Published in: Oxford Economic Papers 48.1996, pp. 537-555

Evaluating tax reforms in the presence of externalities*

by

Ronnie Schöb
University of Essex and University of Munich

Abstract

According to the double-dividend hypothesis, revenue-neutral green tax reforms are expected both to improve the quality of the environment and to reduce existing tax distortions. This paper develops welfare measures which are used to estimate these dividends separately. It is shown that the existing tax system and the choice of the tax rate cuts which accompany an increase in green taxes have considerable impact on the magnitude of the environmental dividend. Even a negative impact cannot be ruled out. Furthermore, the welfare measures allow us to analyse the trade-off between the two dividends and to identify welfare improving tax reforms.

JEL classification: H21, Q28

Correspondence Address
Ronnie Schöb
Department of Economics
University of Munich
Schackstrasse 4
D-80539 Munich
Germany
tel.: ++49/89/2180-6261
fax: ++49/89/397303
email: ronnie.schoeb@ces.vwl.uni-munchen.de

"We shall deal with our economic system as it is and as it may be modified, not as it might be if we had a clean sheet of paper to write upon; and step by step we shall make it what it should be."
Woodrow Wilson

1. Introduction

In recent years, green taxes have become very attractive both as an instrument for environmental policy and as a source of public revenues. Following the seminal paper of Sandmo (1975), which links optimal taxation analysis to environmental issues, a growing literature has emerged on the so-called double-dividend hypothesis. This hypothesis claims that a green tax reform, where existing taxes on non-polluting ('clean') goods are (partly) replaced by taxes on polluting ('dirty') goods, will both improve the environment and reduce the distortion of the existing tax system. To examine these two dividends in detail the paper develops a set of welfare measures which allows us to analyse the two dividends separately. Thereby, it follows Feldstein (1976) and Ahmad and Stern (1984) in focusing on welfare improving *tax reforms* instead of looking for welfare maximizing *tax design*.

It seems to be taken for granted that the *environmental dividend* of such a green tax reform is always positive (cf. Goulder 1995 or Repetto 1994). Obviously, increasing a tax on a polluting good will improve the environment. To determine the environmental dividend from a revenue-neutral green tax reform, however, the effects the accompanying tax rate cuts may have on the environment have also to be taken into account. Due to the complementarity/substitutability relationships between taxed clean goods and dirty goods, environmental quality is affected when the prices of the clean goods change. Hence, to define properly the environmental dividend from a revenue-neutral green tax reform, these effects have to be adequately incorporated into the analysis. The first purpose of this paper therefore is to derive necessary conditions for the environmental dividend to be positive. It turns out that the sign and magnitude of the environmental dividend are critically dependent on the existing tax system from which the green tax reform starts and on the choice of the accompanying tax rate cuts.

The second dividend under the double-dividend hypothesis concerns the effect of a green tax reform on the efficiency of the tax system. According to Goulder (1995) we can distinguish several definitions of the second dividend. A *second dividend* in its 'weak' definition occurs if tax revenues from a green tax can be used to reduce other distortionary taxes and hence improve the allocative efficiency, relative to the case where tax revenues are returned to taxpayers as a lump-sum transfer (cf. Nichols 1984 and Lee and Misiolek 1986). The stronger form defines the second dividend as the effect a revenue-neutral green tax reform has on the non-environmental welfare cost of the whole tax system. Bovenberg and de Mooij (1994) have shown that, interpreted in this stronger form, the second dividend may not be positive. The second purpose of the paper is to clarify the circumstances in which the double-dividend hypothesis is valid and shows how to identify welfare improving tax reforms if the hypothesis fails.

Section 2 develops a set of welfare measures which allows the analysis of the two dividends separately. These welfare measures can be used to identify welfare improving green tax reforms starting from an existing and normally non-optimal tax system (Section 3). The applicability of these measures for estimating the welfare effects of tax reforms in the presence of externalities is demonstrated in Section 4 by estimating both dividends and the welfare effect of different tax reforms for the U.K. Equity considerations follow in Section 5. Section 6 concludes.

2. Welfare measures to evaluate tax reforms

Consider a small open economy. Ignoring distributional issues we assume that there are H identical households all treated equally by the government. Each household consumes N+2 private goods. The quantities are denoted by $x_0, x_1, \ldots, x_N, x_d$ The first N+1 goods are clean goods, i.e. goods whose consumption creates no externality. The aggregate consumption of good d, called the dirty good, creates a negative externality E:

$$E = H \cdot x_d. \tag{1}$$

The preferences of each household are described by a twice continuously differentiable, strictly quasi-concave utility function $u(x_0, x_1, ..., x_N, x_d, E)$. The marginal utilities u_i, $i = 0,...,$ N, d, are positive; the marginal utility of emissions u_E is negative. Positive quantities denote the demand for goods, negative quantities denote the supply of factors. For mathematical convenience, all initial endowments are normalized at zero.

To analyse tax reforms it is convenient to use the indirect utility function v in the social welfare function. In a small open economy, producer prices are equal to world market prices and hence remain constant when consumer prices change. Normalizing all producer prices at unity and choosing good 0 as numéraire, which is assumed to be untaxed, the utilitarian social welfare function is given by:

$$W = Hv(t_1, ...t_N, t_d, T, E), \tag{2}$$

with t_i denoting the tax rate on the clean good i, with $i = 1,...,N$, and t_d denoting the tax rate on the dirty good d. T is a lump-sum transfer from the government to each household.

The welfare change of a tax rate change, normalized by the marginal utility of the numéraire u_0 (i.e. the marginal utility of lump-sum income), is given by

$$\mathrm{d}\tilde{W} \equiv \frac{\mathrm{d}W}{u_0} = H\left(-x_k + \frac{u_E}{u_0}\frac{\partial E}{\partial t_k}\right)\mathrm{d}t_k, \tag{3}$$

with $k = 1,...,N$, d. The first term in brackets represents the direct utility loss of a household according to Roy´s identity. The second term denotes the indirect effect of a tax rate change due to the change in the environmental quality. Assuming that the consumption of the dirty good is independent of the environment, we can use $\partial E/\partial t_k = H \cdot \partial x_d / \partial t_k$.[1] Because of the own-price effect ($k = d$) or the cross-price effect ($k = 1,...,N$), a change in the consumer price changes the consumption of the dirty good d and therefore changes the emissions E.

Total tax revenues R are given by

$$R = H\left(\sum_{n=1}^{N} t_n x_n + t_d x_d\right) - H \cdot T. \tag{4}$$

The first and second term of the right-hand side cover the revenues resulting from commodity taxation, the third term denotes the expenditures for lump-sum transfers to the household.

Assuming separability between emissions and the consumption of all private goods, $\frac{\sigma x_k}{\partial E} = 0,\ \forall k$, we obtain the change of tax revenues resulting from a change of tax rate *k*:

$$\mathrm{d}R_k \equiv \frac{\partial R}{\partial t_k}\mathrm{d}t_k = H\left(x_k + \sum_i t_i \frac{\partial x_i}{\partial t_k}\right)\mathrm{d}t_k\,, \tag{5}$$

with $i = 1,\ldots,N,d$. The term in brackets denotes the marginal tax revenue (per capita) of the tax on good *k*. A *revenue-neutral green tax reform*[2] which increases the green tax t_d and reduces the tax on a clean good *c* so that public revenues remain constant is described by:

$$\mathrm{d}R_d = -\mathrm{d}R_c > 0\,. \tag{6}$$

Positive revenues due to an increase of t_d ($\mathrm{d}R_d > 0$) are equal to the amount to be refunded by decreasing t_c $(\mathrm{d}R_c < 0)$.[3]

2.1 *The marginal direct cost of public funds*

To evaluate the welfare effects of a tax reform it is necessary to separate the costs and the benefits of particular tax rate changes. In a first step, we therefore derive a measure which indicates the *direct cost* of increasing a particular tax rate, assuming environmental quality is constant. Normalizing the utility change with the marginal utility of the numéraire, $\mathrm{d}\tilde{u} = \mathrm{d}u / u_0$ [c.f., equation (3)], and using Roy's identity, the *direct utility loss* of a single household due to a marginal increase of e.g. t_k, is $\mathrm{d}\tilde{u}\big|_{\bar{E}} = -x_k \cdot \mathrm{d}t_k$. Aggregating over all households and relating the total utility loss (in units of the numéraire) to actual marginal tax revenues, we obtain a measure of the Marginal Cost of Public Funds (*MCF*)

$$MCF_k = \frac{-H \cdot \left.\dfrac{\mathrm{d}\tilde{u}}{\mathrm{d}t_k}\right|_{\bar{E}}}{\dfrac{\partial R}{\partial t_k}}\,. \tag{7}$$

2.2 *The marginal environmental impact of public funds*

This *MCF* measure does not take into account the change of the environmental quality with respect to the change in the tax rate on good *k*. If the cross-price effect between any good *k* and the dirty good *d* is non-zero, there will be a change in the demand for the dirty good resulting from the tax rate change. Hence, there will be a change in the environmental quality, too. To derive this *indirect effect on welfare* we have to introduce a measure which relates this indirect loss or benefit to the change in tax revenues in the same way as the *MCF*-measure does with the direct cost.

The marginal environmental damage of the consumption of the dirty good is equal to the sum of the marginal rate of substitution between pollution and the numéraire Hu_E / u_0, i.e. it is measured in units of the numéraire (like the *MCF*-measure). To measure the indirect welfare effect of a tax rate change, however, the marginal environmental damage has to be multiplied by the change of pollution due to the change of t_k. Relating this indirect welfare change to the marginal tax revenues we obtain

$$MEI_k = \frac{H \frac{u_E}{u_0} \frac{\partial E}{\partial t_k}}{\frac{\partial R}{\partial t_k}}, \tag{8}$$

which will be called the *Marginal Environmental Impact* of a tax rate change. According to equation (1), and making use of the separability assumption, the numerator can be reformulated: $H \frac{u_E}{u_0} \frac{\partial E}{\partial t_k} = H \frac{u_E}{u_0} \cdot H \frac{\partial x_d}{\partial t_k}$. The term $H \frac{u_E}{u_0}$ is equal to the marginal environmental damage of consuming the dirty good, while $H \frac{\partial x_d}{\partial t_k}$ is the change in consumption of the dirty good. Hence, the numerator indicates the indirect marginal welfare change resulting from increasing the tax on good *k*. Note that each tax rate change may have an impact on the environment. Therefore, this impact has to be considered whenever analysing tax rate changes.

Subtracting the indirect benefit from the direct cost of taxation we obtain the Marginal Social Cost of Public Funds (*MSCF*):

$$MSCF_k = MCF_k - MEI_k. \tag{9}$$

This decomposition of the *social costs* into *direct costs* and its *environmental impact* allows the welfare effects of tax reforms to be analysed with respect to both the inefficiency of the tax system and the environmental damage. For revenue-neutral green tax reforms the welfare change is given by [cf. equation (3)]:

$$\mathrm{d}\tilde{W} = H\left(-x_d + \frac{u_E}{u_0}\frac{\partial E}{\partial t_d}\right)\mathrm{d}t_d + H\left(-x_c + \frac{u_E}{u_0}\frac{\partial E}{\partial t_c}\right)\mathrm{d}t_c \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0. \tag{10}$$

Solving equation (5) for $k = c, d$ with respect to $\mathrm{d}t_c$ and $\mathrm{d}t_d$, using the separability condition, and applying the revenue-neutrality condition (6), comparison of equations (7), (8) and (9) shows that

$$\frac{\mathrm{d}\tilde{W}}{\mathrm{d}R_d} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \;\Leftrightarrow\; MSCF_c \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} MSCF_d . \tag{11}$$

Hence, the change in welfare is correctly measured using the *MSCF*-measures.[4]

3. The evaluation of revenue-neutral tax reforms

Using equation (9) to decompose the *MSCF* into its direct and indirect effects, equation (11) can be rearranged to analyse the double-dividend hypothesis for green tax reforms:

$$\frac{\mathrm{d}\tilde{W}}{\mathrm{d}R_d} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \Leftrightarrow (MEI_d - MEI_c) + (MCF_c - MCF_d) \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 . \tag{12}$$

The first bracket term denotes the environmental dividend. Because of an increase in the green tax, the environment improves ($MEI_d > 0$; provided that *d* is not a Giffen good). This is often the only effect considered as the environmental dividend (cf. Repetto 1994, p. 3). However, we have to take into account the effects of the accompanying measures the government takes. If, e.g., the marginal environmental effect of the clean good, MEI_c, is positive (the dirty good is a complement to the clean good), a tax cut for the clean good cet. par. leads to a worsening of the environment. The environmental dividend of the whole tax reform is smaller than the marginal environmental impact of the green tax.

The second dividend is equal to the reduced distortion of taxing the clean good, MCF_c, minus the increased distortion of taxing the green good, MCF_d. This difference measures the impact the revenue-neutral green tax reform has on the allocative efficiency of the *whole tax system*. The 'strong' form of the double-dividend hypothesis, as defined by Goulder (1995, p.

159f) holds if both bracket terms are positive, i.e. $MEI_d - MEI_c > 0$ and $MCF_c - MCF_d > 0$, respectively.[5]

It is often argued that the environmental dividend of green tax reforms is positive (cf. Goulder 1995). However, this need not be the case. To see this, we first analyse a revenue-neutral tax reform starting from a *Ramsey-optimum,* i.e. a situation in which taxes have been set optimally to raise revenues, but environmental considerations have not been taken into account. This is characterized by the identity of all direct marginal cost of public funds measures (*MCF*) except for the measure of lump-sum transfers. Attention can thus be focused solely on the environmental consequences of tax reforms. Then, in Section 3.2, the analysis is extended to tax reforms starting from *an arbitrary, i.e. non-optimal tax system*. Here the direct *MCF*-measures differ and it is necessary to consider both environmental and distortionary consequences of tax reforms.

3.1 The environmental dividend of a revenue-neutral green tax reform

Starting from the Ramsey-optimum the second bracket term of condition (12) is identically zero for all clean goods. Using the definitions (8) and (5) and applying the revenue-neutrality condition (6) yields:

$$(MEI_d - MEI_c)\begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \;\Leftrightarrow\; \frac{\partial x_d}{\partial t_d} - \frac{\partial x_d}{\partial t_c}\frac{\dfrac{\partial R}{\partial t_d}}{\dfrac{\partial R}{\partial t_c}} \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} 0 \;\Leftrightarrow\; \left.\frac{\mathrm{d}E}{\mathrm{d}t_d}\right|_{\mathrm{d}R_d = -\mathrm{d}R_c} \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} 0. \tag{13}$$

As total differentiation of (1) shows, a positive (negative) marginal environmental impact is equivalent to a reduction (an increase) in emissions. Hence, rearranging (13) yields:

$$\left.\frac{\mathrm{d}E}{\mathrm{d}t_d}\right|_{\mathrm{d}R_d = -\mathrm{d}R_c} \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} 0 \;\Leftrightarrow\; \frac{\dfrac{\partial x_d}{\partial t_c}}{\dfrac{\partial x_d}{\partial t_d}} \begin{Bmatrix} < \\ = \\ > \end{Bmatrix} \frac{\dfrac{\partial R}{\partial t_c}}{\dfrac{\partial R}{\partial t_d}}. \tag{14}$$

Emissions fall if, and only if, the ratio of the cross-price effect on the dirty good to the own-price effect of the dirty good is less than the ratio of the marginal tax revenues. However, if the dirty good is a substitute for the clean good, i.e. $\partial x_d / \partial t_c > 0$, the left-hand side will be negative and emissions will be reduced both by increasing the tax on the dirty good and by reducing the tax on the substitute.[6]

In the case of a complementarity relationship between the two taxed goods, i.e. $\partial x_d / \partial t_c < 0$, the change in emissions becomes ambiguous. The environment improves if, and only if, the reduction in the consumption of the dirty good due to its own-price increase is higher than the increase due to the price reduction of the complement.

To see why emissions may actually increase, assume that the government increases the tax on the dirty good by one unit. Other things being equal, increasing the tax t_d lowers the consumption of the dirty good, while reducing the tax on a complement tends to raise its consumption. The question is what determines the net effect of these two countervailing effects. If the marginal revenue ∂R/###t_d is very high, the additional funds the government raises are large. If the marginal tax revenue from taxing the clean good ∂R/###t_c is relatively low compared to $\partial R / \partial t_d$, the tax on the clean good can, therefore, be reduced at a relatively high rate. As the ratio of marginal tax revenues $\partial R / \partial t_d \, / \, \partial R / \partial t_c$ equals the inverse of the ratio of the tax rate change [cf. equation (5)], it determines the weight of the cross-price effect $\partial x_d / \partial t_c$ in equation (13). If the weighted cross-price effect becomes large compared to the own-price effect, it might happen that, even for a low cross price-effect, relative to the own-price effect, the increased consumption of the dirty good resulting from a reduction in t_c outweighs the reduction in consumption resulting from an increase in t_d. Hence, it is the existing tax system which determines the effect a revenue-neutral green tax reform has on the environment.

PROPOSITION 1 (Green tax reform): In a world with distortionary taxation, a revenue-neutral marginal green tax reform reduces (increases) emissions from the consumption of the dirty good, if and only if, either (*i*) the dirty good is a substitute for, or is unrelated to, the clean good whose tax rate is reduced or (*ii*) the dirty good is a complement to the clean good whose tax rate is reduced and the ratio of the cross-price effect on the dirty good to the own-price effect of the dirty good is smaller (larger) than the ratio of the associated marginal tax revenues.

For tax reforms starting from the Ramsey-optimum, we can add the following corollary:

> ***COROLLARY 1 (Green tax reform):*** Starting from the Ramsey-optimum, a marginal revenue-neutral green tax reform is welfare increasing (decreasing) if, and only if, the environmental dividend is positive (negative).

Proposition 1 and Corollary 1 are related to the analysis of Ng (1980). He looks at labour taxation and states that welfare will increase, "provided that an increase of the (consumer) price of the externality-producing good is more effective in reducing its consumption proportionately than is an increase in the (consumer) price of labor in increasing it, proportionately to labor" (Ng 1980, p. 745). Thereby, he does not recognize that the effectiveness of price changes depends on the marginal tax revenues (see his equation (15) and the succeeding discussion). Instead, Ng abstracts "from the complications of a positive revenue requirement." (Ng 1980, p. 747). Condition (14), however, shows that because of the revenue neutrality condition, the marginal tax revenues actually determine the relative magnitudes of the tax rate changes and thus the 'relative effectiveness' of the price changes.

If the dirty good is untaxed initially, the question then arises whether there exists at least one revenue-neutral green tax reform which improves welfare. This will be the case if Proposition 1 holds for at least one clean good. Though this seems to be a rather weak condition, this cannot be guaranteed without imposing some restrictions on household's preferences.[7]

In general, we can recognize beneficial incentives of all taxes on goods to which pollution is a complement. Conversely, we also have to be aware of the additional burden of all taxes on goods for which pollution is a substitute. Focusing on the environmental dividend only, the best policy recommendation therefore would be to avoid tax rate cuts for all complements to the dirty good and to look for strong substitutes. Suggestions for using 'green' tax revenues to exempt public transportation from VAT point in this direction.

Another widely discussed green tax reform proposal is to substitute the tax on the dirty good for labour taxes (cf. Bovenberg and de Moiij 1994 or Bovenberg and van der Ploeg 1994). Here, policy recommendations which focus on the environment only are less straightforward. Assuming that the labour supply curve is upward sloping, cutting labour taxes reduces leisure consumption. If the dirty good is a complement to leisure, lower labour taxes imply lower emissions. Conversely, if the dirty good is a substitute for leisure, reducing labour taxes increases emissions. Parry (1995) argues that almost all consumption goods can be considered to be *compensated* substitutes for leisure. If this is true for the dirty good and if the dirty good is a normal good, it is also an *uncompensated* substitute for leisure. In this case, to determine the environmental dividend, we have to know the marginal tax revenues.[8]

Marginal tax revenues are mainly determined by the magnitude of the tax base and the own tax rate. Cet. par., marginal tax revenues are increasing in the tax base and decreasing in the own tax rate. As is pointed out in Bovenberg and de Mooij (1994, p. 1088), substituting the tax on the dirty good for labour taxes implies replacing a broad-based tax by a narrow-based tax. Hence, the ratio of marginal tax revenues in condition (13) tends to be rather low and for a low cross price-effect, relative to the own-price effect, it is reasonable to expect emissions to decrease.[9] In addition, the ratio of marginal tax revenues tends to decrease the 'greener' the tax system becomes.

Hence, taxes on substitutes or on labour are good candidates for green tax reforms as they guarantee the environmental dividend to be positive. However, such tax reforms might have some undesired distributional consequences. If, in the absence of lump-sum transfers, the government wishes to compensate those who suffer from the green tax, the only way to ensure at least an indirect compensation is to 'subsidize' complementary goods. Here, additional tax revenues from green taxes may be used to reduce some narrow-based taxes. The paradoxical case cannot be ruled out a priori.[10]

3.2 Revenue-neutral green tax reforms in an arbitrary tax system

If we look at an arbitrary tax system, a tax reform analysis which does not consider the environment will recommend a tax reform if the second dividend in condition (12) is positive. A tax reform analysis which considers environmental consequences will confirm this recommendation if the environmental dividend is positive, i.e. if the double dividend occurs.

The double-dividend literature emphasizes that in general we cannot expect a double dividend in its strong form to occur. There is a trade off between the efficiency of the tax system and the environmental quality. Therefore, welfare analysis requires measuring both dividends properly. If the true marginal environmental damage is known, the measures derived above allow us to do so. If, however, there is uncertainty about the magnitude of the marginal environmental damage, we can calculate at least a minimum marginal environmental damage necessary to guarantee that a green tax reform is welfare improving. Assuming that the environmental dividend is positive, a *critical value of the marginal environmental damage* MED^{cv} exists for which the environmental dividend exactly outweighs the direct cost of the green tax reform:

$$MED^{cv} \equiv \left\{ H\frac{u_E}{u_0} \middle| MEI_d\left(H\frac{u_E}{u_0}\right) - MEI_c\left(H\frac{u_E}{u_0}\right) = MCF_d - MCF_c \right\}. \quad (15)$$

If the actual environmental damage is expected to be larger than the critical value of the marginal environmental damage, than the green tax reform can be expected to be welfare improving, too. Proposition 2 summarizes.

> ***PROPOSITION 2 (Critical value of the marginal environmental damage):*** If the second dividend of a green tax reform is negative, a marginal revenue-neutral increase of the green tax is welfare increasing (decreasing) if the environmental dividend is positive and the actual marginal environmental damage is larger (smaller) than the critical value of the marginal environmental damage.

The concept of the critical value of the marginal environmental damage permits the identification of welfare improving tax reforms provided that a consensus about at least a lower bound for the estimates of the marginal environmental damage exists. As the critical value is different for each tax reform, the critical value approach also shows the sensitivity of the welfare sign of different tax reforms with respect to the estimated marginal environmental damage (see Section 4).

3.3 Revenue-neutral tax reform with a lump-sum rebate

Recently, lump-sum rebates of green tax revenues have been discussed in e.g. Switzerland and Germany. The proposal of the so-called 'eco bonus' is to rebate tax revenues from green taxes lump-sum per capita (cf., e.g. Teufel et al. 1993). Such a tax reform proposal can be evaluated using the welfare measures defined in Section 2. As these measures are related to additional tax revenues, a measure for lump-sum transfers per unit of additional tax revenues is equivalent to the measure of the marginal costs of public funds from lump-sum taxes:

$$MCF_T = \frac{-H \cdot \left.\frac{d\tilde{u}}{dT}\right|_{\bar{E}}}{\frac{\partial R}{\partial T}} = \frac{1}{1 - \sum_i t_i \frac{\partial x_i}{\partial T}}. \tag{7'}$$

The MCF_T measures the consumer surplus loss per additional unit of tax revenues from (reducing) lum-sum transfers. In the presence of distortionary taxes, the MCF_T normally differs from unity as increasing lump-sum transfers changes tax revenues from other sources.

The definition for the marginal environmental impact of public transfers is given by:

$$MEI_T = \frac{H \frac{u_E}{u_0} \frac{\partial E}{\partial T}}{\frac{\partial R}{\partial T}}. \tag{8'}$$

For normal goods the MEI_T-measure is positive. Increasing tax revenues by reducing lump-sum transfers reduces emissions and therefore has a positive impact on the environment.

Using these measures, the analysis of a tax reform $\mathrm{d}R_d = -\mathrm{d}R_T > 0$ is completely analogous to the analysis in Section 3.1. The idea of an 'eco bonus', however, apparently contradicts the results of Dixit (1975) who shows that, even in an arbitrary tax system, the reduction of distortionary taxes combined with a reduction in lump-sum transfers is welfare improving. To see this, consider the Ramsey-optimum, where the *MCF*-measures are the same for all commodity taxes. There we have:

$$sign\left(MCF_T - MCF_d\right) = sign\left(\sum_i t_i s_{id}\right) < 0, \tag{16}$$

where s_{id} denotes the compensated prices effects. The second dividend of the eco bonus, starting from the Ramsey-optimum is always negative.[11] Therefore, a lump-sum rebate of green tax revenues can be welfare improving only if the environmental dividend overcompensates the negative second dividend. This can be seen by determining the critical value of the marginal environmental damage for this particular tax reform (see Section 3.2).

Dixit's (1975) results further imply that reducing some distortionary taxes is preferable to increasing lump-sum transfers. In the presence of externalities, however, this claim holds only for commodities whose marginal environmental impact is smaller than the marginal environmental impact of lump-sum transfers. This becomes apparent by analysing a succeeding second tax reform which reduces both lump-sum transfers and some distortionary taxes on clean goods.

4. Theory at work

To calculate the *MCF*- and *MEI*-measures we have to estimate a complete demand system. To illustrate how the theory can be applied in practice we make use of Pashardes' (1993) estimates of the demand system for a representative household in the UK. Using the 'Almost Ideal Demand System' and data from the British Family Expenditure Survey 1970-1986, Pashardes (1993) calculates the uncompensated price and cross-price elasticities and the expenditure elasticities of seven commodity groups. To analyse the impact of gasoline taxation, however, it is necessary to disaggregate the commodity group 'transportation' into 'gasoline' and 'other transportation'. Assuming the same expenditure elasticities for both groups and an own-price elasticity of –0.7 for gasoline, this can be done by using the conditions of Cournot and Engel aggregation. The elasticities are presented in Table 1.

Uncompensated elasticities	1	2	3	4	5	6	7	8	expen-diture elast.	budget shares	total tax
1: food	-0.55	0.065	-0.048	-0.005	0.012	0.013	-0.11	0.061	0.561	0.345	0
2: alcohol	-0.065	-1.957	0.732	0.14	-0.016	-0.018	-0.404	-0.127	1.716	0.067	0.418
3: fuel	-0.096	0.674	-0.519	0.031	-0.209	-0.234	0.33	-0.249	0.276	0.085	0.149
4: clothing	-0.333	0.109	-0.076	-0.782	-0.175	-0.196	0.359	-0.385	1.479	0.100	0.149
5: gasoline	-0.237	0.009	-0.307	-0.201	-0.700	-0.030	-0.063	0.133	1.391	0.084	0.687
6: transportation (other)	-0.237	0.009	-0.307	-0.201	-0.027	-0.703	-0.063	0.133	1.391	0.094	0.149
7: other	-0.504	-0.208	0.208	0.397	-0.015	-0.017	-0.84	0.006	0.975	0.106	0.149
8: services	-0.118	-0.053	-0.277	-0.323	0.090	0.101	-0.041	-0.812	1.419	0.120	0.149

Table 1: *Uncompensated Elasticities (From Pashardes (1993) and own calculations)*

In addition, further information about the British commodity tax structure is needed. The total tax as a percentage of the consumer price (net tax rate) is listed in the last column of Table 1. Except for alcohol and gasoline, where we consider both specific average excise taxes and VAT, we consider only the VAT at the standard rate of 17.5%. (Note that there is no VAT on food.)[12] Normalizing total expenditures at unity, tax revenues are equal to the budget share times the net tax rate.

From the data given in Table 1 it is possible to calculate the *MCF*-measures. Assuming the actual marginal environmental damage of gasoline consumption to be 35 pence/l in case a) and 70 pence/l in case b) we can also calculate the *MEI*-measures and hence the *MSCF*-measure - depending on the actual marginal environmental damage. The results are shown in table 2 (see the appendix).

	a) actual marginal environmental damage 35 Pence/l				b) actual marginal environmental damage 70 Pence/l			
	MCF	***MEI***	***MSCF***	**net welfare gain**	***MEI***	***MSCF***	**net welfare gain**	**critical value Pence/l**
1: food	1.113	0.043	1.070 (2)	– 0.104	0.085	1.028 (5)	+ 0.280	44.5
2: alcohol	3.576	– 0.027	3.603 (10)	+ 2.428	-0.054	3.630 (10)	+ 2.882	– 152.2
3: fuel	1.146	0.231	0.916 (1)	– 0.259	0.461	0.685 (1)	– 0.063	81.1
4: clothing	1.268	0.142	1.127 (3)	– 0.048	0.284	0.985 (4)	+ 0.237	40.9
5: gasoline	1.602	0.427	1.175 (5)	xxx	0.854	0.748 (2)	xxx	xxx
6: transportation	1.468	0.288	1.180 (6)	+ 0.005	0.577	0.892 (3)	+ 0.144	33.7
7: other	1.236	0.041	1.195 (7)	+ 0.020	0.082	1.154 (7)	+ 0.406	33.2
8: services	1.169	-0.072	1.242 (8)	+ 0.067	-0.145	1.314 (8)	+ 0.566	30.3
9: VAT-reduction	1.512	0.09	1.422 (9)	+ 0.247	0.18	1.331 (9)	+ 0.583	9.3
10: lump-sum rebate	1.271	0.098	1.173 (4)	– 0.002	0.197	1.074 (6)	+ 0.327	35.2

Table 2: *Marginal Social Cost of Public Funds*

In case a) the net welfare gain of a marginal green tax reform is given in column 5. If, e.g., we increase taxes on gasoline and reduce VAT on services, the net welfare gain of that reform is 6.7 pence per pound of additional tax revenues from gasoline taxation ($MSCF_8$ - $MSCF_5$ = 0.067). The environmental dividend is $MEI_5 - MEI_8 = 0.427 - (-0.072) = 0.499$, the second dividend is $MCF_8 - MCF_5 = 1.169 - 1.602 = -0.433$ [cf. equation (12)]. Table 2 shows that none of the possible green tax reforms yields a negative environmental dividend. However, the variance of the *MEI*-measures indicates that the choice of the accompanying tax rate cuts has considerable impact on the total magnitude of the environmental dividend.

A ranking of the *MSCFs* (column 4) shows which commodities are the best candidates for the government for raising additional public funds. The smaller the *MSCF* the fewer additional social costs accrue. As gasoline taxation has a relatively high marginal cost of public funds (Ranking no. 5), only an accompanying reduction in VAT of 'transportation', 'other goods', 'services' or 'alcohol' yields a net welfare gain to society.

Note that alcohol taxation has a very high *MCF* (= 3.576). It is argued that alcohol consumption itself creates a large negative externality, which is not considered here. In the presence of more than one externality, however, the marginal social cost of public funds has to be redefined for all goods. Equation (9) has to be rewritten as

$$MSCF_k = MCF_k - \sum_d MEI_{dk}, \ \forall k, \tag{9'}$$

with MEI_{dk} being the marginal environmental impact the tax on good k has on the consumption of the dirty good d, with $d = 1,...D$ and $D \leq N+2$.[13]

The data allows us to consider the effects of two 'broad-based' taxes, a lump-sum rebate and a uniform VAT-reduction. With a fixed labour supply, a lump-sum rebate is equivalent to a tax cut on labour income. This differs from a uniform VAT-reduction because there are positive excise taxes and there is a zero-rate of VAT on food. Disregarding other externalities, a uniform VAT-reduction yields a high net welfare gain of 24.7% although the second dividend is negative. A lump-sum rebate of green tax revenues has to be rejected as the negative second dividend outweighs the positive environmental dividend (see Section 3.3). In both cases, the double-dividend hypothesis in its strong form fails.

The empirical results are similar in spirit to the analysis of Bovenberg and de Mooij (1994) who consider the distortion taxes on labour have on the labour-leisure decision. They argue that the narrow-based green tax has a higher *MCF* than a broad-based tax on labour income as the green tax 'distorts' the composition of the consumption basket (cf. Bovenberg and de Mooij 1994, p.1088). Here, we assume fixed labour supply. Hence, the reason for a negative second dividend must be different. The *MCF* of a uniform VAT-reduction is a weighted average of the distortions of all the narrow-based taxes involved (see the appendix). The larger the *MCF* of the green tax, relative to the *MCFs* of all other commodity taxes, the more likely it is that the second dividend becomes negative and - in the case of a lump-sum rebate - it outweighs the positive environmental dividend.

If the actual marginal environmental damage is 70 pence/l [case b)], the results change drastically. Even a subsidy on food is welfare increasing on pure efficiency grounds and only a VAT reduction for energy still implies a welfare loss. However, any particular VAT-reduction - except for alcohol - is an inferior solution compared to a uniform VAT reduction.

The critical value of the marginal environmental damage can be derived from the demand system without knowledge of the actual environmental damage. This permits different tax reforms to be distinguished even if all that is known is a lower bound on the value of the marginal environmental damage. For example, a green tax reform which decreases VAT on 'clothes' only is welfare decreasing in case a), but welfare improving in case b). While most critical values are in the range between 30 pence/l and 40 pence/l the critical value for e.g. fuel suggests that tax rate cuts for fuel consumption should not be considered unless the actual marginal environmental damage is expected to be larger than 80 pence/l. Note that a negative critical value indicates a 'free lunch', i.e. the tax reform is welfare increasing even without considering the environment.

5. Distributional considerations

So far, we have ignored distributional considerations. However, the welfare measures derived for identical households can be adequately defined for heterogeneous households using a welfare function of the Bergson-Samuelson-type. In this case, the individual measures have to be derived first. Then, these measures have to be aggregated, weighted with the individuals' social welfare weights, to achieve the *MCF*-, *MEI*- and *MSCF*-measures.

In the Ramsey-optimum, every possible tax reform is neutral with respect to direct cost. Hence, only if the environmental quality changes, does welfare also change. If every household considers pollution as a non-positive externality ($u_E^h \leq 0, \forall h$), an improvement of the environment makes every household better off - regardless of their social welfare weights. Therefore proposition 1 holds.[14]

Starting from an arbitrary tax system, we have to apply the concept of the critical value of the marginal environmental damage. In this respect proposition 2 also holds. However, the marginal environmental damage and therefore the critical value now depend on both the marginal willingness to pay of each household and its social weight.

6. Conclusions

Decomposing the welfare effects of tax rate changes shows that every tax rate change may have an impact on both the efficiency of the tax system and the environmental quality. Thus, to evaluate a green tax reform properly, we have to consider an environmental dividend which comprises the marginal environmental impacts of both the green tax and the accompanying measure the government takes to guarantee revenue neutrality.

If a tax reform analysis which does not take account of environmental consequences recommends increasing a green tax, a tax reform analysis which does take account of the environment will do so, too, if the environmental dividend of the reform is guaranteed to be positive. This is the case if the accompanying tax rate cut applies to a good for which the dirty good is a substitute. It will also be guaranteed in the case of a complementarity relationship if one additional condition is met. The efficiency of a particular green tax reform in reducing emissions is determined by the starting point of the tax reform, i.e. the existing tax system. This result is independent of the actual marginal environmental damage of pollution.

If the double-dividend hypothesis fails, the concept of the critical value of the marginal environmental damage can be used to decide whether tax reform analysis which does take account of the environment will confirm or reject the traditional recommendations.

The measures developed for the analysis of green tax reforms have to be applied to clean tax reforms as well. The complementarity/substitutability relationships between taxed goods and the dirty good requires that environmental consequences have to be considered for all tax reforms. We are used to talking about the beneficial incentives of green taxes. Taking the ecological perspective on analysing tax reforms seriously, we can also recognize beneficial incentives of all taxes on goods to which pollution is a complement. Conversely, we also have to be aware of the additional burden of all taxes on goods for which pollution is a substitute.

Appendix

To calculate the measures in Section 4 we need explicit formulations of the measures suggested. The explicit form of the *MCF*-measure is given by

$$MCF_j = \frac{x_j}{x_j + \sum_{i=1}^{8} t_i \frac{\partial x_i}{\partial t_j}}.$$

Using the definitions $R_i = t_i x_i$, $w_i = p_i x_i$, and $\varepsilon_{ij} = \frac{p_j}{x_i}\frac{\partial x_i}{\partial t_j}$, this can be rewritten as:

$$MCF_j = \frac{1}{1 + \frac{1}{w_j}\sum_{i=1}^{8} R_i \varepsilon_{ij}}.$$

The *MEI*-measure is given by:

$$MEI_j = MCF_j \cdot \left(H \frac{u_E}{u_0} \right) \cdot \frac{R_d / t_d}{w_j} \varepsilon_{dj}.$$

For a uniform VAT-reduction, the *MCF* is given by:

$$MCF_{VAT} = \sum_{i \neq d} R_i \Bigg/ \sum_{i \neq d} \frac{R_i}{MCF_i}.$$

References

AHMAD, E. and STERN, N. (1984): "The Theory of Tax Reform and Indian Indirect Taxes," *Journal of Public Economics* 25, 259-98.

BOVENBERG, A. L. and VAN DER PLOEG, F. (1994): "Environmental Policy, Public Finance and the Labour Market in a Second-Best World," *Journal of Public Economics* 55, 349-90.

BOVENBERG, A. L. and DE MOOIJ, R. A. (1994): "Environmental Levies and Distortionary Taxation," *American Economic Review* 84, 1085-89.

DIXIT, A. K. (1975): "Welfare Effects of Tax and Price Changes," *Journal of Public Economics* 4, 103-23.

FELDSTEIN, M. S. (1976): "On the Theory of Tax Reform," *Journal of Public Economics* 6, 77-104.

GOULDER, L. H. (1995): "Environmental Taxation and the "Double Dividend:" A Reader's Guide," *International Tax and Public Finance* 2, 157-84.

GUESNERIE, R. (1977): "On the Direction of Tax Reform," *Journal of Public Economics* 7, 179-202.

LEE, D. R. and MISIOLEK, W. S. (1986): "Substituting Pollution Taxation for General Taxation: Some Implications for Efficiency in Pollution Taxation," *Journal of Environmental Economics and Management* 13, 338-47.

MAYSHAR, J. (1990): "On Measures of Excess Burden and Their Application," *Journal of Public Economics* 43, 263-89.

MAYERES, I. and PROOST, S. (1994): *Optimal Tax and Tax Reform Rules with Congestion Type of Externalities*, Paper prepared for the EAERE congress, Dublin, June.

NG, Y.-K. (1980): "Optimal Corrective Taxes or Subsidies when Revenue Raising Imposes an Excess Burden," *American Economic Review* 70, 744-51.

NICHOLS, A. L. (1984): *Targeting Economic Incentives for Environmental Protection*, MIT-Press: Cambridge Mass. and London.

PARRY, I. W. H. (1995): "Pollution Taxes and Revenue Recycling," *Journal of Environmental Economics and Management* 29, S64-S77.

PASHARDES, P. (1993): "Bias in Estimating the Almost Ideal Demand System with the Stone Index Approximation," *Economic Journal* 103, 908-15.

REPETTO, R. (1994): *The Potential Economic Gains From a Tax Shift,* Paper presented on the 50th Congress of the International Institute of Public Finance, Cambridge Mass.

SANDMO, A. (1975): "Optimal Taxation in the Presence of Externalities," *Swedish Journal of Economics* 77, 86-98.

STERN, N. H. (1987): "Aspects of the General Theory of Tax Reform," in: D. NEWBERY and N. H. STERN: *The Theory of Taxation for Developing Countries.* New York: Oxford University Press, 60-91.

TEUFEL, D. et al. (1993): *Das Öko-Bonus-Konzept*, UPI-Bericht Nr. 27, Heidelberg.

Footnotes

---

* Helpful comments by Lans Bovenberg, Jeremy Edwards, Gaute Torsvik, Mick Keen, Ray Rees, Hans-Werner Sinn, Marcel Thum and two anonymous referees are gratefully acknowledged. The usual disclaimer applies. A first version of this paper was written while visiting the University of Bergen. Financial support from the Norwegian Research Council (NAV) is gratefully acknowledged.

1 The consumption of the dirty good might depend on the emissions. In general, the demand for the dirty good is given by $Hx_d(t_1,\ldots,t_N,t_d,T,E)$. Hence, implicit differentiation of (1) yields:

$$\partial E/\partial t_k = (H\cdot\partial x_d/\partial t_k)/(1-H\cdot\partial x_d/\partial E).$$

As long as an increase of emissions by one unit does not reduce the consumption of the dirty good by more than one unit, i.e. as long as the denominator is positive, the separability assumption does not change the results.

2 For tax reform analysis see the seminal papers by Dixit (1975) or Guesnerie (1977) and for a survey, see Stern (1987). Revenue-neutral green tax reforms are considered recently by Mayeres and Proost (1994).

3 In equation (6) it is not necessary to assume the tax rate change to be positive. In the case of negative marginal tax revenues, equation (6) describes a tax reform where the reduction in the tax on good *d* increases the tax revenues which are to be refunded by a reduction in the tax on good *c*. The following measures are not defined for marginal tax revenues equal to zero.

4 This is not necessarily true for all *MCF*-measures suggested in the literature. For a survey see Mayshar (1990).

5 The 'weak' form of the double-dividend hypothesis defines the second dividend as MCF_c - MCF_T (cf. equation (7') below). For welfare comparisons, the total dividend has to be compared with the distortion imposed by a marginal increase in the green tax, relative to the marginal increase of a lump-sum tax, i.e. MCF_d - MCF_T.

6 In what follows all complementarity/substitutability relationships are uncompensated.

---

[7] A counter example is given by Ng (1980) for the three-good case with zero tax revenues and zero initial tax rates. He shows that emissions unambiguously rise due to a revenue-neutral green tax reform if the *compensated* cross-price elasticity of the clean good exceeds the *compensated* own-price elasticity of the dirty good. Without imposing restrictions on preferences, standard consumer theory does not rule out such a result. In this case, however, a revenue-neutral tax reform which reduces the tax on the dirty good would reduce emissions and therefore improve welfare (cf. corollary 1). In a non-optimal tax system there is always a whole half-space of welfare improving directions of tax rate changes.

[8] To analyse this tax reform within the framework developed here, we have to consider leisure as the clean good. With the time endowment being normalised at zero, labour enters the utility function as a negative quantity ($x_c < 0$). A labour tax is equivalent to a subsidy of leisure, i.e., a labour tax is described by $t_c < 0$. If marginal tax revenues of labour taxes are positive, we further have $\partial R / \partial t_c < 0$. Condition (13) remains valid, although the interpretation has to be slightly modified. In condition (14), however, the inequality relations are reversed.

[9] Bovenberg and de Mooij (1994) assume weak separability between leisure and consumption, and homogeneity in consumption. They show analytically that under these assumptions, emissions unambiguously fall, although the dirty good is a substitute for leisure, $\partial x_d / \partial t_c > 0$.

[10] Assume that all uncompensated cross-price effects except those between the clean and dirty good are identically zero and that tax revenues from taxing the dirty good are twice the tax revenues from taxing the clean good. Then, plugging into condition (13) the following parameters $t_d = 0.25$, $t_c = 0.25$ $\varepsilon_{dd} = -0.3$, $\varepsilon_{cc} = -0.9$, $\varepsilon_{cd} = \varepsilon_{dc} - 0.125$ (ε_{ij} denotes the uncompensated elasticity) generates the paradoxical case that emissions increase due to green tax reform.

[11] According to the Ramsey rule, the right-hand term in brackets is negative. Condition (16) can also be derived from Dixit's (1975) theorem 1. Note that for arbitrary tax systems the second dividend might become positive if the distortion of the tax on the dirty good is already very high.

[12] See H.M. Customs and Excise, Annual Report 1992-1993, London: H.M.S.O, October 1993.

[13] Note that in the case of multiple externalities, corollary 1 and proposition 2 do not apply anymore.

[14] However, in condition (14) we have to compare the ratios of total price effects, e.g. $\sum_H \partial x_d^h / \partial t_c \Big/ \sum_H \partial x_d^h / \partial t_d$, with the ratio of marginal tax revenues.