the model show that low pollution taxes clearly could be used in order to be more competitive at the expense of the environment and the welfare of trade partners. Both for trade reasons and for environmental reasons, more information on damage functions across countries is needed in order to be able to distinguish between the different factors that influence the size of pollution taxes in different countries and in different markets.
Mathematical Appendix

Total differentiation of the first-order conditions (6) and (7) give:

\[ \pi_{yt} dy + \pi_{xt} dx + \pi_{yt} dt = 0 \]
\[ -2b dy - bdx + \gamma dt = 0 \]  
(A1)

\[ \Pi_{yt} dy + \Pi_{xt} dx + \Pi_{yt} dT = 0 \]
\[ -bdy - 2bdx + \Gamma EdT = 0 \]  
(A2)

In matrix form:

\[ \begin{bmatrix} -2b & -b \\ -b & -2b \end{bmatrix} \begin{bmatrix} dy \\ dx \end{bmatrix} = \begin{bmatrix} -\gamma dt \\ -\Gamma EdT \end{bmatrix} \]  
(A3)

Solving (by matrix inversion) gives:

\[ dy = \frac{-2\gamma dt + \Gamma EdT}{3b} \]  
(A4)

\[ dx = \frac{-2\Gamma EdT + \gamma dt}{3b} \]  
(A5)

The comparative statics based on (A1) and (A2) are:

\[ \frac{dy}{dt} = \frac{-2\gamma e}{3b} < 0 \]

\[ \frac{dy}{dT} = \frac{\Gamma E}{3b} > 0 \]

\[ \frac{dx}{dT} = \frac{-2\Gamma E}{3b} < 0 \]  
(A6)

\[ \frac{dx}{dt} = \frac{\gamma e}{3b} > 0 \]

as shown in (10). These comparative statics results are used in the governments’ welfare maximization problem, where governments maximize welfare simultaneously, taking the other country’s tax as given (Nash equilibrium in taxation).

Welfare maximization (the welfare is kept on a general form where \( r \) is revenue and \( c \) is cost):

\[ \frac{\partial w}{\partial t} = r_y \frac{\partial y}{\partial t} + r_x \frac{\partial x}{\partial t} - c_y \frac{\partial y}{\partial t} - c_x \frac{\partial x}{\partial t} + e \frac{\partial y}{\partial t} + te \frac{\partial y}{\partial t} - d'(z) \left[ \frac{\partial z}{\partial y} \frac{\partial y}{\partial t} + \frac{\partial z}{\partial x} \frac{\partial x}{\partial t} \right] = 0 \]

(A7)
From the first-order condition of profit maximization, $r_y = c_y$. Furthermore,

$$c_y \frac{\partial q}{\partial t} = e\gamma y.$$ 

The first-order condition for welfare maximization with specific functional form as in (11) and with the use of comparative statics results from (10) becomes:

$$\frac{\partial w}{\partial t} = -by\frac{\gamma e}{3b} + te\gamma - 2\gamma e \frac{d'(z)}{3b} - d'(z) \left[ (1-s)\gamma e - 2\gamma e \frac{E}{3b} + \delta \gamma e \frac{E}{3b} \right] = 0 \quad (A7')$$

where $d'(z) = md(z)$ (marginal damage of pollution).

Solving for $t$ gives (13) and a similar procedure for the foreign country gives (14).
References


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