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GREEN TAXES AND ADMINISTRATIVE COSTS: THE CASE OF CARBON TAXATION

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ABSTRACT

This paper explores the trade-off between incentive effects and administrative costs associated with the implementation of various environmental tax instruments, with special reference to carbon taxes. In a simple model, we show under what conditions it is optimal to use input rather than emission taxes to internalize environmental externalities. Mixed tax regimes are also studied. If linkage of emissions to inputs is close, if abatement possibilities are costly, and if administrative costs of emission taxes are high, emission taxes should not be introduced. It is shown that these conditions directly apply to current tax policies toward CO_2 emissions in several European countries that harness pre-existing energy taxes. First, there is a one-to-one correspondence between carbon content of energy and CO_2 emissions. Second, only few possibilities exist to abate CO_2 emissions separately. Third, "piggy-backing" on existing administration for energy excises allow to save on administrative costs. Broadening the carbon tax base by removing certain widely-used exemptions for energy production (and possibly adding emission taxes or abatement subsidies for selected industries) is likely to increase incentives for carbon reduction without significant additional administrative costs.

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1. Introduction

Implementing environmental policies -- through standards, tradable permits or environmental taxes alike -- is far from costless. For instance, when implementing an environmental tax, the tax department has to run a special unit to enforce and collect taxes and to monitor compliance. In practice, the costs of implementing environmental policies plays a significant role in the choice between different policy options. The proposals of the European Commission for a European wide energy/CO_2-tax provide clear examples (Vollebergh, 1995). Instead of proposing a totally new tax on CO_2-emissions, the European Commission employed the close linkage between CO_2-emissions and the implicit taxation of carbon by the existing taxes on energy products (which are usually intermediate inputs). Indeed, using existing instruments rather than introducing new ones to address new policy areas may save considerably on administrative costs.

However, just minimization of transaction costs might come at a cost for society. A strategy based on input taxes, for example, foregoes the gains that are potentially reaped by a more direct way of taxing the externality through emission taxes. Any deviation from the principle of taxing externalities at the point where they arise, introduces an incentive to misallocate resources. Thus a trade-off arises between minimizing transaction costs and directly inducing incentive effects. The optimal tax structure has to balance the burden of complex and expensive-to-run tax systems against the incentives it induces to internalize the externality that is aimed to be addressed.

This paper investigates the potential trade-off between administrative costs and incentives of environmental regulation, in particular if the government aims to reduce CO_2

emissions. We analyze how the optimal choice of carbon taxes is affected by the administrative cost incurred by the regulator (government). Using a simple model, we determine the optimal rates for emission and input taxes in the presence of administrative costs and which of these taxes should optimally be introduced. Moreover, we explore and interpret the scarce empirical evidence on administrative costs of taxation in the light of optimal carbon taxation. As empirical information on the role of implementation cost in the design of environmental policy is almost entirely lacking, we concentrate on what factors might be expected to determine those costs, based on studies about administrative costs outside the environmental policy area.

Although most formal analysis of environmental regulation ignores administrative costs, compliance costs, or transaction costs in general, a growing literature takes these issues seriously (see overview of Krutilla, 1999).[1] Several papers recognize that administrative costs may be important and rule out the use of emission taxes on these grounds. It is typically investigated which taxes could best replace or `approximate' emission taxes (Smith, 1992). Moreover, under some circumstances other taxes or tax combinations are even equivalent to perfect emission taxes (that is, emission taxes in a world without transaction costs). For instance, Xepapadeas (1999) reviews the conditions under which input taxes and emission taxes are equivalent. Eskeland and Devarajan (1996) show how the combination of mandated technology and output taxes approaches the ideal emission tax. Fullerton and Wolverton (1997) propose to combine output taxes and subsidies on clean goods, or more general two-part instrument systems of a deposit-refund nature, to replace the monitoring-costly emission tax.

The implicit assumption in these papers, however, is that emission taxes are prohibitively costly to administer and that other taxes have negligibly low administrative costs. We extend this approach by more explicitly taking into account administrative costs of all type of taxes, without assuming beforehand that emission taxes will always be the most costly type of tax from the administrative point of view. In particular we allow different tax instruments to feature differences in administrative costs, which, in addition, are endogenously dependent on the tax rates. Once other taxes as well as emission taxes are subject to significant administrative costs, it becomes unlikely that the first-best optimum can be reached. Hence, alternative tax systems should be considered that are no longer equivalent to perfect emission taxes.

Shortle, Horran and Abler (1998) study to what extent input taxes can approach perfect emission taxes if not all inputs that directly affect emissions can be taxed. We extend their analysis by explicitly taking into account administrative costs and allowing for the simultaneous use of emission and input taxes. We find that a mixed tax system might be (second-best) optimal. Schmutzler and Goulder (1997) arrive at a similar result in a model of mixed output and emission taxation that incorporates monitoring. We complement their analysis by investigating input taxation and by exploring in more detail how optimal tax rates in the presence of administative costs differ from Pigouvian taxes. Administrative costs in our model mainly represent costs stemming from monitoring, and thus our paper is related to the literature on monitoring and enforcement of environmental policy (see Cohen 1998 for a survey). As we are primarily interested in optimal taxation rather than optimal monitoring, we do not model monitoring in an explicit way.

The theoretical part of this chapter is also closely related to the chapter by Fullerton, Hong and Metcalf (1999) in this volume. The two chapters complement each other in various respects. Both chapters compare ideal emission taxes with alternative taxation, but differ with respect to the production structure and the government budget constraint. First, Fullerton et al. analyse a model in which there is a on-to-one correspondance between input use and emissions. Input taxes and emission taxes are therefore equivalent, but output taxes provide an (imperfect) substitute form of taxation. In contrast, our model separates input use from emissions, and considers abatement explicitly. Accordingly, we allow for three ways to reduce pollution, *viz.* output reduction, input reduction and abatement. We study input taxation as an (imperfect) substitute for emission taxes. Second, whereas Fullerton at al. consider a second-best world with a distortionary labor tax for revenue-raising purposes, the second-best nature of policies considered here arises because of administrative costs. Thus, the present chapter abstracts from tax-interaction effects due to recycling effects.

The structure of our paper is as follows. First, we explain the nature of the trade-off involved if the implementation cost of corrective taxes, in particular administrative costs, are considered explicitly. Second, we analyze a stylized model that incorporates both emission and input taxes to sort out critical determinants that shape this trade-off. Finally, we evaluate both explicit and implicit carbon taxation in OECD countries in terms of the trade-off and suggest some opportunities for welfare improving carbon tax policies. Note in advance, that taxing carbon inputs is not equivalent to taxing CO_2 emissions as is sometimes suggested. Although a close linkage exist between the carbon content of energy products and CO_2-emissions, this is not a fixed chemo-technological relationship as several opportunities for carbon abatement or removal exist (Holloway et.al., 1996).

2. The trade-off between incentives and administrative costs

In this section we argue that the administrative cost argument per se is not sufficient to rule out the implementation of emission taxes. In the presence of administrative costs, the costs *and* benefits associated with each specific type of tax should be compared. First, we hypothesize which factors influence the shape of the administrative cost curve. Next, we show why administrative cost introduce such a general trade-off between cost and benefits of different implementation strategies. We also develop some useful terminology.

2.1. Administrative costs

We define *transaction costs* as the costs associated with the tax assessment, collection and enforcement, and all other costs incurred by any party to enable, faciliate, and ensure transactions from tax payers to tax authorities (Vollebergh, 1995). An alternative term that we will use is implementation costs. The terms include ex-ante costs (e.g. cost of exclusion) and ex-post costs (e.g. monitoring cost). It is common to categorize these costs further into cost for the government (tax receiver), or *administrative cost*, to handle forms and enforce compliance, and the cost for the tax liable agent (tax payer), or *compliance cost*, to carry out the obligations of calculating and paying the tax (see Sandford *et al.* 1989). In our analysis we concentrate on administrative cost.[2]

Administrative costs of a particular tax are closely related to the base to which the tax is applied. The tax base usually varies with the type of tax. For example, an emission tax taxes physical volumes of hazardous substances, while an input tax taxes such substances indirectly, for instance through its use as (intermediate) inputs. In turn, these differences induce both tax authorities and tax payers to set up and maintain different systems for collecting and processing information about the tax, that is, to record how much is emitted or how much input is used, in order to be able to calculate total tax payments due.

One important characteristic of the tax base that determines (differences in) administrative costs is the number of agents liable to the tax. A large number of taxable legal units implies a large implementation cost for the tax agency since each unit requires separate treatment. Taxing a particular pollutant that is emitted by many producers may be associated with large administrative costs. Taxing the inputs from which the pollutant arises as a by-product may be associated with significantly lower administrative costs. For instance, inputs need no longer be taxed at the points of consumption, but can also be taxed at the point of delivery, such as gas stations or distributors of electricity. Hence, switching from emissions to inputs as the tax base could change administrative costs.

Note that the difference in administrative costs is independent of the induced regulatory effect. It is a difference in the *fixed cost* component of administrative cost. This regards the set-up cost and part of the cost to run the information system. Each liable unit submits its own tax form. The cost of processing forms depends on the number of forms rather than the tax amount due. Nevertheless, this still leaves the possibility of economies of scale for a given type of tax. If the tax base can be broadened across a larger number of tax payers, the overall administrative cost per tax payer can be reduced. A second important determinant of administrative costs is measurability of the base. In most cases emission levels are likely to be more difficult to measure, report and record than input or output levels. Heterogeneity across industries and their technologies compounds to the complexity of a tax system. For instance, a tax base in terms of weighted units of measurement, rather than in terms of a single unit, may be expected to create higher administrative costs if firms use highly firm-specific technologies. One well-known example is NO_x-emissions from road transportation which depends on vehicle type, equipment, fuel type, driving patterns, etc. (see also Hoel, 1998, p.89).

Administrative costs are also likely to vary with the tax rates and the revenue raised. The possibility of evasion by tax payers asks for monitoring expenditures by regulators. The remark by Fullerton (1995, p.7) that many of the administrative costs "are `fixed' costs of calculating the tax base, not marginal costs of collecting more revenue by raising the rate of tax on a given tax base" seem to call for a qualification in this respect. The larger is the tax bill, the larger are the incentives to evade tax payment and the more attractive it is for the regulator to spend resource to reduce tax evasion.

Regulators usually have various strategies for monitoring and need to sort out the efficient choice of monitoring levels and techniques. A large literature on monitoring and enforcement studies this policy in detail (Cohen 1998). Here, we do not need to dig into this level of detail. With respect to environmental monitoring, we can safely assume that when the optimal mix of monitoring instruments is chosen, total cost of monitoring is increasing in the extent to which stochastic elements determine actual pollution, in the number of polluters, the variety of production and abatement techniques used, and in the difficulty of measuring emissions.

To sum up, no general shape can be assumed ex ante for different type of taxes. However, it seems fruitful to assume that both fixed and variable costs (varying with the tax rate) play a significant role. Both in theory and practice, we need a case-by-case approach to study the nature and implications of administrative costs.

2.2. The role of linkage

Efficiency of instruments to reach a certain policy goal is usually defined in terms of the extent to which the instrument increases social welfare. The most efficient instrument to hit a given target has the smallest gross welfare cost, where gross welfare cost[3] refers to the change in welfare apart from that arising from the reduction in the externality.[4]

In a first-best world without transaction costs, different instruments can be ranked in terms of efficiency by investigating their effect on private welfare. Things become more complicated in a world with transaction costs as both administrative cost and the linkage between regulatory aim, emission reduction, and the type of tax used to regulate play a role (Smith, 1992).[5] First of all, different type of taxes usually differ with respect to the directness of the incentive they provide to reducing emissions (assuming emission reduction reflects the goal of the government). Less direct taxation of the marginal damages caused by an individual pollutor causes an efficiency loss but may lower administrative costs. Furthermore, different instruments not only differently distort private welfare directly, but also indirectly through their implications for transaction costs. The usual gross welfare cost of taxation has to be supplemented by the transaction cost of the tax.

Before turning to how welfare analysis of environmental taxation is influenced by transaction cost, it is useful to clarify and precisize our terminology. We explicitly separate out the transaction costs from the total change in welfare associated with the use of a certain (tax) instrument. Hence, in our case of environmental taxation, we distinguish (i) administrative (transaction) costs, (ii) the welfare gain from an improvement in the environment, (iii) the "residual" welfare change, that is the gross welfare cost ignoring transaction costs. The latter component will be called "private gross welfare cost".[6] An instrument that has relatively low private gross welfare costs is called relatively privately efficient. Of course, in a world without transaction costs, efficiency just coincides with this notion of private efficiency, since gross welfare costs do not contain transaction costs.

Thus, the relative efficiency of different type of taxes can be measured with the following formula:

$$U = Y - T - D(E) \tag{1}$$

where U is social welfare of the representative agent, Y is gross private welfare, T is the welfare loss due to transaction (administrative) costs, and D is the damage from pollution. Let t_1 and t_2 be two different tax regimes that yield the same aggregate emissions: $E(t_1) = E(t_2)$. The private costs of t_1 are lower than those of t_2 if: $Y(t_1) > Y(t_2)$.

We do not need to discuss extensively the determinants of "private efficiency" here, since they are well-known from analyses without transaction costs. For example, the efficiency of a tax to internalize pollution externalities is larger if the individual's tax bill is more directly linked to the externality. Hence emission taxes are more (privately) efficient than input taxes. Also, efficiency requires that the effective tax rate on marginal contributions to damage (D) is equal across pollutors. Hence, an emission tax that applies to all polluters is (privately) more efficient than an emission tax with exemptions or a non-uniform emission tax.

As noted in the introduction, it is often argued that emission taxes are too costly to implement and that administrative costs provide a basic motivation for other (tax) solutions.[7] However, instead of simply *assuming* that such a shift away from emission taxes is optimal, we aim at explicitly deriving such a conclusion within a comprehensive welfare framework. A first step in this direction has been taken by McKay, Pearson and Smith's (1990) who hypothesize that a clear trade-off exists between shifts in the tax system to save on transaction costs on the one hand, and tax reforms that harness incentives and promote (private) efficiency, on the other hand. They assume that regulation that is linked less directly to the externality indeed saves on administrative costs, but that it comes at a cost for society by distoring private decisions more.

Figure 1 illustrates. The horizontal axis measures different tax systems with respect to the directness with which they address incentives to reduce damage. For example, an emission tax ranks high, an input tax ranks low. Taxes on different inputs rank differently, depending on the closeness of the linkage between input use and emissions subject to regulation. The vertical axis measures two components of utility. The figure compares a continuum of different tax systems. It is assumed that all of them yield the same level of damage D by appropriate choice of tax rates. The two curves represent the other two components of overall utility, transaction costs T and private utility Y, for each of the tax systems. Administrative costs T increase when taxation is better linked to emissions. The idea behind this is that more direct taxation implies less links to already existing procedures of the existing tax system. The (private) utility loss Y also increases with the linkage of taxation to emissions. The more direct taxation is, the larger (private) utility is for a given level of emissions.

INSERT Figure 1

The optimal tax system balances transaction costs and efficiency. In the figure, welfare is maximized by choosing an indirect tax that corresponds to points A and B. The complete switch to emission taxes is too costly: the associated increase in administrative costs would outweigh the gains from having a more direct tax with better incentives.

Figure 1 is hypothetical and suggestive. As noted before, we have to assess different tax proposals case-by-case. For example, if marginal administrative costs increase only slowly, emission taxes may be optimal despite the presence of administrative costs. Moreover, it is not guaranteed at all that the curves T and Y have nice convex and concave shapes respectively. Smulders and Vollebergh (1998), for instance, represent the linkage to pollution by the fraction of (symmetric) sectors that is liable to an emission tax, and find in a very simple setting that the Y curve first declines and then increases. In general, administrative costs introduce non-convexities because of their fixed-cost nature, and the conventional marginal approach to optimal taxation has to be extended.

Administrative costs have many dimensions. The government may affect administrative costs by varying the number of firms or sectors subject to the tax, the tax rates chosen for input and emission taxes, accuracy of measurability aimed for, and enforcement spending to reduce the (probability of) tax evasion, and so on. Each of these dimensions can be measured along the horizontal axis in a figure similar to Figure 1. Needless to say, each of these factors directly influences the overall welfare effect of implementing environmental taxes.

Not only the multi-dimensionality of administrative costs makes the simple diagram of

Figure 1 problematic. As Feldstein has pointed out long ago (Feldstein, 1976), a careful distinction should be made between the design of a tax system *de novo* and the reform of an existing tax system. This is true for its associated administrative system as well. Indeed, in practice every tax *reform* starts from a given tax and administrative system inherited from the past. This system determines the (short run) scope for welfare improving tax reform at low administrative cost (Smith, 1992; Vollebergh, 1995).

For instance, increasing existing taxes, rather than introducing new taxes might save on the "fixed costs" of administration and therefore on total administrative costs. Such economies of scale and scope are also attractive to exploit when designing environmental taxes. Levying environmentally motivated taxes on a base that is already taxed for other purposes, rather than introducing an entirely new emission tax, would certainly save on administrative costs. Furthermore, also economies of scope with the administrative system used for other regulatory instruments may arise. When implementing environmental taxes, the regulator could benefit from experience in related administrative procedures for operations already undertaken. Like Smith (1992), we label this use of existing administrative procedures and experience for new purposes "piggy-backing".

3. Critical determinants shaping the trade-off

This section develops a simple model along the lines of Kaplow (1990) and Shortle, Horran and Abler (1998) to compare emission taxes and input taxes in the presence of administrative costs. The aim of the regulator is to correct externalities from pollution. The presence of administrative costs implies that the regulator should deviate from the first-best

Pigouvian tax. Hence, administrative costs in itself cause policies to be second best. We abstract from other second-best issues. In particular, we assume that lump-sum taxes and transfers are available to the government, so that there is no revenue requirement that affects tax rates and we can ignore labour taxes.[8]

3.1. The model

We assume a given number of heterogenous sectors, indexed i. Production of one unit of final output q_i requires labour l_i and a single homogenous intermediate input x (in amount x_i). Moreover, firms can spend labour services on abatement a_i, which reduces emissions per unit of output e_i. The minimum labour requirement per unit of output equals $l_i(x_i)$. Labour and inputs are substitutes: $l_i' \equiv \partial l_i / \partial x_i < 0$. Emissions per unit of output depend negatively on abatement effort and positively on inputs: $e_i(a_i, x_i)$ with $e_{ai}' \equiv \partial e_i / \partial a_i < 0$ and $e_{xi}' \equiv \partial e_i / \partial x_i > 0$.[9]

Final good producers face a (sector-specific) emission tax τ_i and a (per unit) input tax (t_{xi}). Perfect competition prevails, and firms take the output price p_i as given. They maximize profits by choosing output, abatement and input levels. We normalize the wage to unity. The first order conditions can be written as:

$$p_i = l_i + a_i + e_i \tau_i + (p_x + t_{xi}) x_i, \tag{2}$$

$$1 \geq (-e_{ai}') \tau_i \text{ and } a_i \geq 0 \text{ waloe,}^{10} \tag{3}$$

$$p_x + t_{xi} + \tau_i e_{xi}' \geq -l_i' \text{ and } x_i \geq 0 \text{ waloe.} \tag{4}$$

Equation (2) says that price equals cost which in turn equals labour cost for production, labour cost for abatement, and taxes due per unit of output. Condition (3) states that with positive abatement levels, the marginal cost of abatement (on the left-hand side) equals the marginal benefits in the form of reduces emission tax payments (on the right-hand side). Condition (4) equates the marginal cost to the marginal benefits of input use. Marginal input costs consist of price of the input p_x, the sector-specific input tax t_{xi} and the induced additional emission tax payments. Marginal benefits consists of the labour saving in production.

The intermediate good is produced with labour only and subject to constant returns to scale. We choose units such that one unit of labour produces one unit of the intermediate. For simplicity we assume that the production of the intermediate input is non-polluting (but this can be easily modified in a way that is completely analogous to pollution in the final goods sector). Intermediate good producers face a price p_x which they take as given. Hence, their first order condition for profit maximization simply states that the price equals the wage which is normalized to one:

$$p_x = 1, \tag{5}$$

Equilibrium in the market for the input requires:[11]

$$X = \sum x_i q_i$$

where X is total supply of the intermediate good.

We impose a very simple demand structure by choosing a quasi-linear utility function with no cross-demand effects, and where the opportunity cost of labour is constant (and normalized to one). The utility function is:

$$U = \sum_i u_i(q_i) + l_0 - D(E) \tag{6}$$

where l_0 is leisure, D is damage from emissions, and E is aggregate emissions defined as

$$E = \sum e_i q_i . \tag{7}$$

Consumers take prices and emissions as given and maximize utility, subject to their budget constraint $\sum p_i q_i = L - l_0 + Z$, where Z are transfers from the government. The first order conditions read:

$$u_i{}' = p_i \tag{8}$$

The government collects tax revenue, pays civil servants for the tax administration (T) and rebates the remainder of tax revenue to households in a lump-sum fashion (Z). The tax administration employs T units of labour at wage $w=1$. The required administrative costs are sector-specific and depend on sectoral taxes and output levels.[12]

$$T = \sum F_i(I_{\tau i}, I_{txi}) + \sum V_i(\tau_i, t_{xi}, q_i) \tag{9}$$

where F represents the fixed cost of the tax system, and V represents the administrative costs varying with the size of the rates and bases of the tax system. Fixed costs are determined only by certain taxes being implemented or not. This is modeled by the dependence of F on indicator functions I_t, each of which takes a value 1 if tax t^*(e.g. τ_i) is positive and a value zero if the tax is zero. The natural restrictions we impose are $sign\ V_t{}'$ $= sign\ t^*$ for any tax t^*, that is both taxes and subsidies are costly to implement, and $V_i(0,0,q_i) = 0$, that is, all fixed costs are excluded from $V(\,)$.

The labour market clears. Labour endowment is fixed and given by L. Hence, we write:

$$L = l_0 + \sum(l_i + a_i + x_i)q_i + T \tag{10}$$

Substituting (7) and (10) into (6), we may write utility as:

$$U = \sum u_i(q_i) + L - \sum(l_i + a_i + x_i)q_i - T - D(\sum e_i q_i) \tag{11}$$

Totally differentiating utility, and substituting the first order conditions for firms' and households' maximization problems (2), (3), (4), (5) and (8), we obtain:

$$dU = \sum t_{xi} dX_i - dT - \sum (D' - \tau_i) dE_i \tag{12}$$

where $E_i \equiv e_i q_i$ is total emissions in sector i and $X_i \equiv x_i q_i$ is total input use in sector i. Equation (12) shows the welfare impacts associated with changes in input demands, transaction costs, and environmental quality. The first term on the right-hand side of (12) stand for the distortionary effect of excises on the goods market associated with input taxes. The last term reveals that a reduction in emissions ceteris paribus improves utility as long as the marginal damage is larger that the emission tax.

3.2. Optimal taxation

We can rewrite (12) so as to separate the three components of welfare as in (1):

$$dU = \sum \left[\tau_i dE_i + t_{xi} dX_i \right] - dT - D' dE \tag{13}$$

Equation (13) categorizes the welfare effect of any policy in the three components mentioned in section 2.2. The bracketed term on the right-hand side is the private gross welfare effect of the policy (in line with (1) to be denoted by dY), dT is the transaction cost of the policy, and $-D'dE=-dD$ is the environmental welfare gain. Note that the private gross welfare cost is a tax base effect. The change in each tax base times the tax rate corresponding to that tax base together determine this effect.[13]

In the presence of administrative costs, a necessary condition for optimality of the tax system is that the expression in (13) is zero. The government maximizes welfare, taking as given the reactions of households and firms to changes in taxes. It faces a two-stage decision problem: i) deciding which taxes to use (tax base decision), and ii) setting the appropriate tax level (tax rate decision).

Concerning the tax rate decision, we find conditions for optimal taxation by rewriting

(12) in terms of the total derivatives with respect to each of the taxes, and setting these expressions equal to zero.[14] For any tax $\hat{t}$ this condition reads:

$$\frac{dU}{d\hat{t}} = \sum \left[t_{xi} \frac{dX_i}{d\hat{t}} - \frac{dT}{d\hat{t}} - (D' - \tau_i) \frac{dE_i}{d\hat{t}} \right] \leq 0 \quad \wedge \quad \hat{t} \neq 0$$

waloe (14)

Equation (14) guides the tax rate decision, conditional on the tax being implemented.

Concerning the tax base decision, the regulator should compare utility levels associated with any combination of taxes implemented at the rate implied by (14). The optimal tax system may include non-zero taxes, set at the level implied by (14), as well as zero taxes, that is, taxes that are not implemented. For the latter taxes, equation (14) may be violated, that is, utility may *marginally* increase in this tax. Yet it is optimal not to implement these taxes. The reason is that, by construction, in an optimally designed tax system, setting any tax belonging to the latter catagory at the level implied by (14) -- and adjusting all non-zero tax rates such that they satisfy (14) -- decreases welfare (*non*-marginally) because of fixed administrative costs. Similarly, in an optimally designed tax system, switching the rate of any non-zero tax from the rate implied by (14) to a zero rate -- and adjusting all other non-zero taxes such that they satisfy (14) -- decreases welfare (*non*-marginally). Since fixed administrative costs play a role, the tax base decision is subject to non-convexities and no simple "smooth" optimality condition can be written down.

Instead of optimizing the overall tax system, a more practical issue is to find a welfare improving *tax reform*. Such an approach takes account of the fact that actual changes of the tax system are usually slow and piecemeal due to the role of the existing tax system (Feldstein 1976), and, as we like to add, its associated administrative costs. A change in an existing tax system is worth pursuing if this change entails an increase in welfare even if not the maximum level of welfare is reached. In particular, we are interested in the welfare effects of the introduction of a new tax, if some taxes already exist (as well as their associated tax administration). The obvious rule for a welfare-improving introduction of a new tax is that the net welfare gain from exploiting the newly introduced tax should exceed the fixed cost of introducing the tax. For any tax $\hat{t}$, this condition can be written as:[15]

$$\hat{t}^{*} = \hat{t}^{o} \quad if \quad \left[\int_{0}^{\hat{t}^{o}} \frac{dU}{d\hat{t}} d\hat{t} \right] \geq F_{t} \tag{15}$$

where $\hat{t}^{o}$ is the level of the tax that corresponds to (14) (that is the solution to $dU/d\hat{t}=0$, or the corner solution 0), $F_t \equiv dT/dI(\hat{t})$ is the "fixed cost" (set-up administrative cost) associated with introducing tax $\hat{t}$, $\hat{t}^{*}$ is the (second-best) optimal tax rate,[16] and we evaluate all total derivatives taking into account changes in other taxes so as to satisfy (14) for all other taxes.

As a benchmark, consider the (first-best) case without transaction costs, i.e. $T=dT=0$. As is well-known, the optimal emission tax then equals the marginal damage D' in each sector and all other taxes should be zero.[17] This can be immediately seen from (12). Indeed (14) is satisfied for these tax rates. Under the usual conditions on utility and production functions, the tax base optimality condition is automatically met since fixed costs do not play a role and the maximization problem is convex. Starting from a situation without any taxes, introducing the emission tax improves welfare.[18]

The first-best outcome may be realized in some special cases even if transaction costs play a role. Obviously, if transaction costs are associated with other taxes, but not to emission taxes, the Pigouvian tax should still be implemented. The other way around, if transaction costs apply to emission taxes only, and other taxes can be implemented without such costs, a first-best outcome may arise provided that other taxes (or tax combinations) are equivalent to emission taxes with respect to their incentive effects ("private efficiency"). For example, if the emission input ratio is fixed, an input tax can bring about the first best outcome.[19]

A second-best situation arises when other taxes also involve transaction costs or when other instruments are privately less efficient than emission taxes. Once transaction costs play a role, it is no longer guaranteed that emission taxes should be uniform, nor that output or input taxes should be excluded. Most of the literature on second-best optimal environmental taxation concentrates on cases in which other taxes (taxes on output or inputs) can replace emission taxes without loss of incentives and without administrative costs (see, for example, the double dividend literature, De Mooij 1999).

If administrative costs are mentioned as a reason not to use emission taxes, the most common case in the literature is the one where emission taxes are too costly to be implemented because of transaction costs associated with emission taxes but not with other taxes (the most discussed case is non-point pollution, see Xepapadeas 1999). Our model allows for more subtle impacts of administrative costs by considering administrative costs throughout the entire tax system and taking into account that administrative costs may endogenously vary with tax rates. To investigate these in more detail, we consider some special cases.

3.3. Pure emission taxes

Let us first focus on emission taxes by considering the case where all other taxes are ruled out. Note that we cannot simply suppose that only emission taxes are used, but that we have to explain whithin the model why this is so. We will give this explanation in the next subsection and concentrate here on the optimality conditions for emission taxes only.

Evaluating (14) for an emission tax in sector i, we find that the following optimality conditions should hold:

$$\frac{dU}{d\tau_i} = -\frac{dT}{d\tau_i} - (D' - \tau_i)\frac{dE_i}{d\tau_i} \leq 0 \quad \wedge \quad \tau_i \geq 0 \quad \textit{waloe} \tag{16}$$

Hence, if implemented, the optimal emission tax reads:

$$\tau_i^o = \max\{\, 0 \,,\; D' - \frac{dT/d\tau_i}{-dE_i/d\tau_i} \,\} \tag{17}$$

This tax should be implemented if the total welfare gain exceeds the fixed administrative cost, see (15). We approximate the welfare gain by a second order Taylor expansion, evaluated at $\tau_i = \tau_i^o$. The optimal tax τ_i^* is given by

$$\tau_i^* = \tau_i^o \quad \text{if} \quad \frac{1}{2}\left[-\frac{dE_i}{d\tau_i}(\tau_i^o)^2 + (\eta_{Ei} + \eta_{T\tau i})\frac{dT_i}{d\tau_i}\tau_i^o \right] \geq F_{\tau i}$$

(18)

$$\tau_i^* = 0 \text{ otherwise}$$

where η_E and $\eta_{T\tau}$ are the positively-defined elasticities of $dE/d\tau$ and $dT/d\tau$ with respect to τ.

Conditions (17) and (18) reveal two cases in which it is optimal *not* to use emission taxes in a particular sector because of administrative costs. The first case is the case in which the *fixed* costs of administering the tax are large relative to the total potential gains, see (18). The gains are small indeed if emissions are insensitive to the emission tax, that is, if abatement *and* changes in the input mix are expensive ($dE_i/d\tau_i$ small), if the marginal damage (D') is small, and if marginal administrative costs ($dT/d\tau_i$) are large.[20] A second case in which a sector should be optimally exempted from an emission tax is the case that *marginal* administrative costs for the sector are relatively large, such that, for any small increase in the sector-specific emission tax, higher administrative costs more than offset gains from the induced emissions reduction ($dU/d\tau_i < 0$ for any τ_i so that $\tau_i^o = 0$).

Figure 2 illustrates the case of emission taxes in terms of the trade-off between efficiency and administrative costs (see section 2). Private gross welfare, Y, is maximized for zero emission taxes, since -- loosely speaking -- emission taxes impede free market forces. However, they reduce damage D and hence improve social welfare. In a first-best world without administrative costs, the Pigouvian tax τ_i** maximizes welfare $Y-D$. In the presence of administrative costs T, the gross welfare cost of emission taxation (that is, the effect on $U-D$) is higher and rises more steeply with tax rates. The (second-best) optimal tax maximizes $Y-T-D$ and it can be easily seen that this tax is below the first-best tax. In panel b of Figure 2, transaction costs rise steeply with the tax rate and the fixed cost component is large. As a result the second-best optimal emission tax is zero.

INSERT Figure 2

How emission taxes should be optimally differentiated across sectors is also revealed by condition (17), conditional on being implemented. Note that the optimal tax equals marginal damage minus a correction term that is proportional to marginal administrative costs. The optimal tax equals the Pigouvian tax if marginal administrative costs are zero ($\mathrm{d}T/\mathrm{d}\tau_i=0$). The gap between optimal taxes and the Pigouvian tax widens if administrative costs rise steeply with tax levels and if emissions are not very sensitive to emission taxation. The latter may arise because of a low elasticity of demand (it is hard to accomplish emission reductions by cutting demand) or because the emission intensity is not very sensitive to emission tax changes (steeply rising abatement and input substitution costs). To clarify this, we decompose the emissions reduction effect of the tax, that emerges as the denominator in (17), into these three effects:

$$-\frac{dE_i}{d\tau_i} = \epsilon_i + \alpha_i + \lambda_i \xi_i \tag{19}$$

where

$$\epsilon_i \equiv -\frac{dq_i}{d\tau_i} e_i = \left(-\frac{dq_i}{dp_i} \right) e_i e_i \tag{20}$$

$$\alpha_i = -q_i \, e'_{ai} \, \frac{da_i}{d\tau_i} \tag{21}$$

$$\xi_i = -q_i \, \frac{e_i}{x_i} \, \frac{dx_i}{d\tau_i} \tag{22}$$

$$\lambda_i = e'_{xi} x_i / e_i \tag{23}$$

that is, ϵ represents the effect of emission taxes on emiss ons through changes in demand, α measures the direct effect of emission taxation on emissions through abatement, and $\xi\lambda$ measures the analogous effect through input reduction (the reason to separate ξ and λ becomes clear in the next subsection).

So far, we have assumed that administrative costs rise with tax rates because incentives to evade increase with the tax rate, thus raising the cost for the tax authority to administer the tax. The opposite, however, is possible as well. Using a partial-equilibrium model, Polinsky and Shavell (1982) find that the optimal emission tax in the presence of administrative costs may be larger than the Pigouvian tax. The argument is that a higher emission tax saves on transaction costs if administrative costs depend on the number of tax paying firms and if an increase in the emission tax reduces market demand and the number of firms. In our set-up the number of firms is indeterminate because of the constant returns to scale production functions, but the equation immediately shows that Polinsky and Shavell's result also applies here if administrative costs decrease with the tax rate, that is if $dT/d\tau_i < 0$.

3.4. Input taxes: the role of linkage

To investigate the trade-off between emission taxes and input taxes, we first consider sector-specific taxes on emissions (τ_i) and on the use of input x (t_{xi}). Evaluating (14) for these taxes, we find:[21]

$$\tau_i^o = \max \left\{ 0 \,,\; D' - \frac{dT/d\tau_i}{\epsilon_i + \xi_i \lambda_i + \alpha_i} - \left(\frac{\epsilon_i + \xi_i}{\epsilon_i + \xi_i \lambda_i + \alpha_i} \right) \frac{x_i}{e_i} t_{xi} \right\} \tag{24}$$

$$t_{xi}^o = \frac{e_i}{x_i} \left[(D' - \tau_i) \left(\frac{\epsilon_i + \xi_i}{\epsilon_i + \xi_i \beta_i} \right) - \frac{dT/dt_{xi}}{(x_i/e_i)(\epsilon_i + \xi_i \beta_i)} \right] \tag{25}$$

where

$$\beta_i = \frac{e_i}{x_i}\frac{dx_i/dt_{xi}}{dx_i/d\tau_i} = \left[\lambda_i + \left(\frac{-e'_{a_i}}{e'_{aa_i}}\frac{x_i}{e_i}\right)e''_{ax_i}\right]^{-1} \tag{26}$$

Note that ξ measures the direct effect of input taxation on emissions,[22] λ measures the elasticity of the emission function with respect to input use, and β measures how much input use is more sensitive to input taxation than to emission taxes.

According to (24), input taxes can serve as environmental taxes and reduce the need for explicit emission taxes. Note that the first two terms are the same as in (17) after substitution of (19). The smaller is the direct emission tax effect $\epsilon+\lambda\xi+\alpha=-dE/d\tau$, the larger is not only the effect of marginal administrative costs on optimal emission taxes, but also the larger is the scope for input taxes to replace emission taxes as appears from the third term in (24). Indeed, with high marginal administrative costs of emission taxes, input taxes only should be used as environmental tax and should be set according to (25) with $\tau_i=0$, which can be written as:

$$t_{xi} = \left(\frac{dE_i/dt_{xi}}{dX_i/dt_{xi}}\right)D' - \left(\frac{dT/dt_{xi}}{-dX_i/dt_{xi}}\right) \tag{27}$$

Note that inputs should then be taxed according to their marginal emission content dE_i/dX_i times marginal damage D' corrected for administrative costs as a result of changes in input use. (Of course we must make the provision that in the presence of large fixed administrative costs, such that (15) is violated for t_{xi}, the input tax should not be implemented.)

Replacing emission taxes by input taxes reduces efficiency. Input taxes distort the input mix and fail to provide direct incentives for abatement. Only if the input to emission ratio is constant and there are no abatement possibilities, then input taxation and emission taxation are *equivalent* in the absence of transaction costs. This corresponds to e_i/x_i = constant, $\lambda=\beta=1$, and $\alpha=0$. With an interior solution, conditions (24) and (25) can then be rewritten as:

$$D' - \tau_i - t_{xi}x_i/e_i = \left(\frac{1}{\epsilon_i+\xi_i}\right)\frac{dT}{d\tau_i} = \left(\frac{1}{\epsilon_i+\xi_i}\right)\frac{dT}{d(t_{xi}x_i/e_i)}. \tag{28}$$

With a fixed emission input ratio, input and emission taxes would be equivalent in the absence of administrative costs (as is well-known, see e.g. Xepapadeas 1999). Indeed, according to (25), with zero marginal administrative costs, any combination of taxes such that $\tau_i+t_{xi}x_i/e_i=D'$ would achieve the first best optimum. This implies that the two taxes are equally efficient in terms of the sum of gross private welfare and the environmental benefit (see section 2). Hence, transaction costs considerations entirely determine the choice between the two taxes.

Differences in (fixed and/or variable) administrative costs across tax instruments remove the indeterminacy in the optimal tax choice. First, if fixed administrative costs differ across the two taxes but administrative costs are not affected by tax rate levels, to satisfy the "entry-condition" only the tax with lowest fixed administrative cost should be introduced, either $\tau_i=D'$ or $t_{xi}x_i/e_i=D'$. Note that the effective tax on pollution equals marginal damage (the Pigouvian tax). Second, when both tax rates increase administrative costs, the effective tax on pollution ($\tau_i+t_{xi}x_i/e_i$) should be smaller than marginal damage D'. When, in addition. the sum of fixed costs of administration for the two taxes are sufficiently small to justify the introduction of both taxes, the taxes should be set so as to minimise variable administrative costs, as appears from the second equality in (26).

In the general case of variable and sector-specific emissions per unit of input, input taxes are less efficient than emission taxes. Hence, if at the same time administrative costs for emission taxes are higher, efficiency and administrative costs may be optimally traded off by choosing a *mixed system* of input and emission taxes. Solving (24) and (25) for an interior solution, and for simplicity assuming that abatement and input use separately affect emission ($e_{ax}''=0$ so that $\beta=1/\lambda$), we obtain:

$$\tau_i^o = D' - \frac{1}{\Delta_i}\left(\frac{\lambda_i}{\xi_i}+\frac{1}{\epsilon_i}\right)\frac{dT}{d\tau_i} + \frac{\lambda_i}{\Delta_i}\left(\frac{1}{\xi_i}+\frac{1}{\epsilon_i}\right)\frac{dT}{dt_{xi}} \tag{29}$$

$$t_{xi}^o = \frac{e_i}{x_i}\left[\frac{\lambda_i}{\Delta_i}\left(\frac{1}{\xi_i}+\frac{1}{\epsilon_i}\right)\frac{dT}{d\tau_i} - \frac{\lambda_i}{\Delta_i}\left(\frac{1}{\xi_i}+\frac{\lambda_i}{\epsilon_i}+\frac{\alpha_i}{\xi_i\epsilon_i}\right)\frac{dT}{dt_{xi}}\right] \tag{30}$$

where
$$\Delta_i = (\lambda_i-1)^2 + \left(\frac{1}{\epsilon_i}+\frac{\lambda_i}{\xi_i}\right)\alpha_i > 0. \tag{31}$$

Δ_i measures the "efficiency edge" of emission taxes over input taxes. Indeed with a constant emission input ratio ($\alpha=0$ and $\lambda=1$), we have $\Delta=0$, and (29)-(30) collapse to (28). The efficiency edge of emission taxes increases in abatement possibilities α and in $|\lambda-1|$. We call this latter expression the extent of linkage between emissions and inputs. The closer is the elasticity of emissions with respect to inputs (λ) to unity, the closer is the correspondence between inputs and emissions and the more efficiently can input taxes mimic emission taxes. Equations (29) and (30) reveal that marginal administrative costs are less important to determine the optimal tax rates if the efficiency of emission taxes relative to input taxes (Δ) is larger, i.e. if the more abatement possibilities abound (α larger) and emissions are more closely linked to inputs (λ closer to one).

3.5 Conclusions

To internalize environmental externalities in the presence of administrative costs, pure emission taxes are optimal only under specific conditions. These conditions include (i) low fixed administrative costs, (ii) not too steeply rising administrative costs (as a result of increases in emission taxes) relative to marginal damage and direct emission reduction effect of emission taxes, and (iii) relatively low incentives effects from alternative environmental taxes (taxes on polluting inputs) to reduce emissions. The optimal second best rate of emission taxes falls short of marginal damage.

Input taxes may serve indeed serve as (optimal) environmental taxes. With close linkage between input use and emissions, and if abatement of emissions (as an alternative means to reduce the pollution intensity of production besides changing the input mix) is relatively costly, taxes on polluting inputs may supplement emission taxes that fall short of marginal damage to internalize pollution externalities more fully. In this case a mixed system of emission taxes and input taxes is optimal, essentially because it saves on administrative costs with only moderately affecting incentives to reduce emission. If linkage is close and abatement expensive, and if also administrative costs associated with input taxation are sufficiently low relative to administrative costs associated with emission taxation, input taxes should fully replace emission taxes.

4. Carbon taxation and administrative costs

In this section we assess existing and potential environmental taxes relevant for climate change policy, in particular through carbon taxation. We argue that current policy (proposals) can be substantially improved if the trade-off between incentive regulation and administrative costs is explicitly taken into account. We concentrate on the explicit carbon taxes introduced in a number of European countries since the beginning of the 1990s. We first review relevant facts on existing carbon taxes, then present evidence on administrative costs, next assess current carbon taxes, and, finally, discuss scope for improvement.

4.1 Carbon taxes in practice

Since the early 1990s, taxes are considered seriously to combat climate change, in particular carbon taxes that would curb CO_2-emissions (e.g. Pearce, 1991; Cnossen and Vollebergh, 1992; Poterba, 1992). The debate in Europe was strongly influenced by a proposal of the European Commission (see COM(92)226) for a hybrid EU-tax on energy/CO_2 to be implemented at the European level. The basic idea behind this proposal is to bring the (minimum) rate structure more in accordance with the carbon content across currently taxed energy products, mainly hydrocarbon fuels, as well as to extend the carbon tax base to energy products that are not yet subject to an excise. The same idea is also behind the carbon taxes actually implemented in several European countries.

INSERT Table 1

Thus the aim is to raise the implicit taxation of carbon at the margin. As is well-known CO_2 emitted per kind of fuel differs considerably (see Table 1). Clearly, oil emits less carbon than coal does. Natural gas, in turn, is cleaner than oil. The obvious implication is that emission intensities also can be reduced by internalizing the respective carbon contents in the price of each kind of fossil fuel. By differentiating the fossil fuel excise by carbon emission coefficient instead of energy content coefficient, or even a hybrid coefficient, the consumption of carbon is put at a disadvantage *at the margin*. Thus, users would be induced to substitute oil for coal and natural gas for coal and oil, and, further, nonfossil fuels for fossil fuels.

However, the EU proposal was never implemented due to considerable resistance of industry and specific countries like the UK. Despite this failure to implement an EU-wide carbon tax, several individual European countries have introduced explicit carbon taxes (see also Table 2). Finland, at that time not a Member State, was the first country to impose a CO_2-tax in 1990. This environmental tax is additional to an excise tax (basic duty) and calculated according to the carbon and energy content of the energy products. Furthermore, it is imposed on primary energy inputs, including heavy fuel oil, LPG, coal and natural gas.

INSERT Table 2

Other Nordic countries followed soon: Norway and Sweden in 1991, and Denmark in 1992. The CO_2-tax in Norway affects the use of mineral oils, coal, natural gas and petroleum on the continental shelf. Interestingly, CO_2 tax rates differ between these products with petroleum and natural gas (sic!) taxed most heavily (per unit CO_2) and heavy fuel oil and coal at a much lower level. Also electricity production and consumption is taxed. The CO_2 tax of Sweden applies to primary energy inputs, such as natural gas and coal, but also includes heavy fuel oil and gas oil. The Danish tax is levied on all energy products with the exception of petrol and amounts to a tax rate reform from $/liter to $/unit carbon. A tax reform in 1996 explicitly distinguishes energy consumption in industry according to categories of room heating, light processes and heavy processes with tax rates varying accordingly.

The Netherlands already have an environmental tax on fuels (hydrocarbon oils) since 1988, with the CO_2-component added in 1990. However, only the regulatory tax on energy from 1996 was specifically aimed to achieve carbon emission reduction by households and small firms. The tax base included primary energy products while the tax rates correspond to the proposed CO_2-energy tax of the EU. Also Austria imposed an energy tax on electricity and natural gas in 1996.

In a recent analysis of these carbon taxes, Ekins and Speck (1999) show how *exemptions* for industry are used to provide considerable tax relief for certain sectors facing considerable `competitive pressure'. Tax relief is usually established by applying lower or zero carbon tax rates or systems of rebate for specific industries which use these products as inputs (often in addition to exemptions already provided for already existing energy excises). Sometimes a maximum is set to the tax liability for specific energy-intensive industries, like the steel industry, usually in terms of a percentage of sales value (this provision was also envisaged in the hybrid EU-tax). Finally, improvements in energy-efficiency are promoted by explicitly targeted tax reliefs. As a result, nominal and effective tax rates for specific industries tend to differ considerably.

INSERT Table 3

Table 3 shows for several energy products that both Sweden, Denmark and Norway apply much lower effective rates for specific industries. Only Finland does not apply lower rates, although this heavily debated now. Furthermore, it is remarkable that considerable differences exist in tax rates per ton CO_2 across energy products, especially in Norway. Norway, like Finland, exempts LPG, while coal and natural gas are taxed (much) more heavily than is oil.

The carbon taxes in the Nordic countries are quite similar to the original proposal for a common carbon tax within the EU jurisdiction (see COM(92)226 and its evaluation by Smith and Vollebergh, 1993). This tax is aimed to lower the use of fossil fuels in proportion to their carbon content. The European carbon/energy tax, the first explicit uniform Union-wide tax, was proposed as an additional tax on top of the (non) existing taxes. Since the tax base would include several energy products that were not subject to tax before, the proposal also broadens the tax base of current energy taxes. Thus, an incentive would be provided for industry and consumers to reduce their use of carbon-based energy, and hence for CO_2 emissions to be reduced.

As this EU proposal was never implemented, a later proposal was more closely linked to the existing drafts on Mineral Oil Excise Harmonization (see COM(95)172) and therefore concentrated effort on a much smaller carbon tax base (see Table 2 and its evaluation in Vollebergh, 1995). In 1997 the European Commission came up with a new proposal to use the directive on excise harmonization across EU countries more specifically for the purpose of carbon tax policy (see Ekins and Speck, 1999, for further details). According to this proposal the minimum target levels for the existing excise taxes on mineral oils should be raised in three steps, while also small minimum rates on primary energy products, like coal and natural gas, are proposed, as well as a tax on electricity (see Table 2 for the proposed rates for 2000).

All EU proposals allow for *exemptions*. In the 1992 draft directive an exemption would depend on a case-by-case assessment of the degree of competitive pressure faced from countries not taking equivalent measures. Member states could grant firms a reduction in the carbon tax payable (through an exemption or an equivalent refund), if energy costs (minus value added tax) amount to at least 8 per cent of value added. In addition, the proposed directive in 1992 also allows for reductions or refunds if firms invest in energy efficiency improvements or abate carbon.

Summarizing, the recently introduced (unilateral) carbon taxes in several European countries indeed broaden the existing (implicit) carbon tax base by including specific primary energy products, like coal and natural gas. These products were usually not taxed before. Usually the agents who pay the tax are mainly (downstream) distributors of final fuel products or electricity at the point of delivery to households, small and large businesses. Furthermore, with the exception of Norway, the tax rate is equal per unit carbon across energy products and is interwoven with (existing) energy excise rates, if available. Finally, with the exemption of Finland, all Nordic countries choose to exempt *specific agents, mainly energy-intensive industries, by applying (much) lower or even zero carbon tax rates.

4.2 Evidence on administrative costs

Empirical estimation of the administrative costs of different environmental tax policies is, to our knowledge, absent. The same holds for compliance cost with only a few exceptions, such as Fullerton's (1996) analysis of the Superfund's Corporate Environmental Tax. Also direct estimates of the administrative costs of carbon taxes are lacking. Therefore this section reviews the existing evidence on the administrative costs of taxation in general, and the factors that appear from this literature as relevant for the level of these costs.

The lack of evidence on administrative cost is not surprising as only few explicit environmental taxes exist in practice (see for example Fullerton 1996). Explicit environmental taxes are those for which the legislator has expressed explicitly the aim that this tax should serve some environmental purpose. However, the analysis of environmental taxation and administrative cost would be severely restricted if one limits the analysis to explicit environmental taxes only. As shown in the previous section, also input taxes are important for environmental purposes. Indeed, taxes like excises and VAT matter for the environment (taxes on petrol and motoring), as well as facilities in the income tax (tax allowances for commuting expenses, mine exploration, pollution control equipment, etc).[23] For carbon taxation, current energy taxes, like excises on hydrocarbon oils, are the most important as they are likely to have an impact on emissions through changes in input mix and changes in demand for energy.

Unfortunately, empirical information on the administrative costs of other taxes is scarce as well. Only a few studies exist.[24] Many problems exist regarding how to measure these costs, especially their absolute levels. One issue is the significant element of transferability between compliance costs and administrative costs (Sandford *et al.* p. 203). Also, difficulties arise in categorizing operating costs. For instance, the (marginal) cost of transferring forms is highly influenced by the level of integration with existing administration.

Table 4 summarizes the results of Sanford *et al.* (1989). Both administrative and compliance costs of each tax are expressed as a percentage of the revenue raised by the tax. Administrative cost vary from 0.12% for the Petroleum revenue tax to 1.53% for the income tax. The overall picture is clear: income tax and VAT are relatively expensive to administer, while especially excise duties are inexpensive in terms of administrative costs. This finding is also in accordance with findings in other studies: although the OECD (1988) provides lower estimates on the total cost of VAT (between 0.40 and 1.09%), this study also ranks income taxes as being relatively most expensive and excises (interpreted as single-stage general consumption tax) as being least expensive to implement (total cost around 0.5%).[25]

INSERT Table 4

As Sandford *et al.* also include compliance costs, we can test whether we bias our analysis by focusing on administrative costs only. On average, compliance costs are 3 times higher than administrative costs. Compliance costs are relatively higher only for VAT. It is more important for our purposes, however, that the ranking of different types of taxes according to implementation costs is the same whether we use administrative costs or total operating costs. Hence, the basic picture is not influenced by adding compliance cost. The similar relative importance of compliance, and administrative costs across different taxes suggests that administrative costs can be taken as being representative for both.

We now turn to the factors that determine the level of the administrative costs (see also section 2.1). Administrative cost as a percentage of the total revenue raised by a tax is not very relevant for the choice between different type of taxes. It is more important to know their fixed and variable cost characteristics, and how they are affected by the choice of tax base and rate. Unfortunately, such information is available only in a very limited way. As far as the role of the number of tax payers is concerned, empirical information on the administrative cost of VAT indeed suggests the existence of economies of scale as far as the number of tax payers is concerned. In that case costs per registered business should be relatively lower in countries with a low small-business exemption than in countries with a high exemption: broadening the tax base across a larger number of tax payers reduces overall administrative cost per tax payer. Cnossen (1994, p.1652) notes that the data observed by OECD (1988), with the exception of Denmark, indeed fit this observation.

Another important determinant of administrative costs is measurability of the tax base. One factor here are differences among tax payers. Some tax payers will be more expensive to tax due to specific characteristics that have to be checked. Again an interesting example is the small-business exemption in VAT. The larger the exemption, the smaller the number of registered businesses, and the lower the absolute levels of administrative cost (see Cnossen, 1994, p.1652). Usually exemptions will be responsible for higher administrative cost. For instance, to give a tax rebate to a particular industry requires extra excise officers to handle and check such claims. Of course, exemptions for specific agents can also lower administrative costs if the agent is neither liable for tax payment nor for a rebate. We did not find evidence for the assumption that more complex forms for calculating the tax base would raise administrative cost. Also no empirical studies have not tried to quantify the precise shape of the fixed and variable cost component of administrative costs of different tax types in relation to the use of differences in tax rates.

No decisive empirical information exist on the (general) shape of the transaction cost curve for different type of taxes, especially environmental taxes. Moreover, as observed by Cnossen (1994, p.1663), the findings of Sandford *et al.* (1989) on the comparatively high VAT compliance costs are in clear contrast with evidence on VAT compliance costs in Germany. Here the estimated cost are only a fraction of the costs observed for the UK, which is mainly explained by the much longer tradition and experience in Germany, and the integration of VAT with the administration of the business income tax. Thus, even if some information exist, the evidence seems to be dependent on local circumstances and institutional settings.

The implementation and enforcement of environmental taxes, however, has much in common with the operation of the age-old excises on alcohol, tobacco and petroleum products (Cnossen, 1977). Generally, these excises rely on quantitative measurement for assessment purposes, with compliance ensured through physical controls. Similar close controls should be exercised at points of import.[26] Thus, it seems safe beforehand not to expect always prohibitively high administrative costs for environmental taxes. This might be different only if the regulatory tax base asks for monitoring of emissions which are difficult to measure, and therefore require costly metering technology.

Furthermore, the change in administrative costs depends heavily on the sectors already subject to other existing taxes or environmental regulation. For instance, according to Hoornaert (1991, p.87), the physical control necessary for energy excises is very closely related to carbon taxes, while administrative controls for VAT are quite different and more time-consuming. The same might hold for other regulatory procedures which are already in force. Usually direct controls for environmental purposes also reflect tight supervision of technological processes and quantitative measurement. Thus, if closely linked production processes are already subject to monitoring, administrative costs need not be very high.

Summarizing, the level of administrative cost depends much on how emissions specifically relate to the production processes, their heterogeneity and the number of these processes included in the tax base. Using existing excises for environmental regulation might be a relatively cheap way of taxing bads since tax officers already have a lot of information required to operate the tax system.

4.3 Assessment in terms of the trade-off

As noted before, the overall effect on welfare of introducing `new' environmental taxes, like carbon taxes, should be compared to the incentives provided by the tax. An important result of our theoretical model is that input taxes offer an interesting alternative for emission taxes if three conditions are met (see the end of section 3.4 in particular). First, there should be a `clear' *linkage* between inputs and emissions. Second, only few possibilities must exist to abate carbon emissions separately. Third, administrative cost of emission taxes should be high. In this section we argue that these conditions are indeed met in the case of carbon taxation which supports the strategy chosen by the different countries applying these taxes. At the same time, however, the current design of the carbon taxes in practice leaves considerable room for improvements.

The first condition is related to the *linkage* issue (measured through $|\lambda-1|$ as part of the "efficiency edge" Δ_i in section 3.4). In the carbon case CO_2-emissions are indeed in a 1:1 correspondence to the carbon-content in energy products used as inputs (e.g. crude or refined oil products, natural gas and different types of coal). Moreover, (potential) harmful CO_2-emissions are mainly related to the consumption of fossil fuels in modern societies. Thus, rather than taxing each unit of carbon emitted separately, it is rational to use taxes on energy products which contain carbon to pursue climate change objectives. Such taxes on energy products provide indirect incentives, using the relationship between the burning of these products and transactions which can more easily be taxed. Thus instead of taxing the emissions from car exhausts, additional tax may be levied on petrol purchases, on the assumption that the environmental damage caused is proportional to the amount of petrol used.

This approach is indeed largely reflected in the carbon taxes applied in practice. They all take advantage of this fact by using carbon content of fuels as its tax base (although often a hybrid tax base is applied with a combination of both carbon ánd energy content). Thus coal-based energy production processes are put at a disadvantage compared to other fossil and non-fossil fuel energy products. The same holds for oil relative to natural gas and non-fossil fuels. This is entirely in alliance with the purpose of the tax: providing much better targeted incentives compared to an indirect excise tax on energy alone. However, applying differences in tax rates per unit of carbon, as in the Norwegian case, cannot be justified and the rate structure applied considerably weakens its incentive effect (e.g. coal is taxed at a much lower rate compared to natural gas which contains fewer units of carbon per unit of energy).

The second important condition is that only few possibilities should exist to abate carbon emissions separately (measured through α as part of the "efficiency edge" Δi). If emissions are very sensitive to emission taxation, that is if agents can abate CO_2-emissions easily, input taxes might become inefficient because they do not provide appropriate incentives for reducing carbon emissions directly. In other words, a loss in efficiency of input taxes can be expected only if direct carbon abatement is possible, though not stimulated by a tax levied on the *agents* who are responsible for these CO_2-emissions. With respect to the abatement of carbon emissions (`carbon disposal') indeed relatively few possibilities are available and almost none is actually employed.[27] Furthermore, these possibilities can usually be applied only on a rather large scale. Therefore they are outside the reach of small individual firms or households. Thus the use of input taxes in the case of carbon is indeed justified in this respect, in particular because the explicit carbon tax rates are considerably low.[28]

The third condition is that administrative cost related to emission taxes should be high, or, in other words, the cost of input taxation should be relatively small (see equations (29) and (30) in particular). Usually administrative cost of newly designed taxes are relatively expensive due to a fixed set-up cost element of monitoring activities. This also applies to excise taxes, whether they are emission or input taxes, even though they are cheap to administer compared with other type of taxes (see section 4.2). For that reason tax reform of existing taxes is very attractive for policy makers, as the effect on (marginal) administrative cost can be expected to be small. A rise of the *marginal* carbon tax rate is simply reached by using the existing implicit energy taxes on carbon, i.e. the existing energy excises. Thus, tax rate reform is sufficient, i.e. a reform of currently existing energy input taxes into taxes based on emission coefficients (see section 4.1).

Indeed, the strategy chosen by the Nordic countries when implementing carbon taxes, basically follows this logic. We tentatively checked which products and agents were already subject to energy excises in these countries in the pre-carbon tax period, say 1990.[29] Table 5 presents our results. We distinguish between three potential groups of tax payers: households (Hh), industrial consumers (I), and electricity generators (E). It is immediately clear from this table that the most important carbon-containing energy products consumed or produced in the Nordic countries were already subject to energy excises before the introduction of the carbon tax. The basic picture was that existing excises were levied on fuels consumed by households, with the exception of natural gas in Sweden and Norway (which is a small category anyway). The inputs of electricity were usually not subject to tax, in contrast to the delivery to consumers (both households and industries). Although many energy products are subject to tax, including even the products used as inputs in industry, it turns out that the industrial sector is often exempted or pays lower tax rates, especially energy intensive industries (refineries; steel and aluminium production).

INSERT Table 5

Thus, the effects on administrative cost of introducing carbon taxes on fuel content in these countries is dominated by the use of the existing energy excise administration. As long as this administration is also used for the carbon tax, one can safely assume a small rise in administrative costs. The only factor that might give an upward effect is the more complicated tax base calculations due to the integration of two instead of one indicator (both energy content ánd carbon content). The same holds for carbon tax exemptions, especially in the case of rebates. As noted before, rebates often complicate the tax and cause higher administrative costs. If, however, exemptions in the carbon tax also take advantage of these institutional set-up, additional administrative costs still need not be high (sunk cost element).

In all Nordic countries, however, the carbon excise is also imposed on new products, especially the production of electricity (use of inputs) and natural gas. Also coal seems to be taxed now on a more comprehensive basis. But the effects on administrative costs of these changes also seem to be limited. Like the existing excise systems for other energy products, tax administration can take advantage of the way in which final fuel products, like diesel or electricity, is usually delivered to consumers (both industry and households). The administration of energy excise taxes saves on the number of tax payers by using points of delivery (eg. fuel stations and energy distributors) instead of taxing all consumers separately. This is applicable in the case of natural gas (delivery through pipe lines), as well as in the case of coal (points of distribution). Thus, the broadening of the tax base implies only a small increase in the number of tax payers.

4.4 Scope for improvement

Although the current carbon tax strategy in the Nordic countries satifies the conditions for using input taxes instead of emission taxes, considerable scope for improvements seems to exist. The coverage of the carbon excises in the Nordic countries (as well as the Netherlands) is far from exhaustive, especially in terms of the *agents* subject to an effective tax. Exemptions are widely used, mainly motivated by concerns about international competiveness. Often energy inputs of domestic industries are taxed at lower rates or not taxed at all. Furthermore, the existing energy excises related to oil products are of the final fuel type, which implicitly exempts production of the fuels themselves. Also extraction of any fossil fuel is not subject to this tax (although other type of taxes ánd subsidies apply).

Our theoretical results suggest that sectoral differentiations in the tax rate are justified by administrative costs, if linkage and marginal abatement cost (MAC) differ among sectors. Exemptions can also be justified by differences in fixed administrative costs. A difference between linkage and MAC, as well as fixed administrative cost among sectors, seems to apply in the carbon case. However, current differentiation is exactly the opposite to what our model suggests as optimal. Dijkgraaf and Vollebergh (1997) have shown that this observation generalizes across OECD countries. In general, households face much higher taxes on average compared to industry. Furthermore, most OECD countries tax final oil products (diesel, gasoline) much more heavily compared to primary energy products on average (heavy fuel oil, natural gas and coal). In this respect the countries that introduced a carbon tax, already applied a much broader (implicit) carbon tax base compared to the other countries.

Thus the industries that are usually exempted now, mainly the energy-intensive industries (both producing energy products as energy-intensive products), are also the tax payers who can be taxed with lowest transaction costs *per unit emission*. In other words, the most important polluters (small number of tax payers consuming the larger part of fossil fuels) still do not pay any or only a very small amount of tax. The same holds for the choice to exempt certain energy products consumed by specific sectors, like coal by electricity generation. Finally, not taxing particular energy products that cause considerable carbon emissions, like coal, seems to be particularly unattractive.[30] Of course, issues of carbon leakage are of considerable importance here. If a country follows a unilateral strategy without any compensation for its carbon-exposed industries, import substitution could easily reduce the effectiveness of its carbon abatement policy. However, several mechanisms are available to compensate for these effects with small or even no negative effect on administrative costs, such as tax credits (Vollebergh et.al., 1997).

Another issue closely linked to the selectivity of coverage is that all explicit carbon taxes are based simply on the amount of carbon contained in the actual products. This implies that carbon emitted in the production processes producing those fuels is not taxed at all. As Pearson and Smith (1991, p.29) noted long ago, such a scheme gives an undesirable incentive towards the use of highly-refined fuel products, in which as much as possible of the carbon emissions have taken place before the excise is applied. Thus this tax will be less efficient at encouraging carbon-reducing fuel substitutions. According to Vollebergh (1995) it might be an efficient strategy in this case to use a materials balance approach to impute the amount of upstream carbon emissions that are related to energy products of the final fuel type.

A third possibility for improvement is to supplement current input taxes with incentives for abatement (introducing a mixed system of input and emission taxes). Although abatement of CO_2 emissions is very limited for small energy users, large industries and energy producers may have some opportunities for abatement that are less costly than separate abatement possibilities like carbon sequestration. Large-scale firm-specific investments are involved in these abatement projects. Emission taxes for energy producers may provide appropriate abatement incentives. Moreover, the administration costs for emission taxes in the energy production sector can be expected to be considerably lower than for small industry and households. Technologies are more homogenous, and the number of agents is small. For large energy-intensive industries, however, the competitiveness argument may prevent the implementation of emission taxes, since these taxes increase costs and require again compensation schemes. Alternatively, abatement subsidies decrease costs, and seem more feasible.

The most important step toward more efficient carbon policies is explicit coordination of carbon policies on EU, OECD or, better, world scale. Carbon leakage then no longer offsets unilateral carbon policies. Thus, exemptions of large energy-intensive exporting industries to restore international competitiveness would no longer be a reasonable strategy. Only then it is possible to initiate a full-fledged tax reform toward imposing carbon taxes on agents that have most options for abatement, contribute most to

CO_2 emissions, and for which the administrative costs involved are relatively smallest.

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Table 1 Characteristics of main fossil fuels

Fuel	Unit	Energy Content	Carbon Content	Tons of oil-equivalent	Normalized Carbon Content
		GJ	Ton	TOE	Ton/TOE
Coal	Metr. Ton	25-30	0.61	0.6	0.96-1.00
Crude Oil	Barrel	6.1	0.12	1	0.76-0.84
Natural Gas	1000 m3	9.6-10.7	0.17	8.0[1)]	0.56-0.64

1) Based on average above (8,37381) and under (7,535714) Gronings' gas

Source: OECD/IEA (1991)

Table 2 Excise taxation of energy products in countries applying carbon taxes, 1997 [1)]

Country	Petrol	Diesel	Gas oil	Heavy Fuel Oil	Coal	Natural Gas	Electricity
	ECU/1000 l	ECU/1000 l	ECU/1000 l	ECU/1000 l	ECU/ton	ECU/m^3	ECU/kWh
Denmark	533	321	236	266	160	0.03091	0.06719
Finland	616	307	50	38	29	0.02443	0.00533
Netherlands	579	302	47	16	0	0.00962	0
Norway	658	485	56	79	56	0.10897	0.00397
Sweden	597	337	210	217	144	0.12031	0.01316
EU minimum	337	245	18	13	0	0	0
EU prop 2000	450	343	37	23	13	0.01400	0.00200

1) CO_2 taxes as well as existing energy excises per unit of fuel are included

Source: Ekins and Speck (1999), Table 1, p.371

Table 3 Effective tax rates of explicit CO_2-taxes for some industries in the Nordic countries (in % of nominal tax rates)

Energy products	Sweden	Denmark	Norway	Finland
	Manufacturing industry	Heavy processes	Pulp/paper industry	All industry
Gas oil (heating)	0.50	0.24	0.50	1.0
Heavy fuel oil	0.50	0.23	0.50	1.0
LPG	0.50	0.25	0	0
Coal	0.50	0.25	1.0	1.0
natural gas	0.50	0.24	1.0	1.0

Source: own calculations based on Ekins and Speck (1999), p.380

Table 4 Relative administrative and compliance costs of different type of taxes

Tax or group	Administrative costs	Compliance Costs	Total Operating Costs
	% Total Revenue	% Total Revenue	% Total Revenue
Income tax	1.53	3.40	4.93
VAT	1.03	3.69	4.72
Corporation tax	0.52	2.22	2.74
Petroleum revenue tax	0.12	0.44	0.56
Excise duties (hydrocarbon oils; tobacco; alcoholic drinks)	0.25	0.20	0.45
Minor taxes (stamp duty; car, betting and gambling)	0.85	1.48	2.33

Source: Sandford *et al.* (1989), p.192

Table 5 Energy Excises Applying to Households, Industry and the Electricity Sector in the Nordic countries in 1990

Energy product	Sweden			Denmark			Norway			Finland		
	Hh	I	E	Hh	I	E	Hh	I	E	Hh	I	E
- Diesel	+	+	-	+	+	-	+	+	-	+	+	-
- Heavy fuel	-	+	0	-	+	0	-	+	0	-	+	+
- Coal	+	+	0	+	+	0	0	0	na	na	+	+
- Natural gas	0	0	0	+	na	na	0	0	0	+	+	na
- Electricity	+	+	-	+	0	-	+	+	-	+	0	-

Notes: Hh: Households; I: Industry; E: Electricity Generation;

\+ = tax; 0 = no tax; - = not used; na = not available.

Source: OECD *Energy Prices and Taxes*; OECD (1993); IFA (1993)

NOTES:

1. The relation between taxation in general and transaction costs is more widely analysed, see Slemrod and Yitzhaki (1998) for an overview.

2. Section 4.2, however, shows that administrative and compliance costs turn out to move together in practice, that is, taxes for which compliance costs are relatively important are also associated with relatively high administrative costs).

3. The term "gross welfare cost" is due to Goulder (1995).

4. This definition applies to corrective taxes. The gross welfare cost in case of revenue raising can be similarly defined as the change in welfare apart from that arising from relaxing the government budget constraint.

5. There is an interesting analogue between the current paper and the long standing issue in environmental economics of selecting instruments to improve ambient quality directly or indirectly through the reduction of emissions. It is well-known that linkage between emissions and ambient quality is often indirect, but the cost of ambient quality regulation can be prohibitive. Thus an interesting trade-off exist between the utility loss in terms of the directness of linkage on the one hand, and the cost of regulation on the other hand. We owe this point to Dallas Burtraw.

6. We realize that this term might be misleading, since transaction costs also affect (ultimately) private welfare. However, the term captures the fact that we focus on administrative costs that first affect the tax authority (and not directly private agents). Indeed of the three terms in (1), only the first captures direct changes in private welfare. The third term, the environmental gain, is a "public" component of the welfare change if the environment is assumed to be a public good. Alternatively, we could have used the

terms "frictionless gross welfare cost" and "frictionless efficiency".

7. In fact, Smith (1992) has shown that the basic idea can be traced back to the seminal paper of Diamond (1972).

8. We also abstract from output taxes and abatement subsidies. See Smulders and Vollebergh (1999) for the interaction between these instruments and administrative costs.

9. Furthermore, $e_{xx}''>0$, $e_{aa}''>0$, and $l''>0$. We ensure concavity by assuming $[l''+(-e_a')e_{xx}'']e_{aa}''-(-e_a')(e_{ax}'')^2>0$.

10. with at least one equality

11. To simplify notation, all summation sign refer to summation over all final goods sectors, unless stated otherwise.

12. Note that, by assuming linear sectoral separability, we ignore economies of scope as discussed in section 2.

13. See the analysis in Bovenberg and Goulder (1998, section 3.1).

14. Note that equations (2), (3), (4), (5) and (8) allow us to determine how a_i, x_i, q_i, p_i and p_x -- and hence also $l_i(x_i)$, $e_i(a_i,x_i)$, E_i, X_i, T and U -- depend on the tax rates.

15. This condition can be called the "entry condition" analogous to industrial organization models where firms enter if the operating profits (cf. welfare), measured at the optimal price (cf. tax), exceed the entry cost (cf. tax introduction/set-up cost).

16. To be precise, t^* is the tax that maximizes welfare given the set of taxes employed; $t^*=0$ if (15) is violated.

17. Solving the social planner problem for the case without transaction costs, we find the following optimality conditions: (i) $u_i'=l_i+a_i+x_i+e_iD'$, (ii) $1\geq -e_{ai}D' \perp a_i\geq 0$, (iii) $1\geq -l_i'-e_{xi}D' \perp x_i\geq 0$. Comparing these conditions to (2), (3), (4), (5) and (8) we find that

$\tau_i = D'$, $t_{xi} = 0$ implements the first-best outcome. As a special case, if $e_{ai}' = 0$ and $e_{xi}' = e_i/x_i$ $\forall i$, any combination of taxes that satisfies $\tau_i + (x_i/e_i)t_{xi} = D' \forall i$, also implements the first-best social optimum (input taxes and emission taxes are equivalent, cf. section 3.4).

18. For this case $\mathrm{d}U/\mathrm{d}\tau$ reduces to $(\tau - D')\,\mathrm{d}E_i/\mathrm{d}\tau$ which is positive for $\tau < D'$. Hence the left-hand side of the second inequality in (15) is positive while the right-hand side is zero and (15) is satisfied.

19. Similarly, *two-parts instruments* may do the job. If only one pollutant causes an externality and if all other outputs and inputs can be taxed at zero transaction cost, the first-best outcome can be reached (see Fullerton and Wolverton 1997). In the present model this would require a (sector-specific) taxes on output and input use and a (sector-specific) subsidy on abatement. Note, however, that optimality breaks down once more pollutants play a role.

20. To see this, substitute (17) into (18).

21. Note that $(x_i/e_i)^2(\epsilon_i + \xi_i\beta_i) = -\mathrm{d}X_i/\mathrm{d}t_{xi}$ and $(x_i/e_i)(\epsilon_i + \xi_i) = -\mathrm{d}E_i/\mathrm{d}t_{xi} = -\mathrm{d}X_i/\mathrm{d}\tau_i$.

22. It can be derived from (3) and (4) that $\mathrm{d}x/\mathrm{d}\tau_i = e_{ai}'(\mathrm{d}a_i/\mathrm{d}t_{xi}) + e_{xi}'(\mathrm{d}x_i/\mathrm{d}t_{xi})$.

23. Barthold mentions 51 federal tax code provisions for the US (Barthold, 1994) and the OECD in more recent inventories also mentions a much larger number of relevant taxes.

24. Sandford *et al.* (1989) analyse administrative and compliance costs of different taxes in the UK in 1986-1987. OECD (1988) discusses operating cost for consumption taxes relative to other taxes.

25. See the discussion in Cnossen (1994).

26. Note that the tax base of specific excises requires *physical* control due to the physical dimensions in which they are usually expressed ($ per unit, litre, etc). This is

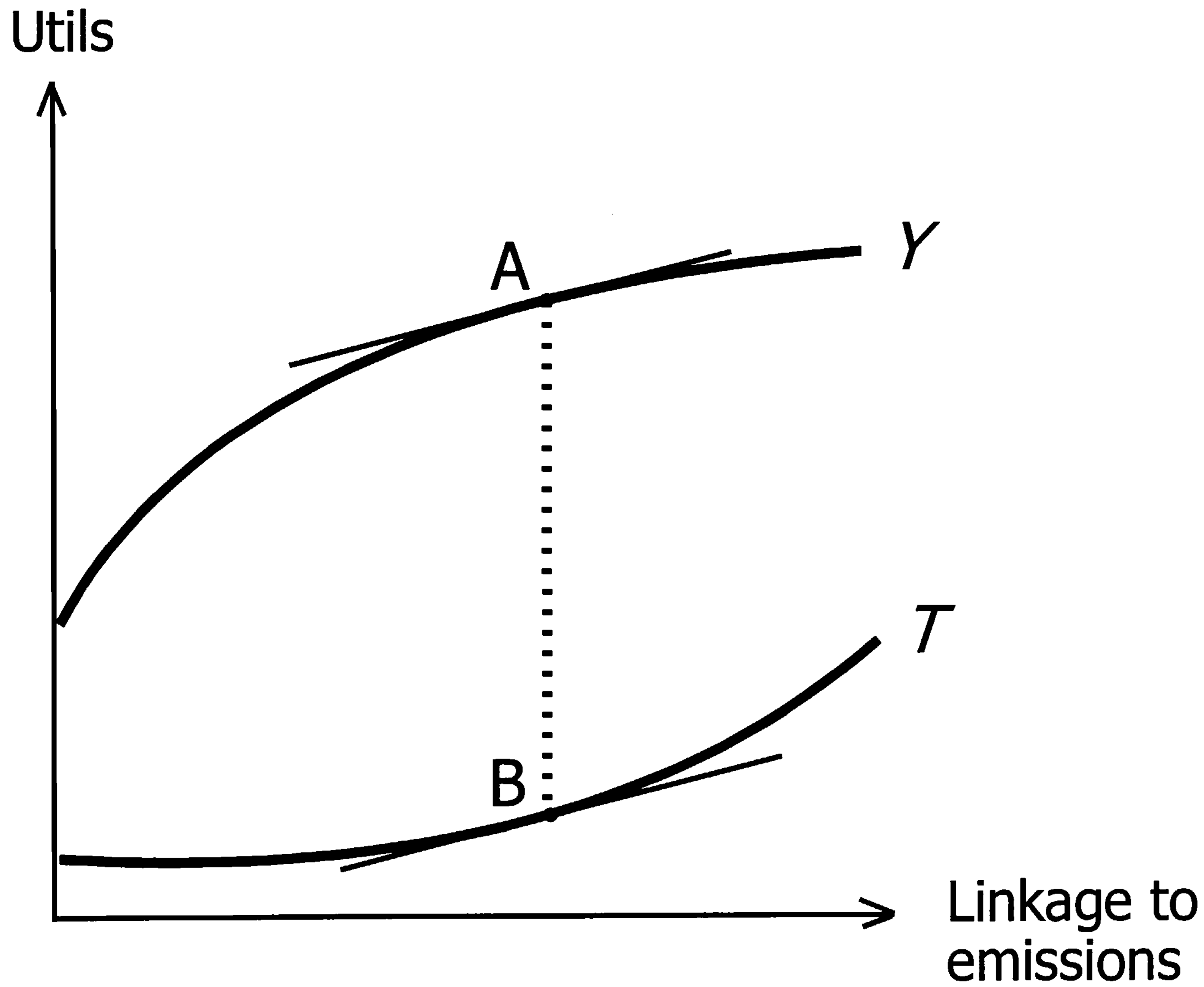
fundamentally different from taxes expressed on an *ad valorem* basis (% of price or (added) value).

27. Of course, many opportunities exist for savings on energy use (improvements of energy efficiency) which also implicitly reduces carbon emissions (Eskelund and Deravajan, 1996). However, the condition applied here is the improvement of *carbon* efficiency at the margin (as measured through the efficiency edge of emission taxes over input taxes, see section 3.4). We also exclude `compensation' techniques, like carbon sequestration (by planting trees), as they are not directly related to the production techniques employed for producing output.

28. This might change if carbon tax policy would become more strict as technological improvements might considerably reduce the cost of existing carbon abatement potentials.

29. We only checked excises as the introduction of a carbon tax is closely related to existing energy excises. Furthermore, in terms of the fixed cost element, it is not important whether these products are VAT-exempt or not. As discussed in section 4.2, the administrative procedures for VAT differ considerably with excise administration.

30. OECD (1998) shows that coal is even still subsidised in quite a number of OECD countries.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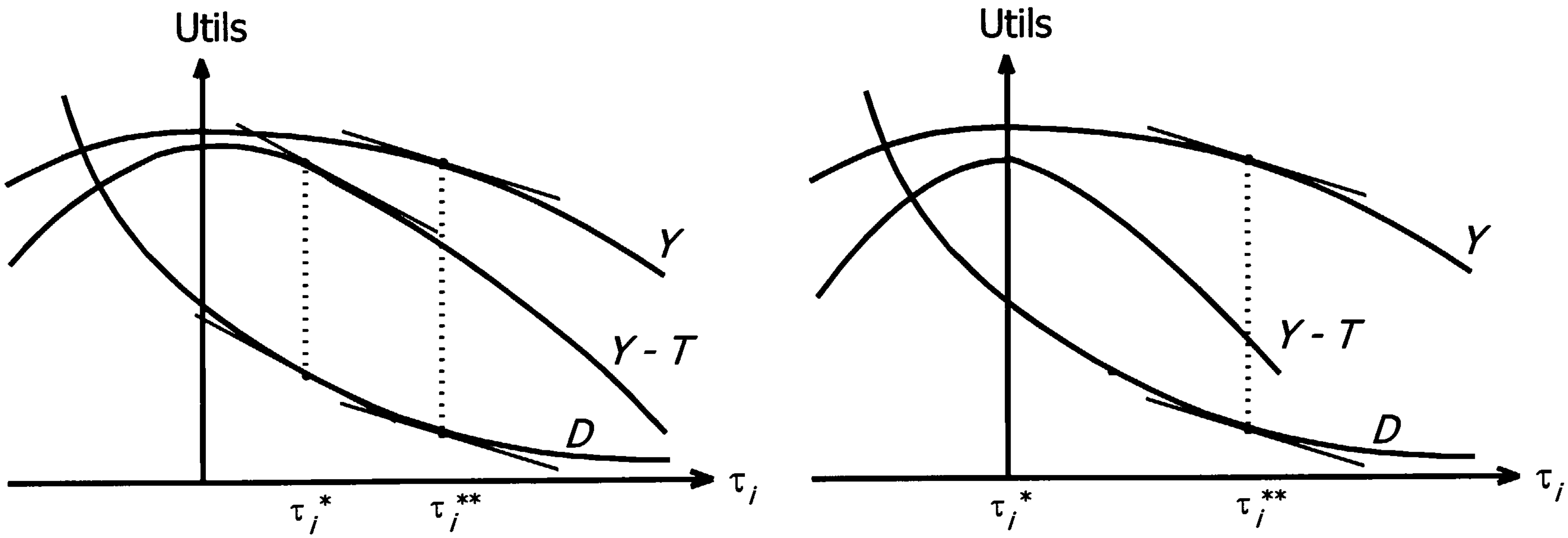
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