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by

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Public Economics

Center for Economic Studies
Discussions Paper Series (DPS) 99.18
http://www.econ.kuleuven.be/ces/discussionpapers/default.htm

September 1999

DISCUSSION
PAPER

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August, 1999

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Abstract

The consensus view among economists seems to be that a green tax reform is unlikely to be associated with a "double dividend" (Bovenberg 1998). However, the results derived in the present paper suggest that this view needs to be qualified. We demonstrate that a green tax reform is likely to be associated with a significant "double dividend" if the government prior to taking the environmental aspect into account has adopted a proportional tax structure due to the administrative costs involved in differentiating commodity tax rates, and if the green tax reform stimulates the labour supply and has desirable income distributional effects.

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Keywords:
Optimal taxation, externalities, administrative costs, green tax reform, double dividend

JEL classification codes:
H2, H29

Acknowledgements:
The work for this article has been made partly at CES, Catholic University of Leuven, and partly at the EPRU, Institute of Economics, University of Copenhagen. The resources provided at both places for this work are gratefully acknowledged. Comments by Ken Thomson, Søren Bo Nielsen, Inger Mayeres, Gunnar Thorlund Jepsen, Peter Birch Sørensen and participants at the 55th IIPF Congress in Moscow have been very helpful.

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1 Introduction

The "double dividend" question, i.e. whether replacing a tax on labour with taxes on commodities causing environmental damage will increase social welfare, not only by internalising the costs of the environmental damage, but also by reducing the distortionary costs of the tax system, has been considered extensively in the literature. Based on the idea that the tax revenue obtained from environmental taxes could be used to reduce pre-existing distortionary taxes, the first contributions suggested that a green tax reform in general would be associated with a "double dividend". But after a number of public finance economists, in particular Bovenberg and his co-authors (Bovenberg and de Mooij 1994a, 1994b, Bovenberg and van der Ploeg 1994a, 1994b, 1998a, 1998b, Bovenberg and Goulder 1997), have extensively considered the question, it has become clear that the intuition behind the initial suggestion was flawed by not taking into account the disincentive effect of the environmental taxes for the supply of primary factors. Now, the consensus view among economists seems to be that a green tax reform is unlikely to generate a significant "double dividend", if previous policies have been economically rational.

The main motivation for the present paper is to challenge this view. Firstly and fundamentally, by demonstrating that the standard theoretical public finance analysis by disregarding the importance of administrative costs for the optimal tax structure, unduly rules out the potential for a green tax reform to be associated with a "double dividend". Secondly, by arguing that to be relevant in the context of actual policy making, as it was initially intended, the "double dividend" concept should be defined to reflect not only the change in distortionary costs of taxation, but also the distributional consequences of a green tax reform. The potential of a "double dividend" does not depend on taking the distributional aspect into account, and is in itself not sufficient for a "double dividend" to materialise, but it increases considerably the number of cases where a green tax reform will be associated with a "double dividend".

Goulder (1995) defines "the double dividend" (in the context of the so-called "strong "double dividend" proposition") as the negative of the "reduction in individual welfare, abstracting from the welfare effect from changes in environmental quality" assuming a revenue neutral substitution of the environmental tax with "typical or representative distortionary taxes". He justifies his definition by the fact that policy-makers who are interested in a green tax reform are often frustrated with the complexities of evaluating such reforms. If a policy-maker could assume that the net benefits due to other factors than the direct environmental effects and the administrative costs of regulation were non-negative, then his task would be reduced to argue that the benefits due to these direct effects were positive, and thus be considerably simplified. This justification suggests that the task of the decision-maker would be facilitated by the identification of conditions which, when satisfied, would assure a positive net benefit of the tax changes not only due to reduction in the distortionary costs of taxation but also due to improvement of the income distribution. But although it is clear from Sandmo 1975's seminal contribution to the analysis of the optimal taxation and tax reform in the presence of externalities that distributional effects are important for the optimal solution, this aspect is not taken into account in Goulder's definition. In a contemporaneous contribution Proost and Van Regemorter

(1995) pointed out the limitation of basing the definition of the "double dividend" on the efficiency aspect only, and suggested a generalisation of the concept to include also the distributional benefits of the tax changes. Nevertheless it seems that Goulder (1995) in the economic literature remains the standard reference with respect to the definition of the "double dividend". Bovenberg (1998) for example reviews the "double dividend" discussion based on this definition.

Welfare economic analysis of optimal taxation and project evaluation in the presence of externalities is as other areas of second best welfare economics complex and the results not always intuitive. However, the understanding of the theoretical results is often facilitated by considering an example which, although illustrative, refer to a concrete real life situation. To support the interpretation of the theoretical analysis we therefore provide a quantitative analysis of why a green tax reform, which involves the introduction of a differentiated tax on *leisure travel,* is likely to be associated with a significant "double dividend".

The paper is organised as follows: *In Section 2,* we formulate mathematically the government's maximisation problem subject to conditions which include restrictions on the set of feasible tax instruments to reflect the administrative costs associated with their use. In *Section 3,* we define the "the double dividend" of a "green tax reform" and derive an approximate criteria for the "double dividend" to be positive. After having briefly reviewed relevant results of the theory of optimal taxation, we identify conditions conducive to a green tax reform being associated with a "double dividend". In *Section 4,* we support the insight gained in the theoretical analysis by simulation results produced with the help of an illustrative CGE model, which satisfy the conditions identified. A final section summarises and concludes the paper suggesting promising avenues for future research. The specification of the CGE model and details on the simulation results are contained in Annex.

2 The model

We consider a closed economy operating under conditions of perfect competition with a large number of households, a large number of firms and a government. The government adheres to egalitarian value judgements and maximises social welfare defined accordingly, subject to the constraints imposed by the structure of the economy. The households have different skill levels, but supply only one homogeneous primary factor, labour. They demand two produced commodities, a “dirty good", which is associated with external diseconomies, and a “clean good", which is not.[1] We assume that only the aggregate level of the consumption of the "dirty good" - not its distribution among households - matters. The production side of the economy is represented by two constant returns to scale production sectors, each producing one output and using only labour as input. Government consumption is exogenous, except for the costs associated with tax administration. For the usual

[1] To facilitate the exposition only two rather than a greater number of produced commodities are considered. However, a notation has been used to facilitate the comparison with the case of many commodities as e.g. in Sandmo (1975).

reasons (see Atkinson and Stiglitz 1980, p357), we do not consider the optimal differentiation of lump-sum taxes among households as a realistic option for the government. Based on similar considerations, but more unconventionally, we furthermore assume that the administrative costs of tax administration depend on the complexity of the tax structure, more specifically that a proportional tax structure in the form of a proportional income tax (wage tax) or a uniform commodity tax, are the administratively least costly tax systems, requiring the government to gather and process less information than in the case of alternative tax systems. Which tax system the government chooses, a wage tax, a VAT, a linear income tax, or an income tax combined with differentiated commodity taxes, is thus not given a priori, but depends on the administrative costs involved.

Households are labelled $h \in (1,..,H) \equiv H$, labour 0, the "dirty good" and the "clean good" $i \in (1,2) \equiv C$. Households face consumer prices, $\mathbf{q} \equiv (q_0, q_1, q_2)$ and firms face producer prices $\mathbf{p} \equiv (p_0, p_1, p_2)$. We assume that all households have the same time endowment, but differ in productivity, i.e. that the net demand of labour for the h[th] household is $x_0^h = -\psi^h(\grave{u}_0 - c_0^h)$, where w_0 is the time endowment, c_0^h the consumption of leisure, and y^h an index of labour productivity. The h[th] household's net demand vector is denoted by $\mathbf{x^h} \equiv (x_0^h, x_1^h, x_2^h)$ and its preferences are represented by $u^h = u^h(\mathbf{x^h}, e)$ where e represents the public good externality. The corresponding indirect utility function is expressed by $v^h(\mathbf{q}, e, I^h)$, where I^h represents unearned income. For each household $\mathbf{qx}^h(\mathbf{q}, e, u^h) = E^h(\mathbf{q}, e, u^h)$ where $\mathbf{x}^h(\mathbf{q}, e, u^h)$ is the vector of compensated demand functions and $E^h(\mathbf{q}, e, u^h)$, the expenditure function, which indicates the minimum level of expenditure at which the utility level u^h can be achieved at the household prices $\mathbf{q}$ and at the level of the public good externality e. The h[th] household's valuation in monetary terms of a marginal increase in the externality is thus $-E_e^h \equiv -\frac{\partial E^h}{\partial e}(\mathbf{q}, e, u^h)$. We define the following terms to simplify the notation

$$E_i^h \equiv \frac{\partial E^h}{\partial q_i}(\mathbf{q}, e, u^h) = \mathbf{x}_i^h(\mathbf{q}, e, u^h),$$

$$E_{ij}^h \equiv \frac{\partial^2 E^h}{\partial q_i \partial q_j} = \frac{\partial x_i^h}{\partial q_j}(\mathbf{q}, e, u^h) = \frac{\partial x_j^h}{\partial q_i}(\mathbf{q}, e, u^h)$$

$$E_{ie}^h \equiv \frac{\partial^2 E^h}{\partial q_i \partial e} = \frac{\partial x_i^h}{\partial e}(\mathbf{q}, e, u)$$

$$E_i \equiv \sum_{h \in H} E_i^h \equiv X_i \equiv \sum_{h \in H} x_i^h, \; E_e \equiv \sum_{h \in H} E_e^h \text{ and } E_{ij} \equiv \sum_{h \in H} E_{ij}^h$$

$$\frac{\partial X_i}{\partial q_j} \equiv \sum_{h \in H} E_{ij}^h - \sum_{h \in H} x_j^h \frac{\partial x_i^h}{\partial I^h}$$

$$\frac{\partial X_i}{\partial e} \equiv \sum_{h \in H} E_{ie}^h - \sum_{h \in H} E_e^h \frac{\partial x_i^h}{\partial I^h}$$

The functional relationship between the externality and the aggregate consumption of the "dirty good", commodity 1, is represented by $e = \mathrm{e}\left(\sum_{h \in H} x_1^{\mathrm{h}}\right)$.

We assume a linear production structure and perfect competition. By the appropriate choice of units and by choosing labour as numeraire, we can therefore without loss of generality assume all producer prices to be equal to 1, i.e. $\mathbf{p} = (p_0, p_1, p_2) = (1,1,1)$.

The government's expenditures, *A*, are financed by commodity taxes, $\mathbf{t} \equiv \mathbf{q} - \mathbf{p}$, and a uniform lump-sum tax, *T*. Thus, unearned income is for all households equal to the uniform lump-sum tax[2], i.e. I^h=-*T*. A(**q,p**) indicate how *A* depend on the tax structure; A(**q,p**) is homogeneous of degree zero in **q,** equal to $\overline{\mathrm{A}}(\mathbf{p})$ for $t_1 = t_2$, and equal to $\overline{\mathrm{A}}(\mathbf{p}) + \Delta\mathrm{A}(\mathbf{p})$ for $t_1 \neq t_2$.[3] $\Delta\mathrm{A}(\mathbf{p})$ may therefore be interpreted as the extra administrative costs of a differentiated compared to a proportional tax structure.

The government's preferences are expressed by an individualistic, Pareto social welfare function $W = W\left(u^1, u^2, .., u^H\right)$. Using the expenditure function approach (as for example in Munk 1978), we may therefore specify the government's problem in terms of the maximisation of social welfare with respect to *T*, $\mathbf{q}$, *e* and $\mathbf{u} = \left(u^1, u^2, .., u^H\right)$[4], subject to the following constraints:

1) $\mathrm{E}^h(\mathbf{q}, e, u^h) = -T$, h∈*H*, which says that the levels of individual utility must be consistent with the level of unearned income, i.e. $I^h = -T$. These constraints rule out individualised lump-sum transfers, but allow for a linear income tax.

2) $\mathrm{A}(\mathbf{q},\mathbf{p}) = \sum_{k=0}^{2} t_i \sum_{h \in H} \mathrm{E}_{\mathrm{k}}^{\mathrm{h}}(\mathbf{q}, e, u^h)$ +H*T*, which may be interpreted as the government's budget constraint. This constraint represents the three sets of general equilibrium conditions, i.e. the conditions for profit maximisation, utility maximisation and material balance.

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[2] *T* is negative if it is interpreted as the fixed element in a progressive linear income tax schedule.

[3] The administrative costs of tax administration consist of the costs of tax collection and the costs of tax enforcement. They are therefore likely to depend on both the complexity of the tax system and the level of the tax rates. We abstract , however, for the sake of simplicity from the dependence of the administrative costs on the level of the tax rates, since it is not relevant for points we are going to make in this paper.

[4] Only *T* and **t** are the policy instruments. Since producer prices are fixed choosing consumer prices, $\mathbf{q} \equiv \mathbf{p} + \mathbf{t}$, corresponds to choosing **t**. The household utilities, **u,** and the externality, *e*, are included in the set of controls to facilitate the interpretation of the first order conditions by providing expressions for the easy derivation of the net marginal social welfare of income, μ^h, and for the social value of a marginal increase in the externality, ρ.

3) $e = \mathrm{e}\left(\sum_{h\in H} \mathrm{E}_1^{\mathrm{h}}\left(\mathbf{q}, e, u^h\right)\right)$, which represents the relation between the level of the public good externality and the levels of consumer prices and individual utilities, and

4) $q_2 - p_2 = q_1 - p_1$. This constraint represents the restrictions on the government's choice of commodity tax rates when, compared to a proportional tax structure, differentiating the commodity tax rates, the benefits in terms of lower distortionary costs of taxation and a more desirable income distribution are smaller than the extra administrative costs, $\Delta \mathrm{A}(\mathbf{p})$.

To find the optimal tax structure the government therefore has to solve two maximisation problems. The first to maximise social welfare subject to the constraints 1-3, and the second subject to the constraints 1-4. The optimal tax structure is then that of the two solutions which is associated with the largest level of social welfare.

The Lagrangian corresponding to the government's maximisation problem may, in the first case where and $\mathrm{A}(\mathbf{q,p}) = \overline{\mathrm{A}}(\mathbf{p}) + \Delta \mathrm{A}(\mathbf{p})$, be written as

$$\begin{aligned} L^1 &= W\left(u^1, u^2, .., u^H\right) \\ &+ \sum_{h\in H} \mu^h \left(-T - E^h(\mathbf{q}, e, u^h)\right) \\ &+ \lambda\left(\sum_{i=0}^{2} t_i \sum_{h\in H} E_i^h(\mathbf{q}, e, u^h) + \mathrm{H}T - \mathrm{A}(\mathbf{q},\mathbf{p})\right) \\ &+ \rho\left(e\left(\sum_{h\in H} \mathrm{E}_1^{\mathrm{h}}\left(\mathbf{q}, e, u^h\right) - e\right)\right) \end{aligned} \tag{1}$$

and in the second case where $\mathrm{A}(\mathbf{q,p}) = \overline{\mathrm{A}}(\mathbf{p})$, as

$$L^2 = L^1 + \gamma\left(q_2 - q_1\right) \tag{2}$$

From the first order conditions with respect to u^h we have

$$\frac{\partial L}{\partial u^h} = \frac{\partial W}{\partial u^h} - \mu^h \mathrm{E}_u^{\mathrm{h}} + \lambda \sum_{i=0}^{2} t_i \mathrm{E}_{\mathrm{iu}}^{\mathrm{h}} + \rho \frac{de}{dX_1} \mathrm{E}_{1\mathrm{u}}^{\mathrm{h}} = 0 \tag{3}$$

and using that $E_{\mathrm{u}}^{\mathrm{h}} = 1/\frac{\partial \mathrm{v}^{\mathrm{h}}}{\partial I^{\mathrm{h}}}(\mathbf{q}, e, I^{\mathrm{h}})$, $E_{\mathrm{iu}}^{\mathrm{h}} = \frac{\partial \mathrm{x}_i^{\mathrm{h}}}{\partial I^{\mathrm{h}}}(\mathbf{q}, e, I^{\mathrm{h}}) / \frac{\partial \mathrm{v}^{\mathrm{h}}}{\partial I^{\mathrm{h}}}(\mathbf{q}, e, I^{\mathrm{h}})$ we obtain

$$\mu^h = \beta^h + \lambda \sum_{i=0}^{2} t_i \frac{\partial x_i^h}{\partial I^h} + \rho \frac{de}{dX_1} \frac{\partial x_1^h}{\partial I^h} \tag{4}$$

where $\beta^h \equiv \frac{\partial W}{\partial u^h} \frac{\partial v^h}{\partial I^h}$ is the *marginal social value of income for household h*. We may thus interpret μ^h, in analogy with Diamond 1975's *net marginal social value of* *income for household h*, as the increase in social welfare if the income of the h^th^ household were increased by one unit from outside the economy.

From the first order conditions with respect to *e* we have

$$\frac{\partial L}{\partial e} = -\sum_{h=H}\mu^h E_e^h + \lambda \sum_{i=0}^{2} t_i \sum_{h\in H} E_{ie}^h + \rho \frac{de}{dX_1}\sum_{h\in H} E_{1e}^h - \rho = 0 \tag{5}$$

Substituting for μ^h we have

$$-\sum_{h=H}\beta^h E_e^h - \lambda \sum_{i=0}^{2} t_i \left(\sum_{h\in H} E_{ie}^h - \sum_{h\in H} E_e^h \frac{\partial x_i^h}{\partial I^h}\right) + \rho \frac{de}{dX_1}\left(\sum_{h\in H} E_{1e}^h - \sum_{h\in H} E_e^h \frac{\partial x_1^h}{\partial I^h}\right) - \rho = 0 \tag{6}$$

from which we may obtain the following expression for the *social value of a marginal increase in the public good externality*

$$\rho = \left[-\sum_{h\in H}\beta^h E_e^h + \lambda \sum_{i=0}^{2} t_i \frac{\partial X_i}{\partial e}\right] \frac{1}{1 - \frac{de}{dX_1}\frac{\partial X_1}{\partial e}} \tag{7}$$

The first element in the bracket, $-\sum_{h\in H}\beta^h E_e^h$, is the social value of a marginal increase in the externality, disregarding the adjustment in household demand. The second element, $\lambda \sum_{i=0}^{2} t_i \frac{\partial X_i}{\partial e}$, is the opportunity cost value of the change in tax revenue due to change in consumption caused by a marginal increase in the externality. The last factor, $\frac{1}{1 - \frac{de}{dX_1}\frac{\partial X_1}{\partial e}}$, may be interpreted as an adjustment, taking into account the effect on the demand for the "dirty good" of the change in the externality, to the partial social welfare effect of an increase in the externality in order to get the total effect.

From the first order conditions with respect to T we have

$$\frac{\partial L}{\partial T} = -\sum_{h=H}\mu^h + \lambda H = 0' \tag{8}$$

Substituting for μ^h we have when a linear income tax is feasible that the *opportunity cost price of government funds* is

$$\lambda = \bar{\beta} + \lambda \sum_{i=0}^{2} t_i \sum_{h\in H} \frac{\partial x_i^h}{\partial I^h} \tag{9}$$

The remaining first order conditions for a maximum are

$$\frac{\partial L}{\partial q_0} = - \sum_{h=H} \mu^h x_0^h + \lambda \sum_{h\in H} x_0^h + \lambda \sum_{i=0}^{2} t_i \sum_{h\in H} E_{i0}^h + \rho \frac{de}{dX_1} \sum_{h\in H} E_{10}^h = 0 \tag{10}$$

$$\frac{\partial L}{\partial q_1} = - \sum_{h \ H} {}^h x_1^h + \lambda \sum_{\in H} x_1^h + \lambda \ {}^{2}_{i=0} \ t \sum_{H} E_i^h + \gamma + \rho \frac{de}{dX_1} \sum_{h\in H} E_{11}^h = 0 \tag{11}$$

$$\frac{\partial L}{\partial q_2} = - \sum_{h=H} \mu^h x_2^h + \lambda \sum_{h\in H} x_2^h + \lambda \sum_{i=0}^{2} t_i \sum_{h\in H} E_{i2}^h - \gamma + \rho \frac{de}{dX_1} \sum_{h\in H} E_{12}^h = 0 \tag{12}$$

3 Optimal tax structure and green tax reform

3.1 The optimal tax structure.

Criteria for desirable tax reforms are closely linked to the conditions for an optimal tax structure (see Dixit 1975). As background for the subsequent analysis of conditions, which guarantee a "double dividend" of a green tax reform, we therefore briefly summarise the basic insight of optimal commodity tax analysis in the case where there are no externalities and no restrictions on the government's choice of commodity tax rates.

In an economy with only one representative household all commodities must be discouraged at the same rate (see Ramsey 1927). In the case of only two produced commodities, the commodity, which is more complementary with leisure and for which an increase in the tax rate will therefore provide a relatively small encouragement to the consumption of leisure, will be taxed at a higher rate (see Corlett and Hague 1953). In the special and unrealistic case of leisure being separable from consumption, the optimal tax structure is proportional (see Deaton 1981). In an economy with many households the discouragement is, other things being equal, relatively low for commodities with relatively high income elasticity, and vice versa. The actual tax structure depends, however, if tax revenue is raised by an income tax crucially on its characteristics. When the government's revenue requirement is financed by a *linear income tax*, then, general speaking, normal goods will be taxed whereas inferior goods will be subsidised. When the government's revenue requirement is financed by *a proportional income tax* (i.e. T constrained to be zero), then, general speaking, goods with an income elasticity above 1 will be taxed, whereas not only inferior goods, but also normal goods with an income-elasticity sufficiently below 1 (how much below will depend on opportunity costs of government funds, λ) will be subsidised (see Munk 1977).

3.2 Green tax reform and the "double dividend"

Definitions should be judged on whether they are helpful or not in the context where they are to be used. We assume, following Goulder (1995), that the ultimate purpose of defining the "double dividend" is for the definition to be useful in the context of providing advice to policy-makers who consider implementing a green tax reform, i.e. in situations where a policy-maker has become aware of some environmental effects and is considering whether it is worthwhile to change the tax structure to internalise these effects. An example is the realisation by policy-makers of the potential damage of CO_2 pollution in the late 80es. It was in this context that the term the "double dividend" was first used by Pearce (1991) in suggesting that a tax on CO_2 emission would not only discourage environmental damage, but also produce a "double dividend" by reducing the distortionary costs of the tax system.

We assume that household behaviour before and after people have become aware of the environmental damage associated with the consumption of the "dirty good" is the same. We therefore represent the social preference *before* the change in awareness of the environmental effects by

$$\tilde{W} = W\left(\left\{\tilde{v}^h\left(\mathbf{q}, e, I^h\right), \mathrm{h} \in H\right\}\right) \text{ where } \frac{\partial \tilde{v}^h}{\partial e} = 0 \text{ for all } \mathrm{h} \in H \quad (13)$$

and (consistent with the formulation in Section 2) *after* by

$$W = W\left(\left\{v^h\left(\mathbf{q}, e, I^h\right), \mathrm{h} \in H\right\}\right) \text{ where } \frac{\partial v^h}{\partial e} < 0 \text{ for all } \mathrm{h} \in H \quad (14)$$

Based on these social welfare functions we then define a *green tax reform* $\left(\Delta \mathbf{t}^{\Gamma}, \Delta T^{\Gamma}\right)$, as the tax changes transforming the initial tax structure, ($\mathbf{t}^{I}$, T^{I}), which is optimal when no value is attached to the external effects, i.e. when based on $\tilde{W} = W\left(\left\{\tilde{v}^h\left(\mathbf{q}, e, I^h\right), \mathrm{h} \in H\right\}\right)$, into the tax structure, ($\mathbf{t}^{*}$, T^{*}), which is optimal when environmental damage is taken into account, i.e. when based on $W\left(\left\{v^h\left(\mathbf{q}, e, I^h\right), \mathrm{h} \in H\right\}\right)$.

The change in social welfare associated with the green tax reform may therefore be expressed as

$$\Delta W^{\Gamma} \equiv W\left(\left\{v^h\left(\mathbf{q}^*, e^*\left(\mathbf{q}^*, T^*\right), -T^*\right), \mathrm{h} \in H\right\}\right) - W\left(\left\{v^h\left(\mathbf{q}^I, e^I\left(\mathbf{q}^I, T^I\right), -T^I\right), \mathrm{h} \in H\right\}\right) \quad (15)$$

We divide ΔW^{Γ} into two dividends: the *"first dividend"*, D_1, being the change in social welfare due to the decrease in the externality, $\Delta e^{\Gamma} \equiv e^*\left(\mathbf{q}^*, T^*\right) - e^I\left(\mathbf{q}^I, T^I\right)$, net of the increase in the administrative costs, ΔA, if any[5]; and the *"second dividend"*, D_2, being the residual change in social welfare due to changes in the distortionary costs of taxation and in the distribution of income. The distinction is based on the

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[5] We assume ΔA to be equal to zero if the tax rate of the "dirty good" differs from that of the "clean good" already before the green tax reform.

assumption that the "first dividend" is relative easy to estimate or at least to conceptualise, whereas the "second dividend", especially for non-economists, is much more difficult to evaluate. We define a green tax reform to be associated with a "double dividend" if the "second dividend" is positive.

When becoming aware of the importance of environmental effects, policy-makers are often, as pointed out by Goulder (1995), frustrated by the complexities of evaluating green tax reforms due to the difficulty in evaluating the "second dividend". If a policy-maker could assume that the benefits due to other factors than the improvement in environmental quality and the increase in the costs of regulation were non-negative, then his task would be much simpler. In other words, the identification of conditions which would assure that the green tax reform were associated with a "double dividend", as defined here, would potentially facilitate the task of the decision-maker considerably.

Note that, although motivated by the same general objective, our definition differs from the one due to Goulder in taking the distributional aspect into account[6]. The definition is therefore, in our opinion, more relevant to policy-makers, and also more consistent with their decision-making process. Efficiency gains cannot be separated from distributional gains when cost-free individualised lump-sum transfers are not possible, which in fact they never are. Since, as pointed out by Proost and Van Regemorter (1995), and recognised by Bovenberg (1998), almost all governments behave as if they were inequality-averse - a definition of the "double dividend" which does not take this into account seems therefore, if properly understood by policy-makers, not to be pertinent, and, if not properly understood, potentially misleading. A rational policy-maker should design a green tax reform taking into account his distributional preferences. If he uses a definition of the "double dividend" based only on efficiency considerations, he may easily be misled to evaluate the effects of the tax changes as if he were inequality-neutral, which in general would be inconsistent with his preferences.

In order to identify conditions, which will assure a positive "double dividend" it is helpful to consider a first order approximation of the change in social welfare due to a green tax reform. We consider the case where before the green tax reform due to the administrative costs of differentiated tax rates the commodities are taxed at the same rate. A uniform commodity tax is equivalent to a wage tax; we may therefore, without loss of generality, assume that, prior to reform, the commodity tax rates are zero, i.e. $t_i = 0$ for $\mathrm{i} = 1,2$, and limit ourselves to consider tax reforms where the labour tax rate remain constant, i.e. $t_0 = t_0^I$. The green tax reform releases the tax constraints, and thus increases the administrative costs by ΔA. We also assume that the initial tax structure either has been optimised with respect to the lump-sum tax, *T*, or that *T* remains unchanged in real terms. In the case of a proportional income tax the change in tax revenue by increasing the tax on the "dirty good" to internalise the externality is therefore balanced by changing the tax rate on the "clean good", whereas in the case of a linear income tax the green tax reform may also involve a change in *T*.

[6] It also differs in assuming that policy-makers, interested in this type of measure, are rational.

The change in social welfare due to a green tax reform may, given these assumptions, by properties of Lagrangian multipliers be approximated by

$$\Delta\hat{W}^{\Gamma} \equiv \gamma(\Delta t_1^{\Gamma} - \Delta t_2^{\Gamma}) - \lambda\Delta A \tag{16}$$

The first element on the right-hand side of the equality sign represents the benefit of differentiating the tax structure. The second element is the opportunity cost value of the administrative costs associated with the differentiated rather than a uniform commodity tax[7].

From the first order conditions for an optimal tax structure with respect to q_1 and q_2, (11) and 12), we obtain the following expression for the *opportunity costs value of the tax constraint:*

$$\begin{aligned}\gamma &= \lambda t_0 E_{01} + \lambda\sum_{h\in H} x_1^h - \sum_{h\in H}\mu^h x_1^h + \rho\frac{de}{dX_1}\mathrm{E}_{11} \\ &= -(\lambda t_0 E_{02} + \lambda\sum_{h\in H} x_2^h - \sum_{h\in H}\mu^h x_2^h + \rho\frac{de}{dX_1}\mathrm{E}_{12})\end{aligned} \tag{17}$$

Substituting for γ, μ^h and ρ, and collecting terms we have (see Technical Appendix)

$$\Delta\hat{W}^{\Gamma} = \lambda t_0 \sum_{k\in C}\frac{\partial X_0^h}{\partial q_k}\Delta t_k^{\Gamma} + \lambda t_0\frac{\partial X_0}{\partial e}\Delta\hat{e}^{\Gamma} - \sum_{h\in H}\beta^h E_e^h\,\Delta\hat{e}^{\Gamma} + \sum_{k\in C}(\lambda - \mathrm{R}_k)X_k\,\Delta t_k^{\Gamma} \tag{18}$$

where $R_k \equiv \frac{\sum_{h\in H}\beta^h x_k^h}{X_k}$ is *the distributional characteristic of commodity k,* and $\Delta\hat{e}^{\Gamma} = \frac{\frac{de}{dX_1}}{1-\frac{de}{dX_1}\frac{\partial X_1}{\partial e}}\sum_{k=0}^{2}\frac{\partial X_1}{\partial q_k}\Delta t_k^{\Gamma}$ *the first order approximation of the change in the externality due to the green tax reform.*

3.3 Conditions conducive to a positive "double dividend"

Using the framework thus established, we in this section first explain why, as in the standard analysis of the "double dividend" question, ignoring the importance of administrative costs for the optimal tax structure leads to the view that the "double dividend" is always negative. We then briefly restate the case why it is realistic to expect that the tax structure prior to a green tax reform is restricted by administrative costs, and based on this assumption move on to identify conditions under which a green tax reform will be associated with a "double dividend".

[7] The criteria thus take into account that the increased administrative costs will have to be financed by distortionary taxation.

It follows from a simple argument that if the tax constraint is non-binding before a green tax reform, i.e. where the social welfare function attaches no value to the change in the externality, then the "double dividend" is non-positive. If the tax structure before the green tax reform is optimal given the social welfare function, $W\left(\left\{\tilde{v}^h\left(\mathbf{q}, e, I^h\right), \mathrm{h} \in H\right\}\right)$, then the change in social welfare due to any feasible tax reform, including the green tax reform, $\left(\Delta\mathbf{t}^\Gamma, \Delta T^\Gamma\right)$, must by definition be non-positive, i.e. $\Delta\tilde{W} \leq 0$. However, $\Delta\tilde{W}$ is when the tax constraint is non-binding equal to the second dividend calculated based on $W\left(\left\{v^h\left(\mathbf{q}, e, I^h\right), \mathrm{h} \in H\right\}\right)$. A green tax reform will therefore, when prior to reform the tax constraint is non-binding, never be associated with a "double dividend".

There are two reasons why the tax constraint may be non-binding prior to a green tax reform. *First*, that the optimal tax structure is proportional, even disregarding the costs of differentiating the tax structure. In an economy with only one representative consumer where consumption is separable from leisure, as the one considered in Bovenberg (1998), this is the case. In such an economy, when no value is attached to the externality, a proportional tax structure is the optimal solution to the government's maximisation problem. Therefore the tax constraint will not be binding. Replacing a wage tax by a uniform commodity tax does not change the allocation, and differentiating the commodity tax structure to decrease the externality will in this case discourage the supply of labour and hence increase the distortionary costs of taxation. A green tax reform, which replaces a wage-tax with a differentiated commodity tax structure to internalise the externality, will therefore not be associated with a "double dividend". The *second* reason why the tax constraint may not be binding prior to a green tax reform, is that it has been optimal to differentiate the tax structure already before taking the environmental aspect into account, i.e. that the administrative costs needed to differentiate the tax rates have already been incurred prior to the implementation of the green tax reform.

However, in the context of providing relevant policy advice to conclude on this basis that a green tax reform will never be associated with a "double dividend", is clearly to go too far. To assume that consumption is separable from leisure is a very restrictive assumption, and in a many household economy far from sufficient for a proportional tax structure to be optimal. There are in fact no convincing justification for assuming that a proportional tax structure should be optimal, other than the administrative costs for such a tax structure are lower than those of a differentiated tax structure. It therefore reasonable to expect that prior to a green tax reform the administrative costs involved in differentiating commodity tax rates in many cases constrain the tax structure to be proportional. It is therefore relevant, according to the justification provided above, in the context of defining the "double dividend", to try to identify conditions conducive to a green tax reform being associated with a "double dividend" based on this assumption. To do that, we use the first order approximation of the change in social welfare due to a green tax reform, derived in the previous section.

Based on the definition provided above, the "first dividend" of the green tax reform may be approximated by

$$\hat{D}_1 - \sum_{\mathrm{h}\in H} \beta^{\mathrm{h}} E_e^h \; \Delta\hat{e}^\Gamma \qquad (19)$$

and the "second dividend", therefore by

$$\hat{D}_2 \equiv \Delta\hat{W}^{\Gamma} -(- \sum_{h\in H} b^{h} E_e^h \; \Delta\hat{e}^{\Gamma} - \lambda\Delta A) \tag{20}$$

or by substituting for $\Delta\hat{W}^{\Gamma}$ using (16), by

$$\hat{D}_2 = \gamma(\Delta t_1^{\Gamma} - \Delta t_2^{\Gamma}) + \sum_{h\in H} \beta^{h} E_e^h \; \Delta\hat{e}^{\Gamma} \tag{21}$$

and using (18), by

$$\hat{D}_2 \equiv l t_0 (\sum_{k\in C} E_{0k} \; \Delta t_k^{\Gamma} + E_{0e} \, \Delta\hat{e}^{\Gamma}) + l t_0 (\sum_{h\in H} \frac{\P x_i^h}{\P I^h} x_k^h \; \Delta t_k^{\Gamma} + \sum_{h\in H} \frac{\partial x_i^h}{\partial I^h} E_e^h \; \Delta\hat{e}^{\Gamma}) + \sum_{k\in C} (\lambda - R_k) X_k \; \Delta t_k^{\Gamma} \tag{22}$$

Based on (22), $\hat{D}_2$ " may be divided into two elements, $\hat{D}_{2.1}$ and $\hat{D}_{2.2}$:

1) The approximation of *change in social welfare due to the change in the distortionary cost of taxation,*

$$\hat{D}_{2.1} = l t_0 (\sum_{k\in C} E_{0k} \; \Delta t_k^{\Gamma} + E_{0e} \, \Delta\hat{e}^{\Gamma}) + l t_0 (\sum_{h\in H} \frac{\P x_i^h}{\P I^h} x_k^h \; \Delta t_k^{\Gamma} + \sum_{h\in H} \frac{\partial x_i^h}{\partial I^h} E_e^h \; \Delta\hat{e}^{\Gamma}) \tag{23}$$

is the sum of two main effects, represented by the two brackets in (23). The last bracket represents the income effect. Assuming that leisure is a normal good this effect will tend to have the same sign as the change in social welfare and can therefore be disregarded in determining the sign of the change in social welfare[8]. The sign of the change in social welfare is thus in general determined by the first bracket: the change in tax revenue caused by the change in the supply of the labour 1) due to the induced decrease in the externality, $t_0 E_{0e} \; \Delta\hat{e}^{\Gamma}$, and 2) due to the change in tax rates directly, $\sum_{k\in C} t_0 E_{0k} \; \Delta t_k^{\Gamma}$. If the decrease in the externality increases the supply of labour, i.e. if $t_0 E_{0e} \Delta\hat{e}^{\Gamma} > 0$, it contributes to an increased social welfare; if the opposite is the case, it decreases social welfare. The direct effect of the change in the tax rates on the labour supply, $\sum_{k\in C} t_0 E_{0k} \, \Delta t_k^{\Gamma}$, will only be positive if the consumption of the "dirty good" is complementary to leisure. In this case a move from a proportional tax structure to a tax structure in which the "dirty good" is taxed at a higher rate than the "clean good", will decrease the costs of taxation and thus, ceteris paribus, increase social welfare. This is consistent with the commodity, the consumption of which is more complementary with leisure and for which an increase in the optimal tax rate will therefore provide a relatively small encouragement to the consumption of leisure, based on efficiency considerations alone will be taxed at a higher rate (cf. Corlett and Hague 1953).

[8] The effect will strictly have the same sign as the change in social welfare in the case of a one household economy such as the one considered in Bovenberg (1998).

2) The approximation of the *change in social welfare due to income distributional effects* (due to the changes in tax rates without taking the change in the externality into account)

$$\hat{D}_{2.2} = \sum_{k \in C} (l - R_k) X_k \ \Delta t_k^{\Gamma} \tag{24}$$

which is positive if the value of the tax payments valued by distributional characteristics is greater than when valued at the opportunity cost of government funds. When the government's revenue requirement is financed by a *linear income tax*, we have from the first order conditions with respect to T , *(10)*, that $\lambda = \vec{\beta} + \lambda t_0 \sum_{h \in H} \frac{\partial x_0^h}{\partial I^h} \frac{1}{H}$. If the "dirty good" is a normal good, $R_1 < \vec{\beta}$. Therefore if the government can raise tax revenue by a linear income tax, $\hat{D}_{2.2}$ will, in general, be positive if the income elasticity of the "dirty good" is greater than zero. If the government is constrained to raise income tax revenue by *a proportional income tax* $\hat{D}_{2.2}$ will, in general, be positive if $R_1 < R_2$, i.e. if the income elasticity of the "dirty good" is greater than one.

To summarise, if the tax structure prior to the green tax reform has been proportional due to administrative costs, then the following two conditions are sufficient for a green tax reform to be associated with a positive "double dividend":

First, that the tax shift and the resulting change in the externality discourage the consumption of leisure. This will be the case if the "dirty good" and the externality are complementary to leisure.

Secondly, that the tax shift improves the distribution of income (leaving aside the income distributional effects of the change in the externality). Generally speaking, this will be more likely to be the case the more the "dirty good" consumed by the "rich". Whether the tax shift will improve the distribution of income or not depends critically on the type of income tax used, for example whether it is a wage tax or a linear income tax.

4 A quantitative illustration

To support the insight gained in the theoretical analysis we provide a quantitative illustration taking as an example a green tax reform to internalise the externalities associated with *leisure travel*. The results are derived from an illustrative CGE model which is documented in the Annex together with the details of the simulation results.

As seems reasonable in the case of leisure travel, we assume that the share of income spent on the "dirty good", i.e. leisure travel, for high income households is greater than for low income households, and that the time spent consuming the "dirty good", is relatively more important than for consumption in general. We assume that the households' evaluation of the environmental damage associated with the consumption of leisure travel is proportional to household income, and that the externality is separable from the consumption of final commodities and leisure. The extra administrative costs of a differentiated tax structure are assumed to be 100 units greater than of a proportional tax structure[9]. Finally, we assume that the government is inequality-averse, attaching the double value to an increase in the income of low-income households compared to that of high-income households. The opportunity costs of government funds are 1.4 (1.3. if the government is alternatively assumed to be inequality-neutral).

When the externality is not taken into account, the administrative costs make it unattractive to differentiate the tax structure although this would significantly reduce the distortionary costs of tax collection and have positive income distributional effects, given the parameter values which have been chosen (see Annex, Table 3, Column (2) and (3)). However, both for an inequality-neutral and an inequality-averse government a differential tax on leisure travel becomes desirable when the environmental benefits are taken into account (see Annex Table 3, Column (3) and (4)).

Table 1. ***The initial tax structure constrained by administrative costs.***

	Inequality- neutral	*Inequality- averse*
First dividend, D_1, of which	-24	-2
- Environmental benefits	106	138
- Administrative costs	-130	-140
Second dividend, D_2	**33**	**122**
Change in social welfare	9	120

Source: Illustrative CGE model, Annex, Table 3

Table 2. ***The initial tax structure not constrained by administrative costs.***

	Inequality- neutral	*Inequality- averse*
First dividend, D_1	33	30
Second dividend, D_2	**-17**	**-14**
Change in Social welfare	16	16

Source: Illustrative CGE model, Annex, Table 3

Tables 1 and 2 report the simulation results in terms of the change in social value broken down on the "first dividend" and the "second dividend" assuming, respectively, that the initial tax structure is constrained by administrative costs, and that it is not.

We see that in the case where the green tax reform involves a change in administrative costs (Table 1), both for an inequality-neutral and an inequality-averse government the "double dividend" is significant compared to the environmental benefits. The "double dividend" for an inequality-averse government is at 122 relatively more important than for an inequality-neutral government where it is only

[9] For reference the GNP is 161.670, household consumption of leisure travel, 5.000, of other goods, 92.000 and government consumption, 64.670 (see Annex, Table 1)

33. *This illustrates that the scope for a significant "double dividend" is larger when the distributional aspect is taken into account than when it is not.*

However in the case where there are no administrative costs (Table 2) there are no "double dividend". *The simulation results thus also illustrate the crucial role played by the assumptions concerning administration costs*.

It would be easy to provide an example where the "double dividend" is positive for an inequality-averse policy-maker, but negative if only the efficiency gains are taken into account. *The simulation model may thus also illustrate the potential confusion which defining the "double dividend", based only on the effect of the distortionary costs of taxation, may create.*

5 Summary and concluding remarks

With respect to the likelihood of a green tax reform generating a significant "double dividend", the analysis has confirmed the prevailing opinion among economists to the extent that there is no presumption, even taking administrative costs into account, that a shift from indirect taxation to direct taxation with the objective of internalising environmental externalities, is likely, in general, to generate a "double dividend". If the optimal tax structure has been differentiated to exploit the benefits in terms of reduction of distortionary costs of taxation and a more desirable income distribution, the "double dividend", as defined in this paper (and in Goulder 1995), will be negative. However, the analysis has also shown that in those cases where environmental objectives, on the one hand, and the objectives of a more desirable income distribution and of reducing the distortionary costs of taxation, on the other hand, justify tax changes going in the same direction, but where the benefits, based on the second set of objectives taken in isolation, are too small to justify the administrative costs of a differentiated tax structure, a significant "double dividend" may be a realistic possibility. In practice, it is undoubtedly quite common prior to a green tax reform for "dirty goods", for administrative reasons to be taxed at the same rate as a large number of "clean goods". The results established in this paper are therefore not only of theoretical interest, but also, in the context of decision-making on environmental policies, of considerable relevance in practice.

Furthermore, the paper has demonstrated that the "expenditure function approach" in the case of externalities, as in other areas of public economics, facilitates the analysis of optimal taxation and project evaluation. The presence of externalities provides a supplementary reason why taking administrative costs into account can significantly modify the optimal tax structure and criteria for project evaluation. We have in this paper focused on how to integrate the administrative costs of alternative regulatory regimes in the theoretical analysis in the simplest way possible, and therefore have deliberately based the analysis on the well-known standard model with only one primary factor. The simple model prevents, however, certain important issues from being considered, such as for example whether a desirable green tax reform in taking administrative costs of alternative regulatory regimes and income distributional effects into account is likely to create productive inefficiency, and how governments should provide support to alleviate pain of structural adjustment to industries particularly affected by environmental policy changes. However, these issues may be analysed extending the framework to represent more than one primary factor, and sectors with decreasing returns to scale, (see Munk 1980 and 1998). Such an extension of the analysis seems of particular interest in the context of the ongoing search among economists and political decision-makers for ways to reform the tax-transfer system to provide income support and increased employment opportunities for low-skilled workers disadvantaged by globalisation and technological change.

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Technical Appendix:
Derivation of approximation of change in welfare due to green tax reform

Substituting for γ in (16) we have

$$\Delta\hat{W}^{\Gamma} = \sum_{k\in C} (\lambda t_0 E_{0k} + \lambda \sum_{h\in H} x_k^h - \sum_{h\in H} \mu^h x_k^h)\Delta t_k^{\Gamma} + \sum_{k\in C} \rho \frac{de}{dX_1} E_{1k}\,\Delta t_k^{\Gamma} - \lambda\Delta A$$

Substituting for $\mu^h = \beta^h + \lambda \sum_{i=0}^{2} t_i \frac{\partial x_i^h}{\partial I^h} + \rho \frac{de}{dX_1}\frac{\partial x_1^h}{\partial I^h}$ we get

$$\Delta\hat{W}^{\Gamma} = \lambda t_0 \sum_{k\in C} (E_{0k}\, dt_k - \sum_{h\in H} \frac{\partial x_0^h}{\partial I^h} x_k^h)\Delta t_k^{\Gamma} + \rho \frac{de}{dX_1} \sum_{k\in C} (E_{1k} - \sum_{h\in H} \frac{\partial x_1^h}{\partial I^h} x_k^h)\Delta t_k^{\Gamma}$$
$$+ (\sum_{k\in C} \lambda \sum_{h\in H} x_k^h - \sum_{h\in H} \beta^h x_k^h)\Delta t_k^{\Gamma} - \lambda\Delta A$$

and thus

$$\Delta\hat{W}^{\Gamma} = \lambda t_0 \sum_{k\in C} \frac{\partial X_0}{\partial q_k}\Delta t_k^{\Gamma} + \rho \frac{de}{dX_1} \sum_{k\in C} \frac{\partial X_0}{\partial q_k}\Delta t_k^{\Gamma} +. \sum_{k\in C} (\lambda \sum_{h\in H} x_k^h - \sum_{h\in H} \beta^h x_k^h)\Delta t_k^{\Gamma} - \lambda\Delta A$$

Writing $R_j \equiv \frac{\sum_{h\in H} \beta^h x_j^h}{X_j}$ and $\Delta\hat{e}^{\Gamma} \equiv \frac{\frac{de}{dX_1}}{1 - \frac{de}{dX_1}\frac{\partial X_1}{\partial e}} \sum_{k=0}^{2} \frac{\partial X_1}{\partial q_k}\Delta t_k^{\Gamma}$, and using that

$\rho = \left[-\sum_{h\in H} \beta^h E_e^h + \lambda \sum_{i=0}^{2} t_i \frac{\partial X_i}{\partial e} \right] \frac{1}{1 - \frac{de}{dX_1}\frac{\partial X_1}{\partial e}}$ we get the following approximation of change in welfare due to a green tax reform

$$\Delta\hat{W}^{\Gamma} = \lambda t_0 \sum_{k\in C} \frac{\partial X_0}{\partial q_k}\Delta t_k^{\Gamma} + \lambda t_0 \frac{\partial X_0}{\partial e}\Delta\hat{e}^{\Gamma} - \sum_{h\in H} \beta^h E_e^h\,\Delta\hat{e}^{\Gamma} + \sum_{k\in C} (\lambda - R_k) X_k\,\Delta t_k^{\Gamma}$$

Annex : Illustrative CGE model

Introduction

In this note we document a CGE model, which has been specified to satisfy the conditions for the "double dividend" to be positive, and report simulation results to illustrate that a green tax reform may generate a significant double dividend, even if the government policies prior to taking the environmental aspect into account have been economically rational. The CGE model has a number of characteristics which, in our opinion, are essential in order for a CGE model to be used to address the issues of a green tax reform in a politically relevant way. Though simple, the CGE model provides a flexible representation of the interaction between the consumption and leisure for the various commodities. It allows the differences in administrative costs of different regulatory regimes to be taken into account, as well as the distributional consequences of tax changes by representing the household sector by two types of households, a low-skilled households and a high-skilled household, where the government attaches higher social welfare weights to the income of the former than of the latter.

Specification of the CGE model

For optimal tax analyses, the most important aspect of constructing a CGE model is in general the specification of household preferences. Often CGE models are based on assumptions that make them unsuited for optimal tax analyses. Often an economy with only one type of household is considered, and labour supply is assumed either to be fixed, or, if endogenous, preferences are assumed to be homothetic with the consumption of produced goods being separable from the consumption of leisure. These assumptions imply, as we have seen (Section 3.1), that a proportional tax structure is optimal. There are no compelling evidence for justifying these assumptions, rather the contrary (see for example Myles 1995). They may facilitate the theoretical analysis and model construction considerably, and for some purposes they may represent a justifiable simplification of reality. However, this is seldom the case in second-best welfare economic analyses where they may indeed lead to conclusions which in a practical political context are grossly misleading with respect to what constitutes the optimal tax structure and desirable directions of policy reform. The analysis of green policy reform is by no means an exception in this respect. The methodology pioneered by Perroni and Rutherford (1995) and the corresponding computational technique (Rutherford 1994) which have been adopted here to specify household preferences avoid the pitfalls of making such assumptions.

The following supplementary assumptions have been made to specify the CGE model:

The *household utility functions,* $u^{\mathrm{h}}\left(\mathbf{x}^{\mathbf{h}}, e\right)$, are assumed to take the form

$$u^h = U^h\left(C^h\left(C_1^h\left(x_1^h, c_0^{1.h}; \sigma^{C1.h}\right), C_2^h\left(x_2^h, c_0^{2.h}; \sigma^{C2.h}\right)\right), c_0^{0.h}; \sigma^{L.h}\right) + E_e^h e$$ [10]

where $c_0^{i.h}$ is the time used for the consumption of commodity i, and $c_0^{0.h}$ indicates pure leisure, i.e. the amount of time spent on activities which do not involve the consumption of purchased commodities. The elasticity, $\sigma^{L.h}$, expresses for each household the substitution between aggregate consumption C^h and pure leisure $c_0^{0.h}$, $\sigma^{D.h}$ is the elasticity of substitution between the two composite goods C_1^h and C_2^h, and $\sigma^{Ci.h}$ the elasticity of substitution between the amount purchased of the commodity i, x_i^h, and the time spent on its consumption $c_0^{i.h}$. $z_0^h = \omega_0 - \sum_{i \in C} c_0^{i.h} - c_0^{0.h}$ therefore is the time spent supplying labour to the market. The supply of labour in efficiency units (measured negatively) is $x_0^h = -\psi^h z_0^h$, where ψ^h is an indicator of labour productivity. The budget constraint for the h[th] household may therefore be expressed alternatively as $\sum_{i \in COM} q_i x_i^h = Y^h$, where $q_0^h = \psi^h q_0$ is the hourly after-tax wage rate and $Y^h = q_0^h z_0^h + I^h$ is household income. This specification allows household preferences defined over marketed commodities and labour, $u^{\mathrm{h}}\left(\mathbf{x}^{\mathbf{h}}, e\right)$, to represent different degrees of complementarity of the two purchased commodities with "leisure" in the sense of non-market spending of time, i.e. $c_0^h = \sum_{i \in C} c_0^{i.h} + c_0^{0.h}$.

The real income, RI^h, of the h[th] household is defined to be equal to its income in the benchmark situation, $Y^{h.0}$, plus the equivalent variation of the policy change, i.e.

$$RI^h = Y^{h.0} + E^h\left(\mathbf{q}^0, e^0, v^h(\mathbf{q}, e, I^h)\right) - I^{h.0}$$

In the case of an inequality-adverse government, the social welfare weight assigned to the real income of the low-skilled households is twice that of the high-skilled households. Assuming that the number of low-skilled and high-skilled households are the same, the criteria for policy change to be desirable for an *inequality-neutral* government is therefore that

$$\Delta W = \Delta RI^{LS} + \Delta RI^{HS},$$

and for an *inequality-adverse* government that

$$\Delta W = 2\Delta RI^{LS} + \Delta RI^{HS}.$$

[10] Note that this utility function is a special case of the utility function defined on market transactions, $\mathrm{u}^{\mathrm{h}}\left(\mathbf{x}^{\mathbf{h}}, e\right)$, on which the theoretical analysis is based. The results generated by the CGE model are therefore by assumption consistent with any result derived from the theoretical model. The externality has been assumed to be additively separable with a constant marginal utility. This assumption is not realistic, but that is of little importance for the points we want to illustrate here.

The benchmark data set on which the CGE model is calibrated is provided in the form of a Social Accountancy Matrix (SAM) (see Table 1).

The functional form for how the externality is related to the households' consumption of the "dirty good", commodity 1, is

$$e = \sum_{h \in HOUSE} x_1^h$$

Table 1 ***The state of the economy prior to the green tax reform in the form of a SAM***

		1.		2.		3.		4.	5.		6.	*Total*
		S1	S1	1	2	1	2		LS	HS		
1. Production accounts for each sector	S1			5.000		0						*5.000*
	S1				92.000		0					*92.000*
2. Material balance accounts for each commodity	1								100	4900		*5.000*
	2								5000	87000		*92.000*
3. Commodity tax accounts for each commodity	1								0	0		
	2								0	0		
4. Material balance account for labour		5.000	92.000								64670	*161.670*
5. Household income - expenditure accounts	LS							5.100				*5.100*
	HS							91.900				*91.900*
6. Government budget account								64.670				*64.670*
Total		*5.000*	*92.000*	*5.000*	*92.000*			*161.670*	*5.100*	*91.900*	*64.670*	

Note: S1 and S2 indicate production sectors, 1 and 2, "dirty good" and "clean good" respectively, and LS and HS the low-skilled and high-skilled household's, respectively

The SAM represents 6 types of accounts, in total 10 accounts as indicated in Table 1. Note that the share of consumption of the dirty good, α_1^h, is 2% for the low-skilled households, but 5% for the high-skilled household and that the governments revenue requirement is financed by a 40% income tax, which is equivalent to a 66 2/3% uniform tax on the consumption of the produced commodities.

The parameters of the utility functions are provided in Table 2. For both households the shares of time spent consuming the "dirty good", and the "clean good" relative to their share of market purchases, $(c_0^{1.h} / \omega_0) / \alpha_1^h$ and $(c_0^{2.h} / \omega_0) / \alpha_0^h$, are specified so that the consumption of the "dirty good" requires relatively more time for its consumption than the "clean good", and is therefore more complementary with leisure.

Table 2 ***Parameters***

	Low-skilled	**High-skilled**
$\sigma^{L.h}$	0.50	0.50
$\sigma^{D.h}$	0.50	0.50
$\sigma^{Ci.h}$	0.00	0.00
$(c_0^{1.h} / \omega_0) / \alpha_1$	0.50	0.50
$(c_0^{2.h} / \omega_0) / \alpha_2$	0.00	0.00

The CGE model has been specified to generate illustrative results, rather than to be realistic. Elasticities of substitution between leisure and consumption, which determined the costs of government funds are 1.4, which are in line with those used in empirical models (see Snow and Warren 1996). The model has been programmed in GAMS/MPSGE (see Rutherford 1994). The program can be obtained from the author.

Simulation results

The optimal tax structure has been calculated under four different sets of assumptions. The simulation results in terms of household taxes, government expenditures, supply of labour, the size of the externality and normative indicators (real income and social welfare) are provided in Table 3. The initial state of the economy, where the government's tax revenue is raised by a proportional tax structure (wage tax), is represented in Column 1. Columns 2 and 3 represent what would be the optimal solution if the administrative costs of differentiating the tax rates between leisure travel and other goods where taken as exogenous, when, as has been assumed to be the case before the green tax reform, the government attach no value to the reduction in the externality, assuming, respectively that the government is either inequality-neutral or inequality-averse. Columns 4 and 5 represent the optimal solutions after the green tax reform under these two alternative assumptions. We see that when the administrative costs of differentiating the tax rates between the "dirty good" and the "clean good" are taken into account, then a proportional tax structure, as is in the initial state of the economy, is the optimal solution: differentiating the tax rates would when the government is inequality-neutral decrease social welfare by 80 (see Columns 2), and when the government is inequality-averse by 4 (see Columns 3). In contrast, a green tax reform will if the government is inequality-neutral increase social welfare by 9, and under the alternative assumption that it is inequality-averse, by 120.

Table 3. *Consequences of changes in policies*

	State of the economy before the green tax reform	Optimal tax structure without taking the externality into account[1]		Optimal tax structure taking the externality into account	
	(1) *%*	***Neutral(2)*** *%*	***Averse(3)*** *%*	***Neutral(4)*** *%*	***Adverse(5)*** *%*
Household taxes					
Labour, $-t_0$	40	40	40	40	40
Leisure travel, t_1	0	24	37	38	50
Other goods, t_2	0	-1	-2	-2	-3
	Level values	***Change (1) -(2)***	***Change (1) -(3)***	***Change (1) -(4)***	***Change (1) -(5)***
Government expenditures					
Adm. costs and other gov. exp.	64.670	100	100	100	100
Opportunity cost value		130	140	130	140
Supply of labour and externality					
Labour X_0	161.670	273	387	392	503
Externality *e*	5.000	-484	-553	-561	712
Value of reduction in externality		73	108	106	138
Normative indicators attaching no value to the externality		*Disregarding the externality*		*Taking externality into account*	
Real income low-skilled	5.100	61	92	*94*	*123*
Real income high-skilled	91.900	-141	-188	*-191*	*-263*
Social welfare	.	**-80**	**-4**	*-97*	*-18*
Normative indicators attaching value to the externality		*Disregarding the externality*		*Taking externality into account*	
Real income low-skilled		*63*	*95*	97	126
Real income high-skilled		*-71*	*-87*	-88	-132
Social welfare		*-7*	*104*	**9**	**120**

[1] Assuming that the administrative costs are exogenous