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Green Taxes and Administrative Costs

The Case of Carbon Taxation

Sjak Smulders and Herman R. J. Vollebergh

3.1 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 play a significant role in the choice between 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 the minimization of transaction costs might come at a cost for society. A strategy based on input taxes, for example, forgoes the gains that are potentially reaped by a more direct way of taxing the externality through emissions 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

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to balance the burden of complex and expensive-to-run tax systems against the incentives it induces to internalize the externality that it aims to address.

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 costs incurred by the regulator (government). Using a simple model, we determine the optimal rates for emissions 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. Because empirical information on the role of implementation costs 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 of 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 the overview in Krutilla 1999).[1] Several papers recognize that administrative costs may be important and rule out the use of emissions taxes on these grounds. Typically investigated is which taxes could best replace or "approximate" emissions taxes (Smith 1992). Moreover, under some circumstances other taxes or tax combinations are equivalent to perfect emissions taxes (i.e., emissions taxes in a world without transaction costs). For instance, Xepapadeas (1999) reviews the conditions under which input taxes and emissions taxes are equivalent. Eskeland and Devarajan (1996) show how the combination of mandated technology and output taxes approaches the ideal emissions 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 emissions tax that involves costly monitoring.

The implicit assumption in these papers, however, is that emissions 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 the administrative costs of all types of taxes, without assuming beforehand that emissions taxes are always 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 (cf. Yitzhaki 1979). Once other taxes, as well as emissions taxes, are subject to signifi-

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

cant 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 emissions taxes.

Shortle, Horran, and Abler (1998) research to what extent input taxes can approach perfect emissions 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 emissions and input taxes. We find that a mixed tax system might be (second-best) optimal. Schmutzler and Goulder (1997) arrive at a similar result using a model of mixed output and emissions 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 administrative 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). Because 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 Fullerton, Hong, and Metcalf (chap. 1 in this volume). The two chapters complement one another in various respects. Both chapters compare ideal emissions taxes with alternative taxation, but they differ with respect to the production structure and the government budget constraint. First, Fullerton, Hong, and Metcalf analyze a model in which there is a one-to-one correspondence between input use and emissions. Input taxes and emissions 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: output reduction, input reduction, and abatement. We study input taxation as an (imperfect) substitute for emissions taxes. Second, whereas Fullerton, Hong, and Metcalf consider a second-best world with a distortionary labor tax for revenue-raising purposes, the second-best nature of the 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 costs of corrective taxes, in particular administrative costs, are considered explicitly. Second, we analyze a stylized model that incorporates both emissions and input taxes to sort out critical determinants that shape this trade-off. Finally, we evaluate both explicit and implicit carbon taxation in Organization for Economic Cooperation and Development (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 exists between the carbon content of energy products and CO_2 emissions, this is not a fixed chemicotechnological relationship because several opportunities for carbon abatement or removal exist (Okken et al. 1992).

3.2 The Trade-off between Incentives and Administrative Costs

In this section we argue that the administrative costs argument per se is not sufficient to rule out the implementation of emissions 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-costs curve. Next, we show why administrative costs introduce such a general trade-off between the costs and benefits of various implementation strategies. We also develop some useful terminology.

3.2.1 Administrative Costs

We define *transaction costs* as the costs associated with tax assessment, collection, and enforcement; and all other costs incurred by any party to enable, facilitate, and ensure transactions from taxpayers to tax authorities (Vollebergh 1995). An alternative term that we use is *implementation costs.* The terms include ex ante costs (e.g., costs of exclusion) and ex post costs (e.g., monitoring costs). It is common to categorize these costs further into costs for the government (tax receiver), or *administrative costs,* to handle forms and enforce compliance, and the costs for the tax-liable agent (taxpayer), or *compliance costs,* to carry out the obligations of calculating and paying the tax (see Sandford, Godwin, and Hardwick 1989). In our analysis we concentrate on administrative costs.[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 emissions tax taxes the physical volumes of hazardous substances, while an input tax taxes such substances indirectly, for instance through their use as (intermediate) inputs. In turn, these differences induce both tax authorities and taxpayers to set up and maintain various 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 the total tax payments due.

One important characteristic of the tax base that determines (differences in) administrative costs is the number of agents liable for the tax. A large number of taxable legal units implies a large implementation cost for the

2. Section 3.4.2, 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.

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 costs, that is, the setup 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 taxpayers, the overall administrative costs per taxpayer can be reduced.

A second important determinant of administrative costs is measurability of the base. In most cases emissions levels are likely to be more difficult to measure, report, and record than input or output levels. Heterogeneity across industries and their technologies compounds 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 depend on vehicle type, equipment, fuel type, driving patterns, and so forth (see also Hoel 1998, 89).

Administrative costs are also likely to vary with the tax rates and the revenue raised. The possibility of evasion by taxpayers requires monitoring expenditures by regulators. The remark by Fullerton (1996, 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” seems to call for a qualification in this respect. The larger the tax bill, the larger are the incentives to evade tax payment and the more attractive it is for the regulator to spend resources 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 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 increases with the number of polluters, the variety of production and abatement techniques used, the importance of stochastic influences on actual pollution, and the difficulty of measuring emissions.

To sum up, no general shape can be assumed ex ante for different types 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.

3.2.2 The Role of Linkage

The 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 because both administrative costs and the linkage between regulatory aim, emissions reduction, and the type of regulatory tax used play a role (Smith 1992).[5] First of all, different types of taxes usually differ with respect to the directness of the incentive they provide to reduce emissions (assuming emissions reduction reflects the goal of the government). Less-direct taxation of the marginal damages caused by an individual polluter causes an efficiency loss, but may lower administrative costs. Furthermore, different instruments distort private welfare not only directly, but also indirectly through their implications for transaction costs. The usual gross welfare cost of taxation has to be supplemented by the transaction costs of the tax.

Before turning to how welfare analysis of environmental taxation is influenced by transaction costs, it is useful to clarify our terminology and make it precise. We explicitly separate 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 (1) administrative (transaction) costs, (2) the welfare gain from an improvement in the environment, (3) the residual welfare change, that is the gross welfare cost ignoring transaction costs. The third component is called here *private gross welfare cost.* An instrument that has relatively low private gross welfare

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

4. This definition applies to corrective taxes. The gross welfare cost in the 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 the linkage between emissions and ambient quality is often indirect, but the cost of ambient-quality regulation can be prohibitive. Thus an interesting trade-off exists 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.

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.[6] Thus, the relative efficiency of different types of taxes can be measured with the following formula:

$$U = Y - T - D(E), \quad (1)$$

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 distinct 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, emissions 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 polluters. Hence, an emissions tax that applies to all polluters is (privately) more efficient than an emissions tax with exemptions or a nonuniform emissions tax.

As noted in section 3.1, it is often argued that emissions 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 emissions 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 (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 does indeed save on administrative costs, but that it comes at a cost to society by distorting private decisions more.

Figure 3.1 illustrates this. The horizontal axis measures various tax systems with respect to the directness with which they address incentives to reduce damage; for example, an emissions tax ranks high and an input tax

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 private agents directly). Indeed, of the three terms in equation (1), only the first (Y) 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) shows that the basic idea can be traced back to the seminal paper of Diamond (1973).

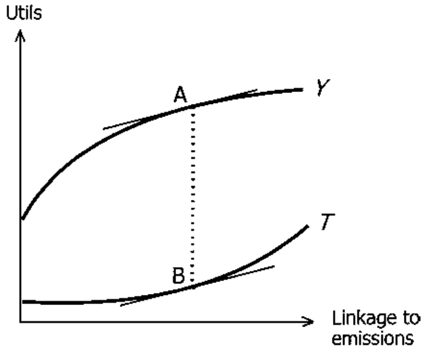

Fig. 3.1 The basic trade-off between transaction costs and the efficiency of internalization of tax systems

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 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 fewer links to already existing procedures of the existing tax system. Gross private welfare *Y* also increases with the linkage of taxation to emissions. The more direct the taxation, the larger the (private) utility is for a given level of emissions. The optimal tax system balances transaction costs and efficiency. In the figure, welfare is maximized by an indirect tax that corresponds to points A and B. The complete switch to emissions taxes is too costly: The associated increase in administrative costs would outweigh the gains from having a more-direct tax with better incentives.

Figure 3.1 is hypothetical and suggestive. As noted before, we have to assess tax proposals case by case. For example, if marginal administrative costs increase only slowly, emissions taxes may be optimal despite the presence of administrative costs. Moreover, it is not at all guaranteed 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 (symmetrical) sectors that is liable to an emissions tax and find that in a very simple setting the *Y* curve first declines and then increases. In general, administrative costs introduce nonconvexities 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 emissions taxes, the accuracy of measurability aimed for, the 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 3.1. Needless to say, each of these factors directly influences the overall welfare effect of implementing environmental taxes.

It is not only the multidimensionality of administrative costs that makes the simple diagram in figure 3.1 problematic. As Feldstein (1976) pointed out long ago, a 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 of 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. It is also attractive to exploit such economies of scale and scope when designing environmental taxes. Levying environmentally motivated taxes on a base that is already taxed for other purposes, rather than introducing an entirely new emissions tax, would certainly save on administrative costs. Furthermore, economies of scope with the administrative system used for other regulatory instruments may also arise. When implementing environmental taxes, the regulator could benefit from experience in related administrative procedures for operations already undertaken. As does Smith (1992), we label this use of existing administrative procedures and experience for new purposes "piggybacking."

3.3 Critical Determinants Shaping the Trade-Off

This section develops a simple model along the lines of Kaplow (1990) and Shortle, Horan, and Abler (1998) to compare emissions 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 themselves 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 labor taxes.[8]

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

3.3.1 The Model

We assume a given number of heterogenous sectors, indexed i. The production of one unit of final output q_i requires labor l_i and a single homogenous intermediate input x (in amount x_i). Moreover, firms can spend labor services on abatement a_i, which reduces emissions per unit of output e_i. The minimum labor requirement per unit of output equals $l_i(x_i)$. Labor 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 $e'_{ai} = \partial e_i / \partial a_i < 0$ and $e'_{xi} = \partial e_i / \partial x_i < 0$.[9]

Final-good producers face a (sector-specific) emissions 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

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

$$1 \geq (-e'_{ai}) \tau_i \quad \text{with equality if } a_i > 0, \tag{3}$$

$$p_x + t_{xi} + \tau_i e'_{xi} \geq -l'_i \quad \text{with equality if } x_i > 0. \tag{4}$$

Equation (2) says that price equals cost, which in turn equals labor cost for production, labor 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 a reduction of emissions 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 the price of the input p_x, the sector-specific input tax t_{xi}, and the induced additional emissions tax payments. Marginal benefits consist of the labor saving in production.

The intermediate good is produced with labor only and subject to constant returns to scale. We choose units such that one unit of labor produces one unit of the intermediate good. For simplicity we assume that the production of the intermediate input is nonpolluting (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 1:

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

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

Equilibrium in the market for the input requires[10]

$$X = \sum x_i q_i ,$$

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 labor is constant (and normalized to 1). 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 $\Sigma p_i q_i = L - l_0 + Z$, 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 labor at wage $w = 1$. The required administrative costs are sector specific and depend on sectoral taxes and output levels.[11]

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

where F represents the fixed costs 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 $I_{\hat{t}}$, each of which takes the value 1 if tax $\hat{t}$ (e.g., τ_i) is positive and the value 0 if the tax is 0. The natural restrictions we impose are *sign* $V_t' =$ *sign* $\hat{t}$ for any tax $\hat{t}$, 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 $V(\cdot)$.

The labor market clears. Labor endowment is fixed and given by L. Hence, we write

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

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

11. Note that by assuming linear sectoral separability we ignore economies of scope as discussed in section 3.2.

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

$$(11)\quad U = \sum u_i(q_i) + L - \sum (l_i + a_i + x_i)q_i - T - D\left(\sum e_i q_i\right).$$

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

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

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 effects associated with changes in input demands, transaction costs, and environmental quality. The first term on the right-hand side of (12) stands 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 than the emissions tax.

3.3.2 Optimal Taxation

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

$$(13)\qquad dU = \sum [\tau_i dE_i + t_{xi} dX_i] - dT - D' dE .$$

Equation (13) categorizes the welfare effect of any policy in the three components mentioned in section 3.2.2. The bracketed term on the right-hand side is the private gross welfare effect of the policy, denoted by dY, in line with equation (1); dT is the transaction costs 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.[12]

In the presence of administrative costs, a necessary condition for optimality of the tax system is that the expression in (13) be 0. The government maximizes welfare, taking as given the reactions of households and firms to changes in taxes. It faces a two-stage decision problem: (1) deciding which taxes to use (tax-base decision), and (2) setting the appropriate tax level (tax-rate decision).

Concerning the tax-rate decision, we find conditions for optimal taxation by rewriting equation (12) in terms of the total derivatives with respect to each of the taxes and setting these expressions equal to 0.[13] For any tax $\hat{t}$ this condition reads

12. See the analysis in Bovenberg and Goulder (1998, sec. 3.1).

13. 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.

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

This equation binds only if the tax is implemented; that is, equation (14) guides the tax 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 equation (14). The optimal tax system may include nonzero taxes, set at the level implied by equation (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 zero tax at the level implied by (14)—and adjusting all nonzero tax rates such that they satisfy (14)—decreases welfare (nonmarginally) because of fixed administrative costs. Similarly, in an optimally designed tax system, switching the rate of any nonzero tax from the rate implied by (14) to a zero rate—and adjusting all other nonzero taxes such that they satisfy (14)—decreases welfare (nonmarginally). Since fixed administrative costs play a role, the tax-base decision is subject to nonconvexities and no simple smooth optimality condition can be written.

Instead of optimizing the overall tax system, a more practical issue is to find a welfare improving tax reform. Such an approach takes into account the fact that actual changes to 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 the maximum level of welfare is not 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 costs of introducing the tax. For any tax $\hat{t}$, this condition can be written as[14]

(15) $$\hat{t}^* = \hat{t}^o \quad \text{if} \quad \left[\int_0^{\hat{t}^o} \frac{dU}{d\hat{t}}\,d\hat{t}\right] \geq F_t,$$

where $\hat{t}^o$ is the level of the tax that corresponds to equation (14) (i.e., the solution to $dU/d\hat{t} = 0$, or the corner solution 0), $F_t \equiv dT/dI(\hat{t})$ is the fixed cost (administrative setup cost) associated with introducing tax $\hat{t}$, $\hat{t}^*$ is the

14. 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/setup cost).

(second-best) optimal tax rate,[15] 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, that is, $T = dT = 0$. As is well known, the optimal emissions tax then equals the marginal damage D' in each sector and all other taxes should be 0.[16] This can be immediately seen from equation (12). Indeed, equation (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 emissions tax improves welfare.[17]

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 with emissions taxes, the Pigouvian tax should still be implemented. The other way around, if transaction costs apply to emissions 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 emissions taxes with respect to their incentive effects (private efficiency). For example, if the emissions-input ratio is fixed, an input tax can bring about the first-best outcome.[18]

A second-best situation arises when other taxes also involve transaction costs or when other instruments are privately less efficient than emissions taxes. Once transaction costs play a role, it is no longer guaranteed that emissions 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 outputs or inputs) can replace emissions taxes without loss of incentives and without administrative costs (e.g., see the double dividend literature; de Mooij 2000).

If administrative costs are mentioned as a reason not to use emissions

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

16. Solving the social-planner problem for the case without transaction costs, we find the following optimality conditions: (1) $u_i' = l_i + a_i + x_i + e_i D'$, (2) $1 \geq -e_{ai}' D'$ with equality if a_i is positive, (3) $1 \geq -l_i' - e_{xi}' D'$ with equality if x_i is positive. Comparing these conditions to equations (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 emissions taxes are equivalent, cf. sec. 3.3.4).

17. For this case $dU/d\tau$ reduces to $(\tau - D')dE_i/d\tau$, which is positive for $\tau < D'$. Hence, the left-hand side of the inequality in (15) is positive while the right-hand side is 0, and (15) is satisfied.

18. Similarly, two-part 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 costs, the first-best outcome can be reached (see Fullerton and Wolverton 1997). In the present model, this would require (sector-specific) taxes on output and input use and a (sector-specific) subsidy on abatement. Note, however, that optimality breaks down when more pollutants play a role.

taxes, the most common case in the literature is the one in which emissions taxes are too costly to implement because of the transaction costs associated with emissions taxes but not with other taxes (the most discussed case is nonpoint 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.

3.3.3 Pure Emissions Taxes

Let us first focus on emissions taxes by considering the case in which all other taxes are ruled out. Note that we cannot simply suppose that only emissions taxes are used; we have to explain within the model why this is so. We give this explanation in subsection 3.3.4 and concentrate here on the optimality conditions for emissions taxes only.

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

$$\text{(16)} \quad \frac{dU}{d\tau_i} = -\frac{dT}{d\tau_i} - (D' - \tau_i)\frac{dE_i}{d\tau_i} \leq 0 \quad \text{with equality if } \tau_i > 0.$$

Hence, if implemented, the optimal emissions tax reads

$$\text{(17)} \quad \tau_i^o = \max\left(0, D' - \frac{dT/d\tau_i}{-dE_i/d\tau_i}\right).$$

This tax should be implemented if the total welfare gain exceeds the fixed administrative costs; see equation (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

$$\text{(18)} \quad \tau_i^* = \tau_i^o \quad \text{if} \quad \frac{1}{2}\left[-\frac{dE_i}{d\tau_i}(\tau_i^o)^2 + (\eta_{Ei} + \eta_{T\tau i})\frac{dT_i}{d\tau_i}\tau_i^o\right] \geq F_{\tau i},$$

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

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 emissions 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 equation (18). The gains are small indeed if emissions are insensitive to the emissions 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 ($dT/$

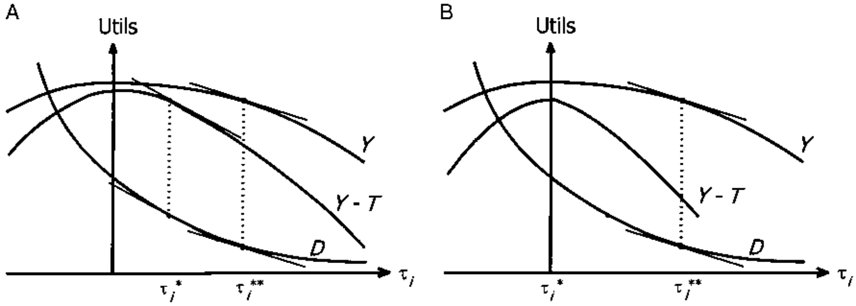

Fig. 3.2 The optimal second-best tax rate for an emissions tax with (*A*) low and (*B*) high transaction costs

$d\tau_i$) are large.[19] A second case in which a sector should be optimally exempted from an emissions tax is the case in which marginal administrative costs for the sector are relatively large, such that, for any small increase in the sector-specific emissions 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 3.2 illustrates the case of emissions taxes in terms of the trade-off between efficiency and administrative costs (see section 3.2). Private gross welfare, *Y*, is maximized for zero emissions taxes, since, loosely speaking, emissions 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 emissions taxation (i.e., 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 3.2, 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 0.

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 0 ($dT/d\tau_i = 0$). 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 emissions taxation. The second may arise because of a low elasticity of demand (it is hard to accomplish emissions reductions by cutting demand) or because the emissions intensity is not very sensitive to emissions-tax changes (steeply rising abatement and input substitution costs). To clarify

19. To see this, substitute equation (17) into (18).

this, we decompose the emissions-reduction effect of the tax, which appears as the denominator in (17), into these three effects:

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

where

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

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

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

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

That is, ε represents the effect of emissions taxes on emissions through changes in demand, α measures the direct effect of emissions 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 subsection 3.3.4).

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 emissions tax in the presence of administrative costs may be larger than the Pigouvian tax. The argument is that a higher emissions tax saves on transaction costs if administrative costs depend on the number of taxpaying firms and if an increase in the emissions tax reduces market demand and the number of firms. In our setup, 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 $dT/d\tau_i < 0$.

3.3.4 Input Taxes: The Role of Linkage

To investigate the trade-off between emissions taxes and input taxes, we first consider sector-specific taxes on emissions (τ_i) and on the use of input x (t_{xi}). Evaluating equation (14) for these taxes, we find[20]

20. Note that $(x_i/e_i)^2(\varepsilon_i + \xi_i\beta_i) = -dX_i/dt_{xi}$ and $(x_i/e_i)(\varepsilon_i + \xi_i) = -dE_i/dt_{xi} = -dX_i/d\tau_i$.

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

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

where

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

Note that ξ measures the direct effect of input taxation on emissions,[21] λ measures the elasticity of the emissions function with respect to input use, and β measures how much input use is more sensitive to input taxation than to emissions taxes.

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

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

Note that inputs should then be taxed according to their marginal emissions 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 equation [15] is violated for t_{xi}, the input tax should not be implemented.)

Replacing emissions 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-emissions ratio is constant and there are no abatement possibilities are the input taxation and emissions taxation 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

21. It can be derived, from equations (3) and (4), that $dx/d\tau_i = e'_{ai}(da_i/dt_{xi}) + e'_{xi}(dx_i/dt_{xi})$.

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

With a fixed emissions-input ratio, input and emissions taxes would be equivalent in the absence of administrative costs (as is well known; see, e.g., Xepapadeas 1999). Indeed, according to condition (25), without 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 3.2). 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 costs 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 administrative costs for the two taxes are sufficiently small to justify the introduction of both taxes, the taxes should be set so as to minimize variable administrative costs, as appears in the second equality in (28).

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

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

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

where

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

In the above expressions, Δ_i measures the "efficiency edge" of emissions taxes over input taxes. Indeed with a constant emissions input ratio ($\alpha = 0$ and $\lambda = 1$), we have $\Delta = 0$, and equations (29)–(30) collapse to equation (28). The efficiency edge of emissions 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 to unity the elasticity of emissions is with respect to inputs (λ), the closer is the correspondence between inputs and emissions, and the more efficiently input taxes mimic emissions taxes. Equations (29) and (30) reveal that marginal administrative costs are less important in determining the optimal tax rates if the efficiency of emissions taxes relative to input taxes (Δ) is larger, that is, if more abatement possibilities abound (α is larger) and emissions are more closely linked to inputs (λ is closer to 1).

3.3.5 Lessons from the Model

To internalize environmental externalities in the presence of administrative costs, pure emissions taxes are optimal only under specific conditions. These conditions include (1) low fixed administrative costs, (2) not-too-steeply-rising administrative costs (as a result of increases in emissions taxes) relative to marginal damage and direct emissions-reduction effect of emissions taxes, and (3) relatively low incentive effects from alternative environmental taxes (taxes on polluting inputs) to reduce emissions. The optimal second-best rate of emissions taxes falls short of marginal damage.

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

3.4 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.

Table 3.1 Characteristics of Main Fossil Fuels

Fuel	Energy Content (GJ)	Carbon Content (ton)	Tons of Oil Equivalent (TOE)	Normalized Carbon Content (ton/TOE)
Coal (metric 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 (1,000 m^3)	9.6–10.7	0.17	8.0[a]	0.56–0.64

Source: OECD/IEA (1993).

[a]Average for Gronings gas, based on the upper bound of 8.37381 and lower bound of 7.535714.

We first review relevant facts on existing carbon taxes, then present evidence on administrative costs, next assess current carbon taxes, and finally discuss the scope for improvement.

3.4.1 Carbon Taxes in Practice

Since the early 1990s, taxes have been seriously considered to combat climate change, in particular carbon taxes to 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, COM(92) 226 (European Commission 1992), for a hybrid European Union (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.

Thus the aim is to raise the implicit taxation of carbon at the margin. As is well known, the amount of CO_2 emitted per kind of fuel differs considerably (see table 3.1). Clearly, oil emits less carbon than coal does. Natural gas, in turn, is cleaner than oil. The obvious implication is that emissions 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 the carbon emissions 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 from industry and specific countries such as the United Kingdom. Despite this failure to implement an EU-wide carbon tax, several individual European countries have introduced explicit carbon taxes (see table 3.2). 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 is calculated according to the carbon and energy content of the energy products. Furthermore, it is imposed on primary energy inputs, including heavy fuel oil, liquified petroleum gas (LPG), coal, and natural gas.

Other Nordic countries soon followed: 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 among 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 are taxed. Sweden's CO_2 tax 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 dollars per liter to dollars per unit carbon. A tax reform in 1996 explicitly distinguishes energy consumption in industry according to the categories room heating, light processes, and heavy processes, with tax rates varying accordingly.

The Netherlands has had 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 at achieving carbon emissions reduction by households and small firms. The tax base included primary energy products, while the tax rates correspond to the proposed EU CO_2 energy tax. Austria also 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 that 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, such as 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.

Table 3.3 shows that for several energy products Sweden, Denmark, and Norway apply much lower effective rates for specific industries. Only Finland does not apply lower rates, although this is now heavily debated in Finland. Furthermore, it is remarkable that considerable differences exist in tax rates per ton of CO_2 across energy products, especially in Norway.

Table 3.2 **Excise Taxation of Energy Products in Countries Applying Carbon Taxes, 1997**

Country	Petrol (ECU/1000 liters)	Diesel (ECU/1000 liters)	Gas Oil (ECU/1000 liters)	Heavy Fuel Oil (ECU/1000 liters)	Coal (ECU/ton)	Natural Gas (ECU/m^3)	Electricity (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, proposed 2000	450	343	37	23	13	0.01400	0.00200

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

Note: CO_2 taxes and existing energy excises per unit of fuel are included.

Table 3.3 Effective Tax Rates of Explicit CO_2 Taxes for Some Industries in the Nordic Countries (% of nominal tax rates)

Energy Products	Sweden, Manufacturing Industry	Denmark, Heavy Processes	Norway, Pulp/Paper Industry	Finland, 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: Calculations based on Ekins and Speck (1999, 380).

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 European Commission 1992 and its evaluation by Smith and Vollebergh 1993). This tax is aimed at lowering the use of fossil fuels in proportion to their carbon content. The European carbon/energy tax, the first explicit uniform EU-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.

Because this EU proposal was never implemented, a later proposal was more closely linked to the existing drafts on Mineral Oil Excise Harmonization, COM(95) 172 (European Commission forthcoming) and therefore concentrated its effort on a much smaller carbon tax base (see table 3.2 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 a 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; small minimum rates on primary energy products, such as coal and natural gas, are also proposed, as well as a tax on electricity (see table 3.2 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 the value-added tax) amount to at least 8 percent of value-added. In addition, the proposed directive in 1992 also allows for reductions or refunds if firms invest in energy-efficiency improvements or carbon abatement.

To summarize, the recently introduced (unilateral) carbon taxes in several European countries indeed broaden the existing (implicit) carbon tax base by including specific primary energy products, such as coal and natural gas. These products were usually not taxed before. The agents who pay the tax are mainly (downstream) distributors of final fuel products or electricity at the point of delivery to households and to 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 exception of Finland, all Nordic countries choose to exempt specific agents, mainly energy-intensive industries, by applying (much) lower or even zero carbon tax rates.

3.4.2 Evidence on Administrative Costs

An empirical estimation of the administrative costs of different environmental tax policies does not, to our knowledge, exist. The same holds for compliance costs with only a few exceptions, such as Fullerton's (1996) analysis of the Superfund's corporate environmental tax. Direct estimates of the administrative costs of carbon taxes are also lacking. 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 costs is not surprising because only a few explicit environmental taxes exist in practice (see, e.g., Fullerton 1996). Explicit environmental taxes are those for which the legislator has explicitly expressed the aim that this tax should serve some environmental purpose. However, the analysis of environmental taxation and administrative costs would be severely restricted if one were to limit the analysis to explicit environmental taxes only. As shown in section 3.3, input taxes are also important for environmental purposes. Indeed, taxes such as excise taxes and value-added taxes (VAT) affect the environment (e.g., taxes on gasoline and driving), as well as provisions in income taxes (tax allowances for commuting expenses, mine exploration, pollution control equipment, etc.).[22] For carbon taxation, current energy taxes, such as excises on hydrocarbon oils, are the most important because 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

22. Barthold (1994) mentions 51 federal tax-code provisions for the United States, and the OECD in more recent inventories mentions a much larger number of relevant taxes.

Table 3.4 Relative Administrative and Compliance Costs of Different Types of Taxes (% of total revenue)

Tax or Group	Administrative Costs	Compliance Costs	Total Operating Costs
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, cars, betting and gambling)	0.85	1.48	2.33

Source: Sandford, Godwin, and Hardwick (1989, 192).

other taxes is scarce as well. Only a few studies exist.[23] 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, Godwin, and Hardwick 1989, 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 3.4 summarizes the results of Sandford, Godwin, and Hardwick (1989). Both the administrative and compliance costs of each tax are expressed as a percentage of the revenue raised by the tax. Administrative costs vary from 0.12 percent for the petroleum revenue tax to 1.53 percent for the income tax. The overall picture is clear: income tax and VAT are relatively expensive to administer, while excise duties are especially inexpensive in terms of administrative costs. This finding is also in accordance with findings in other studies; although OECD (1988) provides lower estimates on the total cost of VAT (between 0.40 and 1.09 percent), this study also ranks income taxes as being relatively most expensive and excises (interpreted as a single-stage general consumption tax) as being least expensive to implement (total cost around 0.5 percent).[24]

Because Sandford, Godwin, and Hardwick (1989) also include compliance costs, we can test whether we bias our analysis by focusing on administrative costs only. On average, compliance costs are three 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

23. Sandford, Godwin, and Hardwick (1989) analyze administrative and compliance costs of different taxes in the United Kingdom in 1986–87. OECD (1988) discusses operating costs for consumption taxes relative to other taxes.

24. See the discussion in Cnossen (1994).

basic picture is not influenced by adding compliance costs. The similar relative importance of compliance and administrative costs across different taxes suggests that administrative costs can be taken as being representative of both.

We now turn to the factors that determine the level of the administrative costs (see also section 3.2.1). Administrative costs as a percentage of the total revenue raised by a tax are not very relevant for the choice between different types of taxes. It is more important to know their fixed- and variable-costs 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 taxpayers is concerned, empirical information on the administrative costs of VAT indeed suggests the existence of economies of scale. 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 taxpayers reduces overall administrative costs per taxpayer. Cnossen (1994, 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 the measurability of the tax base. One factor here is the differences among taxpayers. Some taxpayers will be more expensive to tax due to specific characteristics that have to be checked. Again, an interesting example is the small-business exemption from VAT. The larger the exemption, the smaller the number of registered businesses and the lower the absolute levels of administrative costs (see Cnossen 1994, 1652). Usually exemptions will be responsible for higher administrative costs. 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 liable neither for the tax payment nor for a rebate. We do not find evidence for the assumption that more complex forms for calculating the tax base would raise administrative costs. Also, empirical studies have not tried to quantify the precise shape of the fixed- and variable-costs components of administrative costs of different tax types in relation to the use of differences in tax rates.

No decisive empirical information exists on the (general) shape of the transaction-costs curve for different types of taxes, especially environmental taxes. Moreover, as observed by Cnossen (1994, 1663), the findings of Sandford, Godwin, and Hardwick (1989) on the comparatively high VAT compliance costs are in clear contrast with evidence on VAT compliance costs in Germany. Here the estimated costs are only a fraction of the costs observed for the United Kingdom, 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 exists, 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.[25] Thus, it seems safe beforehand not to always expect prohibitively high administrative costs for environmental taxes. This might be different only if the regulatory tax base asks for the monitoring of emissions that are difficult to measure and that 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 (1992, 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 that 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 costs 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 emissions since tax officers already have a lot of information required to operate the tax system.

3.4.3 Assessment in Terms of the Trade-Off

As noted before, the overall effect on welfare of introducing new environmental taxes, such as 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 emissions taxes if three conditions are met (see the end of section 3.3.4 in particular). First, there should be a clear linkage between inputs and emissions. Second, only few possibilities must exist for abating carbon emissions separately. Third, the administrative costs of emissions taxes should be high. In this section, we argue that these conditions are indeed met in the case of carbon taxation that supports the strategy chosen by the various countries applying these

25. Note that the tax base of specific excises requires physical control due to the physical dimensions in which they are usually expressed (dollars per unit, liter, etc.). This is fundamentally different from taxes expressed on an ad valorem basis (percentage of price or [added] value).

taxes. At the same time, however, the current design of the carbon taxes in practice leaves considerable room for improvement.

The first condition is related to the linkage issue (measured through $| \lambda - 1 |$ as part of the efficiency edge, Δ_i, in section 3.3.4). In the carbon case, CO_2 emissions are indeed in a one-to-one correspondence with the carbon content in energy products used as inputs (e.g., crude or refined oil products, natural gas, and various 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 that 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 that can more easily be taxed. Thus, instead of taxing the emissions from car exhaust, an additional tax may be levied on gasoline purchases, on the assumption that the environmental damage caused is proportional to the amount of gasoline 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 and energy content). Thus coal-based energy-production processes are put at a disadvantage compared to other fossil and nonfossil fuel energy products. The same holds for oil relative to natural gas and nonfossil 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 as 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, Δ_i). If emissions are very sensitive to emissions 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 the efficiency of input taxes can be expected only if direct carbon abatement is possible, although 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.[26] Furthermore, these possibilities can

26. Of course, many opportunities exist for savings on energy use (improvements of energy efficiency) that also implicitly reduces carbon emissions (Eskeland and Devarajan 1996). However, the condition applied here is the improvement of carbon efficiency at the margin (as measured through the efficiency edge of emissions taxes over input taxes; see section

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 very low.[27]

The third condition is that administrative costs related to emissions 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 setup cost of monitoring activities. This also applies to excise taxes, whether they are emissions or input taxes, even though they are cheap to administer compared with other types of taxes (see section 3.4.2). For that reason, tax reform of existing taxes is very attractive for policymakers because the effect on (marginal) administrative costs 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, that is, a reform of currently existing energy-input taxes toward taxes based on emissions coefficients (see section 3.4.1).

Indeed, the strategy chosen by the Nordic countries when implementing carbon taxes basically follows this logic. We checked which products and agents were already subject to energy excises in these countries in the pre-carbon-tax period, say 1990.[28] Table 3.5 presents our results. We distinguish between three potential groups of taxpayers: 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 is 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 its 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 (e.g., refineries, and steel and aluminum producers).

Thus, the effects on administrative costs of introducing carbon taxes on

3.3.4). We also exclude compensation techniques, such as carbon sequestration (by planting trees) because they are not directly related to the production techniques employed for producing output.

27. This might change if carbon tax policy became stricter because technological improvements might considerably reduce the cost of existing carbon abatement potentials.

28. We only checked excises because 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 3.4.2, the administrative procedures for VAT differ considerably with the excise administration.

Table 3.5 **Energy Excises Applying to Households, Industry, and the Electricity Sector in the Nordic Countries, 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	−

Source: OECD (1993a, 1993b).

Notes: Abbreviations: Hh, households; I, industry; E, electricity generation; +, tax; 0, no tax; −, not used; na, not available.

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 and 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 setups, 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 of these changes on administrative costs 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, such as diesel or electricity, is usually delivered to consumers (both industry and households). The administration of energy excise taxes saves on the number of taxpayers by using points of delivery (e.g., fuel stations and energy distributors) instead of taxing all consumers separately. This is applicable in the case of natural gas (delivery through pipelines), 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 taxpayers.

3.4.4 Scope for Improvement

Although the current carbon tax strategy in the Nordic countries satisfies the conditions for using input taxes instead of emissions taxes, considerable scope for improvement 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 competitiveness. Often the 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 the production of the fuels themselves. Also the extraction of any fossil fuel is not subject to this tax (although other type of taxes and 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 costs among sectors, seems to apply in the carbon case. However, current differentiation is exactly the opposite of what our model suggests is optimal. Dijkgraaf and Vollebergh (1997) show 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 (e.g., diesel and gasoline) much more heavily than primary energy products on average (e.g., 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 and energy-intensive products), are also the taxpayers who can be taxed with lowest transaction costs per unit of emissions. In other words, the most important polluters (the small number of taxpayers consuming the larger part of fossil fuels) still pay only a very small amount of tax, if any. The same holds for the choice to exempt certain energy products consumed by specific sectors, such as coal by electricity generation. Finally, not taxing particular energy products that cause considerable carbon emissions, such as coal, seems to be particularly unattractive.[29] 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, Koutstaal, and de Vries 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 process of producing those fuels is not taxed at all. As Pearson and Smith (1991, 29) note, such a scheme gives an undesirable incentive to the use of highly

29. OECD (1998) shows that coal is still subsidized in quite a number of OECD countries.

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 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 emissions 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 such as carbon sequestration. Large-scale firm-specific investments are involved in these abatement projects. Emissions taxes for energy producers may provide appropriate abatement incentives. Moreover, the administration costs for emissions 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 emissions 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 the EU, OECD or, better, world scale. Carbon leakage then no longer offsets unilateral carbon policies. Thus, the exemption of large energy-intensive exporting industries to restore international competitiveness would no longer be a reasonable strategy. Only then would it be possible to initiate a full-fledged tax reform imposing carbon taxes on agents that have the most options for abatement, contribute most to CO_2 emissions, and for which the administrative costs involved are relatively smallest.

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Comment Dallas Burtraw

The insight of the thorough and well-written paper by Sjak Smulders and Herman Vollebergh is in identifying an important trade-off when choosing

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among potential policy instruments. This is the trade-off between transaction costs and incentives, which indeed has not been developed adequately in the environmental literature. In this application, transaction costs include "administrative costs" incurred by the regulator, and "compliance costs" incurred by the agent. "Incentives" refer to the signal to change behavior received by the agent. Focusing on this trade-off informs the choice of policy instruments and also draws attention to the cost of environmental policy, which forces one away from the first-best (Pigouvian) level of regulation.

Drawing on the sketchy evidence available from previous studies, the authors make some key observations. The first is that the administrative costs incurred by the government (which are the focus of paper, rather than compliance costs incurred by agents) are often greater for emissions taxes than for other types of environmental taxes, especially input taxes. Why might this be true? One reason has to do with the measurability of the tax base. It may be more difficult to measure emissions from distributed pollution sources than it is to measure the economic activity of those sources because the purchase of inputs is already accounted for financially. The second reason may have to do with the number of agents that are covered under various tax schemes. Typically one might imagine inputs (such as fuel) to come from a small number of sources while emissions come from a large number of distributed sources, and one might expect administrative costs to vary with the number of agents that have to be monitored.

The second observation recognizes a distinction between fixed and variable components, reminiscent of Stavins's (1995) treatment of transactions costs for tradable permits. Further, it is noted that variable costs may rise with tax burden, or in this case with the quantity of emissions. One reason this may be true has to do with the incentive that agents have for tax evasion.

The authors use these observations as a point of departure to craft broad policy guidance. Their proposition is that other environmental taxes, especially input taxes, are preferable to emissions taxes when

1. Emissions taxes have high fixed administrative costs, that is, the cost associated with setting up a new tax on emissions. For many types of input taxes, it is recognized that these costs are already incurred because these taxes are already in place.

2. Emissions taxes have high elasticity of variable costs; that is, variable costs rise sharply with the level of emissions or the tax revenue collected from the emissions tax (as a result of increases in the tax rate).

3. The incentive effects from input taxes are high with respect to the production of emissions. For example, this occurs when there is little opportunity to abate emissions, so emissions have a high correlation with taxable inputs.

Table 3C.1 Comparison of a Variety of Environmental Problems

Environmental Problems	High Fixed Administrative Costs for Emissions Taxes?	Elastic Variable Administrative Costs for Emissions Taxes?	Little Opportunity for Abatement (Inputs and Emissions Linked)?
CO_2	Strong–weak	Strong–weak	Strong
NO_X	Strong–weak	Strong–weak	Weak
SO_2	Weak	Moderate–weak	Moderate
Mercury	Strong	Moderate–weak	Moderate
Nonpoint water pollution	Strong	Strong	Strong–moderate

This comparison, between environmental (input) taxes and emissions taxes, supplements a yet more fundamental trade-off guiding environmental policy analysis. Emissions taxes as a strategy to address environmental problems are already second-best approaches. Environmental economics ideally would recommend a first-best strategy that would target ambient concentrations of pollution and the marginal damages that result, the class of direct instruments. However, in many settings it is clear that direct instruments are not practical because of the administrative costs of implementing such a system. And so we are already in the second-best world of considering emissions taxes, from which these authors take us still further, toward consideration of input taxes.

The authors take this broad advice and apply it to one problem in particular, controlling emissions of carbon dioxide (CO_2). They find that in this case, at least, the shoe fits. Implicitly the paper provides an endorsement of the approach taken recently by several governments in Europe that have sought to implement various environmental taxes on energy inputs as an indirect means of regulating CO_2 emissions.

The finding is likely to survive in the context of CO_2 policy because, for the foreseeable future, a technology that allows for postcombustion abatement of CO_2 emissions will be prohibitively expensive. Therefore, taxing inputs is identical to taxing emissions, with respect to the incentives for emissions reduction. However, one must use care in seeking to generalize from this example, and it is interesting to attempt to do so.

Table 3C.1 provides a subjective assessment of the authors' criteria applied to a number of environmental problems in the United States. In the cases of CO_2, NO_X, and SO_2, I suggest that a range of values may apply to the first criterion, which asks whether high fixed administrative costs with emissions taxes exist. The reason this criterion may apply in a weak way is that a significant fraction of emissions, especially SO_2, comes from the electric utility sector, where continuous emissions monitors already are required on all large fossil-fired power plants under the 1990 Clean Air Act Amendments. These monitors track the emissions of these three pollutants, making administrative costs of enforcing a tax relatively low. In other sectors the administrative costs could be quite high, and in general that would apply to mercury emissions and nonpoint water pollution.

The second criterion asks whether administrative costs vary with the magnitude of the policy or quantity of emissions. Again, the electricity sector may be a special case because the monitors are thought to be accurate. Outside this sector, however, the incentive and opportunity for avoiding monitoring may be high. However, the magnitude of potential tax revenues is probably not substantial for most affected industries, with the particular exceptions of CO_2 and nonpoint water pollution.

The third criterion addresses the linkage between inputs and emissions. This provides the strongest argument for an input tax for CO_2 policies. Other air pollutants offer some opportunity for abatement, which severs the link between inputs and emissions. Nonetheless, for SO_2 and mercury, mass-balance principles apply, linking inputs and residuals (either abated or emitted). However, emissions of NO_X in large part are variable with respect to combustion temperature and other factors. Nonpoint water pollution provides perhaps the second strongest link (second to CO_2) since nonpoint pollution largely is a function of inputs, although there exist some management practices that affect nonpoint pollution.

Even after taking the contribution of this paper fully into account, environmental economists should remain sensitive and perhaps reluctant to back away from more direct instruments for environmental control. Experience teaches us that important changes in technology and in social organizations occur as we try to build institutions that put strong incentives in place regarding environmental performance. New technologies are emerging for monitoring emissions sources, including continuous emissions monitors on smokestacks, pollution markers that can allow the regulator to trace concentrations to individual pollution sources, and remote sensors that can be used to identify pollutant emissions from individual vehicles. As technologies emerge, administrative costs of more finely tuned environmental instruments fall. Hence, it is important to think about the design of instruments in the dynamic context. For example, in the United States the emissions reduction credit program of the early 1980s was a mixed success. Anecdotal evidence is that the transaction costs of trades under the program were approximately 30 to 40 percent of the value of the trades, on average. However, under the SO_2 emissions allowance trading program in the United States in the 1990s, transaction costs have fallen to less than 1 percent of the value of the trades. This comes from organizational learning, new institutions, and new technologies. In general, one should give consideration in the design of environmental programs to the enhancement of these innovations.

The authors go beyond development of the criteria discussed here to offer another proposition. They suggest that when fixed administrative costs of both environmental (input) taxes and emissions taxes are low, relative to variable costs, a hybrid policy involving both types of taxes may avoid the problem of rising variable administrative costs. This may occur because the tax rate on emissions can be kept low because part of the emissions reduction is occurring through substitution among inputs in response to an input tax, and vice versa.

I remain skeptical about the efficiency characteristics of a hybrid of multiple taxes to achieve a desired level of emissions reduction. Each tax gives rise to the opportunity for political horse-trading, and I fear a mix of taxes to achieve a single policy goal would seemingly give rise to unmodeled coordination costs. I conjecture that, in the broad scheme of things, administrative costs as they are addressed in this paper are typically less than the political costs of navigating the legislative process. The difficulty of fine-tuning the tax system would seem to be even more daunting when multiple tax instruments are considered. In fact, toward the end of the paper the authors provide a useful summary of existing input taxes and identify myriad deviations from consistent or efficient policy. In Europe, I understand, there is increasing use of hybrid tax instruments to achieve environmental tax reform. It may be that the hybrid tax instrument enhances the political acceptability of environmental action or that it is a way to slip the camel's nose (control of CO_2 emissions) under the tent of economic growth. However, it is not obvious that the outcome is likely to be efficient in the sense addressed by these authors.

These thoughts provide some cautionary notes for why we may not necessarily want to move away from a more direct approach to environmental policy making for an approach that in the short run has lower administrative costs. However many of these issues are beyond the scope of the present paper. So to close, let us return to the present paper to reconsider its major contributions and guidance for policy.

The conclusions offered for CO_2 emissions reduction by the authors align with the direction currently being taken by governments as they try to grapple with the greenhouse gas problem. This analysis tells us that this direction of policy is probably the right one. And also this analysis gives us reason to focus on a critical issue—the trade-off between first-best incentives and administrative costs—that is an important consideration in actual policy design and that is often missing from economic models.

Reference

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