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A Comment on the Impact of the Initial Tax Mix on the Dividends of an Environmental Tax Reform*

Daniel Weinbrenner
Department of Economics – VWL IV
University of Siegen
Hoelderlinstr. 3
D – 57068 Siegen
Germany

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Abstract: The effects of an increase in an emission tax rate are analyzed. The initial tax mix of the economy is such that the higher emission tax rate serves to internalize social costs and simultaneously approaches a second–best tax system (in the absence of environmental distortions). It is shown that this kind of tax system as a starting point for an environmental tax reform is not sufficient to reap a clear–cut double dividend even though "unnormal" cases like a backward–bending labor supply curve and adverse revenue effects are excluded. In particular, if the wage elasticity of labor supply is positive and the tax on the clean good is relatively high compared to the tax on the dirty good an environmental tax reform may lead to an "ecological paradox", i.e. increases the demand for the dirty good because the income effects caused by the decrease of the tax rate on the clean consumption good dominate both the substitution effects of the tax rate changes and the income effect of the increased emission tax rate. Hence, there may be no environmental dividend.

JEL classification: H21, Q28
Keywords: environmental tax reform, double dividend, unifying commodity tax rates

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1 Introduction

In the presence of serious environmental problems and undesirable welfare losses caused by high rates of distortionary taxes an environmental tax reform (ETR) appears to be a policy tool coping with both problems simultaneously. Taxing emissions reduces the wedge between private and social costs and therefore enhances efficiency through internalizing the external costs. Using the emission tax proceeds for reducing the rate of at least one distortionary tax means to decrease the welfare reducing wedge between consumer and producer prices and therefore promises to yield a second welfare gain. Unfortunately, this optimistic view finds little support from theoretical analysis. As a tendency, the results from analytical (and some numerical) general equilibrium analyses are that "the second dividend is not likely to obtain" (Goulder (1995)), i.e. tax recycling does not reduce the overall costs of the tax system (cf. Parry (1995), Bovenberg and de Mooij (1994a), (1994b), Bovenberg and van der Ploeg (1994)).

There are at least two major interrelated observations pointing to the reasons for this rather negative conclusion. The first is, that the results may depend on the notion of the double dividend applied. Secondly, the results may depend on the initial tax mix and the choice of the tax used for keeping the government budget constant. In particular, if the ETR starts from a tax system which is sufficiently far from second–best in the absence of external effects, the preconditions for a double dividend may be particular favorable.[1] In the present paper we consider an economy with an initial tax mix that significantly deviates from second–best (in the absence of externalities) and then analyze the effects of an ETR. This may lead to the conclusion that an ETR yields a double dividend in any case. The model is constructed in such a way that without environmental distortions uniform commodity taxation is second–best.[2] Labor is the only factor of production and is assumed to be in endogenous supply. There are two (private) consumption goods, a

[1] As Poterba (1993) points out an extremely inefficient status quo may already induce the government to carry out a tax reform without environmental taxes. However, an ETR may be justified if political constraints prevent raising existing (less distortionary) tax rates although accompanied by the decrease of other taxes.

[2] The framework is based on Bovenberg and de Mooij (1994a).

clean and a dirty good, the consumption of the latter causing emissions which harm the environment and therefore reduce welfare. Both goods are taxed. The situation before the ETR is carried out is characterized as follows:

(1) The emission tax (which is a tax on the dirty good because the emission of pollutants is assumed to be proportional to the output of the dirty good) is lower than the marginal environmental damage, implying that the environmental quality is inefficiently low.

(2) The tax rate on the clean good is higher than that on the dirty good so that by raising the latter the tax mix is moved towards its second–best value.

This procedure is in contrast to Bovenberg and de Mooij (1994a) in whose model uniform commodity taxation is also second–best but who consider a pre ETR situation in which the mix of commodity taxes is optimal if there is no emission tax rate or, alternatively, in which the tax on the clean good is low compared to that on the dirty good. In both cases the change in the tax mix brought about by the ETR moves the tax system farther away from the second–best implying that such an analytical framework defines unfavorable preconditions for deriving a double dividend.[3] Using some helpful results from the optimal taxation literature the analysis below shows that if the ETR is implemented at a more favorable tax mix the second (tax efficiency) dividend is ensured subject to some further (plausible) restrictions, but the environmental dividend often taken for granted may be failed.[4] That is, the ETR may result in an "ecological paradox": a higher emission tax rate reduces environmental quality.

2 The model

2.1 Producers and the government sector

The production sector of the economy is described by a linear technology

$$wl = x + y + g\,. \tag{1}$$

[3]See Schoeb (1995) and Weinbrenner (1996) for critisicm on Bovenberg and de Mooij's analysis leading to the negation of a double dividend.

[4]The importance of the initial tax mix for reaping a double dividend is also stressed by Scholz (1996), whose paper I received after writing this paper. He asserts that within the same framework a double dividend is ensured what is in contrast to our findings.

x, y and g denote the quantities of the clean, dirty, and government consumption good, respectively. Labor (quantity l) is the only input. Output depends on the labor productivity, w, which is constant. We normalize units such that all constant marginal rates of transformation are unity. In competitive equilibrium producer prices equal the fixed input–output coefficients so that producer prices of the private goods are $q_x = q_y = 1$ and the wage rate is w.

The government levies commodity taxes with rates τ_x and τ_y on the consumption of both consumer goods and spends the revenues on good g:

$$\tau_x x + \tau_y y = g \,. \tag{2}$$

There is no lump–sum tax.

2.2 Consumers

The utility of the representative consumer is given by[5]

$$u = \tilde{U}(g, q, f, x, y) = U(g, q, H(f, C(x, y))) \,. \tag{3}$$

In addition to x, y and g, environmental quality, q, and leisure, f, enters the utility function. Labor endowment is normalized to unitiy, $l + f = 1$. We assume that the subutility function C is homothetic.

Environmental quality is determined by the consumption of the dirty good

$$q = Q(y) \,, \qquad Q_y < 0 \,. \tag{4}$$

The consumer takes q as given, i.e. she ignores the negative welfare effect she causes by her own consumption of good y.

[5]See Bovenberg and de Mooij (1994a). It is assumed that (3) is "well–behaved".

The household budget reads[6]

$$(1+\tau_x)x + (1+\tau_y)y = wl\,. \tag{5}$$

Under the present separability conditions of the utility function (3) a two–stage–budgeting procedure can be applied.[7] Thus, aggregation of (5) according to (3) gives

$$p_c\, c = wl\,, \tag{6}$$

where p_c denotes the price (index) of the composite commodity C.

The first–order conditions of the utility maximization problem are

$$\tilde{U}_x = \lambda(1+\tau_x)\,, \tag{7}$$

$$\tilde{U}_y = \lambda(1+\tau_y)\,, \tag{8}$$

$$\tilde{U}_f = \lambda w\,, \tag{9}$$

$$\tilde{U}_c = \lambda p_c\,, \tag{10}$$

where λ is the marginal utility of income. Note that the optimal levels of f and c are determined by (9) and (10) alone because of the homotheticity and separability of $C(x,y)$ in (3).

3 Identifying welfare effects

Marginal welfare effects are easily described with the help of the total differential of (3) and (4)

$$du = \tilde{U}_g dg + \tilde{U}_q Q_y dy + \tilde{U}_f df + \tilde{U}_x dx + \tilde{U}_y dy\,. \tag{11}$$

Since

– a constant government budget implies $dg = 0$,

[6]According to Walras law (5) is already implied by (1) and (2).

[7]For details compare Deaton and Muellbauer (1980), pp. 127–135.

- $l + f = 1$ implies $df = -dl$,
- (1) gives $w\,dl = dx + dy$ for $dg = 0$, and
- (7)–(9) can be inserted,

this expression simplifies to[8]

$$du/\lambda = \tau_x dx + (\tau_y + U_q Q_y/\lambda)dy\,. \tag{12}$$

$\delta := U_q Q_y/\lambda < 0$ represents the marginal environmental damage which by assumption isn't covered by the environmental tax rate, τ_y. Thus, $\tau_y + \delta < 0$ denotes the social cost wedge because of the environmental externality. The marginal excess burden of the tax on good X is given by $\tau_x dx$.

In the present model the welfare effects of policy changes as potential dividends may be defined in two different ways. Bovenberg and de Mooij (1994a), (1994b) suggest that in (12) the term $\tau_x dx + \tau_y dy$ represents the welfare impact of changing tax bases and therefore the change in efficiency of the tax system (the excess burden).[9] The effect on environmental quality is measured by δdy. A different concept of dividends is introduced by Pethig (1996) who shows in a model with a full set of competitive markets as a benchmark that $\tau_y + \delta$ is the distorting "internalisation wedge". It follows that the emission tax rate, τ_y, acts as a price substitute that reduces this social cost wedge. Following Pethig (1996), it is not $\delta\, dy$, but $(\tau_y + \delta)dy$ that defines the environmental dividend of an ETR, while $\tau_x dx$ is the tax efficiency dividend.

In case of an inefficiently low environmental quality this definition of dividends with (12) gives us

Proposition 1: *An ETR yields a positive tax efficiency dividend if the consumption of the clean good increases ($dx > 0$) and a positive environmental dividend if the consumption of the dirty good decreases ($dy < 0$).*

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[8] As common in the literature it is assumed that changes in each of the variables are sufficiently small for λ to be treated as constant throughout the movement. See Burns (1973) for a more in-depth treatment.

[9] See subsection 5.3.

Note that because of the existence of an environmental distortion the emission tax rate is viewed as an environmental policy instrument and therefore doesn't determine the excess burden of the tax system in the meaning of the optimal taxation literature.[10]

4 Comparative statics

To carry out the comparative statics it is convenient to use the hat calculus writing $\hat{x} := dx/x$ etc.

After total differentiation of (2) and (5) and some rearrangements one gets with $\hat{\tau}_i := d\tau_i/(1+\tau_i)$, $i = x, y$[11]

for the government budget

$$\tau_x \alpha_x \hat{x} + \tau_y \alpha_y \hat{y} = -(1+\tau_x)\alpha_x \hat{\tau}_x - (1+\tau_y)\alpha_y \hat{\tau}_y \,, \tag{13}$$

for the household budget

$$\hat{p}_c + \hat{c} = (1+\tau_x)\alpha_x(\hat{\tau}_x + \hat{x}) + (1+\tau_y)\alpha_y(\hat{\tau}_y + \hat{y}) = \hat{l} \,, \tag{14}$$

and for the marginal welfare effects

$$du/\lambda wl = \tau_x \alpha_x \hat{x} + \alpha_y(\tau_y + \delta)\hat{y} \,. \tag{15}$$

Differentiation of the ratio of the first-order conditions (7) and (8) yields

$$\hat{x} - \hat{y} = \sigma(\hat{\tau}_y - \hat{\tau}_x) \,, \tag{16}$$

[10] Schoeb (1995) refers to this definition of the tax efficiency part of the welfare effects as the "environmental view".

[11] Note that by dividing through by wl (1), (2) and (5) are turned into $1 = \alpha_x + \alpha_y + \alpha_g$, $\tau_x\alpha_x + \tau_y\alpha_y = \alpha_g$, and $(1+\tau_x)\alpha_x + (1+\tau_y)\alpha_y = 1$, respectively ($\alpha_i := i/wl$, $i = x, y, g$). A more detailed derivation of comparative statics results of the original Bovenberg–de Mooij model can be found in Weinbrenner (1996).

where σ denotes the elasticity of substitution in consumption between x and y.

Now the changes in consumer demand, $\hat{x}$ and $\hat{y}$, can be derived by using (16) in the household budget (14). This gives

$$\hat{y} = \hat{l} - \underbrace{[(1+\tau_x)\alpha_x(1-\sigma)]}_{\text{cross price effects}}\hat{\tau}_x - \underbrace{[(1+\tau_y)\alpha_y + (1+\tau_x)\alpha_x\sigma]}_{\text{own price effects}}\hat{\tau}_y \tag{17}$$

or after rearranging terms

$$\hat{y} = \underbrace{\hat{l} - (1+\tau_x)\alpha_x\hat{\tau}_x - (1+\tau_y)\alpha_y\hat{\tau}_y}_{\text{income effects}} + \underbrace{(1+\tau_x)\alpha_x\sigma(\hat{\tau}_x - \hat{\tau}_y)}_{\text{substitution effects}} \tag{17'}$$

and

$$\hat{x} = \hat{l} - \underbrace{[(1+\tau_x)\alpha_x + (1+\tau_y)\alpha_y\sigma]}_{\text{own price effects}}\hat{\tau}_x - \underbrace{[(1+\tau_y)\alpha_y(1-\sigma)]}_{\text{cross price effects}}\hat{\tau}_y \tag{18}$$

or

$$\hat{x} = \underbrace{\hat{l} - (1+\tau_x)\alpha_x\hat{\tau}_x - (1+\tau_y)\alpha_y\hat{\tau}_y}_{\text{income effects}} + \underbrace{(1+\tau_y)\alpha_y\sigma(\hat{\tau}_y - \hat{\tau}_x)}_{\text{substitution effects}} . \tag{18'}$$

At the second stage of the utility maximization procedure the consumer allocates f and c such that (9) and (10) are fulfilled subject to the budget constraint (14). Differentiation results in

$$\hat{l} = \underbrace{f(\sigma_{cf} - 1)}_{=:\epsilon}\underbrace{(-(1+\tau_x)\alpha_x\hat{\tau}_x - (1+\tau_y)\alpha_y\hat{\tau}_y)}_{=\hat{p}_c}, \tag{19}$$

where ϵ is the (uncompensated) wage elasticity of labor supply, $\hat{p}_c$ the relative change of the price (index) of the (composite) good C, and σ_{cf} the elasticity of substitution in consumption between c und f.

With the labor supply function (19) the demand functions (17) and (18) can be written as

$$\hat{y} = -(1+\tau_x)\alpha_x(\epsilon + 1 - \sigma)\hat{\tau}_x - [(1+\tau_y)\alpha_y(\epsilon + 1) + (1+\tau_x)\alpha_x\sigma]\hat{\tau}_y, \tag{17''}$$

$$\hat{x} = -[(1+\tau_x)\alpha_x(\epsilon+1) + (1+\tau_y)\alpha_y\sigma]\,\hat{\tau}_x - (1+\tau_y)\alpha_y(\epsilon+1-\sigma)\hat{\tau}_y\,. \qquad (18")$$

Note that general equilibrium cross price effects depend on the sign of $\epsilon + 1 - \sigma$. That means a higher tax rate τ_i for a given tax rate τ_j, $i = x, y$, $i \neq j$ increases j, $j = x, y$, $j \neq i$ if and only if the substitution effect dominates the income effects due to the own price increase **and** changed labor supply, that is $\sigma > \epsilon + 1$. Furthermore, from (17') and (18') one can see that equal tax rate changes $\hat{\tau}_x = \hat{\tau}_y$ imply that only income effects determine the change in consumer demand. This is a consequence of the symmetry between x and y implied by the special structure of the utility function (3).

5 The revenue–neutral tax substitution

5.1 The initial tax mix

The special structure of the utility function (3) allows us to identify the deviation of the initial tax mix from the second–best tax system if environmental distortions are absent. This can be seen by the following result well known in the optimal taxation literature:

Sandmo (1974): *Ignoring environmental effects, $Q_y = 0$, the utility function (3) implies that a uniform tax on both consumer goods is second–best.*

Having fixed this reference point we can obviously identify three possible pre ETR conditions:

(A.1) $\tau_x = \tau_y$

(A.2) $\tau_x < \tau_y$

(A.3) $\tau_x > \tau_y$.

Since an ETR is defined by an increase of an emission tax rate, i.e. $\hat{\tau}_y > 0$, an ETR starting from (A.1) or (A.2) moves the tax system farther away from its second–best structure (for $Q_y = 0$). The initial tax mix assumed by Bovenberg and de Mooij (1994a) precisely satisfies (A.1) or (A.2). They model the compensation in such a way that the emission tax revenues are recycled by a lower labor tax rate which is equivalent to a uniform commodity tax rate on both consumer goods and therefore second–best (see Sandmo (1974)). We want to follow a different route by starting an ETR under the condition (A.3). Additionally, we recycle the emission tax revenues by lowering the tax on the clean good because in the present model (like in Bovenberg and de Mooij (1994a)) the labor tax rate is equivalent to a uniform commodity tax rate. Thus a lower labor tax rate would implicitly be a decrease in the emission tax rate and therefore its reduction would (partly) compensate the direct increase in the "virtual" emission tax rate.

In view of Sandmo's (1974) result and assumption (A.3) it is not too optimistic to expect a double dividend from an ETR: increasing the emission tax rate, τ_y, serves for internalizing the social costs of the external effects, but even if these external effects are absent the initial tax mix is such that a **higher** emission tax rate is a step towards the second–best uniformity of the tax rates.

5.2 Comparative statics of the ETR

With the comparative statics of the previous section we are now able to study the effects of an ETR. We make precise the meaning of an ETR by

Definition 1: *A policy* $\{\hat{\tau}_y > 0,\ \hat{g} = 0\}$ *is called an ETR.*

Note that this definition doesn't include any lump–sum adjustments and doesn't exclude the possibility that an ETR implies $\hat{\tau}_x > 0$ because $\hat{\tau}_x$ is determined endogenously due to the requirement of revenue–neutrality.

Formally, the effects of an ETR are derived by solving the system of linear equations given by (13), (17"), and (18"). After rearranging terms one gets

$$\hat{\tau}_x = \frac{(1+\tau_y)\alpha_y(1-\alpha_g(\epsilon+1)) + \sigma\alpha_x\alpha_y(\tau_x-\tau_y)}{D}\,\hat{\tau}_y\,, \tag{20}$$

$$\hat{x} = -\frac{\sigma}{D}\alpha_y(1-\tau_y\epsilon)\,\hat{\tau}_y\,, \tag{21}$$

$$\hat{y} = \frac{\sigma}{D}\alpha_x(1-\tau_x\epsilon)\,\hat{\tau}_y\,, \tag{22}$$

where

$$D := -(1+\tau_x)\alpha_x(1-\alpha_g(\epsilon+1)) + \sigma\alpha_x\alpha_y(\tau_x-\tau_y).$$

Since $1-\alpha_g(\epsilon+1)$ is indeterminate in sign so is D and therefore $\hat{\tau}_x$, $\hat{x}$, and $\hat{y}$. Furthermore, the terms $1-\epsilon\tau_x$ and $1-\epsilon\tau_y$ can be either positive or negative. Thus, an ETR can result in any conceivable situation including $\hat{x} < 0$ and $\hat{y} > 0$ in which case both distortions will be enhanced. The next proposition summarizes all possible outcomes for non-zero values of the parameters under consideration:[12]

Proposition 2: *Suppose assumption (A.3) holds. Then the possible effects of an ETR are as follows:*

	ϵ	D	$1-\tau_x\epsilon$	$1-\tau_y\epsilon$	$\hat{y}$	$\hat{x}$	*dividends*
1	>0	<0	$>0 \Rightarrow$	>0	<0	>0	*win – win*
2	>0	<0	<0	>0	>0	>0	*lose – win*
3	>0	>0	$>0 \Rightarrow$	>0	>0	<0	*lose – lose*
4	>0	>0	<0	>0	<0	<0	*win – lose*
5	>0	>0	<0	<0	<0	>0	*win – win*
6	<0	<0	>0	>0	<0	>0	*win – win*
7	<0	>0	>0	>0	>0	<0	*lose – lose*

To interpret the results of proposition 2 and to find some routes out of the ambiguities consider first the (uncompensated) wage elasticity of labor supply. One of the hypothesis

[12]Note that with assumption (A.3), $\tau_x > \tau_y$, it follows that $1-\epsilon\tau_x > 0$ implies $1-\epsilon\tau_y > 0$ and that $D < 0$ implies $1-\alpha_g(\epsilon+1) > 0$ which is equivalent to the expressions $\alpha_x + \alpha_y - \epsilon\alpha_g > 0 \Leftrightarrow \alpha_x + \alpha_y - \epsilon(\tau_x\alpha_x + \tau_y\alpha_y) > 0 \Leftrightarrow \alpha_x(1-\tau_x\epsilon) + \alpha_y(1-\tau_y\epsilon) > 0$, which excludes that in row 2 both terms are negative if $D < 0$ is assumed. In the column with the dividends the first win/lose refers to the environmental dividend and the second one to the tax efficiency dividend.

often made in the literature is to exclude a backward–bending labor supply curve, i.e. to assume that the substitution effect is at least as high as the income effect when the wage rate is changed:[13]

(R.1) $\epsilon \geq 0$.

This eliminates the rows 6 and 7 in the table of proposition 2. The next step is to look at the revenue effects of tax rate changes which are obtained by inserting (17") and (18") in (13) for $\hat{g} \neq 0$:

$$\begin{aligned} \alpha_g \hat{g} &= \Big[\underbrace{(1+\tau_x)\alpha_x\{1-\alpha_g(\epsilon+1)\} - \sigma\alpha_x\alpha_y(\tau_x-\tau_y)}_{=:T^x}\Big]\hat{\tau}_x + \\ &\quad \Big[\underbrace{(1+\tau_y)\alpha_y\{1-\alpha_g(\epsilon+1)\} + \sigma\alpha_x\alpha_y(\tau_x-\tau_y)}_{=:T^y}\Big]\hat{\tau}_y \ . \end{aligned} \tag{23}$$

For $\hat{\tau}_y > 0$ and revenue neutrality, $\hat{g} = 0$, the tax adjustment, $\hat{\tau}_x$, necessary to keep tax revenues constant is given by (20). The tax revenue function (23) shows that every tax rate change has three effects. First, for a constant (own) tax base it increases tax revenues ($(1+\tau_i)\alpha_i$ for $i = x, y$). Second, higher tax rates induce income effects which decrease tax revenues because consumers have a loss in real income and therefore reduce their demand. This erodes the tax bases ($-(1+\tau_i)\alpha_i\alpha_g(\epsilon+1), \quad i = x, y$). Third, relative prices change so that substitution takes place ($(-)\sigma\alpha_x\alpha_y(\tau_x-\tau_y)$).[14] It is interesting to see that the two tax rates have opposite tax revenue substitution effects. In contrast to an increasing tax rate τ_x, a higher emission tax rate, τ_y, tends to increase this tax revenue substitution effect because it leads to a substitution to good X on which a higher (i.e. "more revenue–producing" for a given tax base) tax rate is levied. The revenue substitution effect vanishes if both tax rates are equal, $\tau_x = \tau_y$. In this case the revenue effect from a changed tax rate is exactly compensated by the revenue effect induced by the substitution to the other taxed good.[15]

[13] For an empirical evidence cf. Hausman (1985).

[14] Hatta and Haltiwanger (1986) call these revenue effects as primary, real income, and substitution effect, respectively.

[15] As will be shown in subsection 5.3 the term $\sigma\alpha_x\alpha_y(\tau_x-\tau_y)$ points to the distortion caused by the non–uniform tax system.

It is useful to make the following

Definition 2: *The tax on good i, τ_i, $i = x, y$ is called revenue–increasing if $T^i > 0$.*

Revenue–increasingness is also often described as that the economy being in the normal range of the (fictive) Laffer–curve with respect to each tax rate.

Now we can state a second useful *hypothesis*:

(R.2) *The taxes on good X and Y are revenue–increasing.*

This assumption seems to be reasonable as long as the tax rates are not "too high". If τ_x and τ_y are revenue–increasing it follows that $D = -T^x < 0$. In this case an ETR implies $\hat{\tau}_x < 0$. Hence (R.2) eliminates the rows 3 – 5 in proposition 2 above.

Applying these hypotheses to (21) and (22) enables us to consider some special cases of an ETR:

Proposition 3:
a) *If $\sigma = 0$ holds, an ETR has no welfare effects.*
b) *Suppose (A.1), (R.1), and (R.2) hold. Then an ETR yields a double dividend.*
c) *Suppose (A.3) and (R.2) hold. If i) (R.1) holds with equality sign ($\epsilon = 0$), then an ETR yields a double dividend. If ii) (R.1) holds with strict inequality ($\epsilon > 0$) and if $\tau_x\epsilon > 1$, then an ETR reduces environmental quality ($\hat{y} < 0$), i.e. yields no environmental dividend.*

3a) – c) are easily be proved by using $\sigma = 0$, $\epsilon = 0$, $\tau_x = \tau_y$, and $\tau_x\epsilon > 1$ respectively in (21) and/or (22) and then in proposition 1.

It is obvious from (21) and (22) that $\sigma > 0$ is a necessary condition for reaping a double dividend. The tax rate changes from an ETR doesn't have any impact if households don't substitute goods, irrespective of the assumptions (A.i), i=1,2,3 , (R.1) and (R.2). From propositions 3b) and 3c) we conclude that a low wage elasticity of labor supply and a small distortionary tax wedge between τ_x and τ_y are sufficient for a double dividend to occur.[16]

At the first glance it does not seem to be clear why the wage elasticity of labor supply is an important determinant of the dividends because the substitution effects from the increased emission tax rate ($\hat{\tau}_y > 0$) and from the decreased tax rate on the clean good ($\hat{\tau}_x < 0$) tend into the same direction. Moreover, (22) tells us that $\hat{y}$ is negative if τ_x and ϵ are sufficiently high, i.e. $1 < \tau_x \epsilon$, although the emission tax rate is increased.

To identify the effects working to this rather unexpected result it is helpful to derive the changing labor supply from simultaneous tax rate changes of the ETR by inserting the consumer demand functions (17) and (18) in $\hat{l} = \alpha_x \hat{x} + \alpha_y \hat{y}$ making use of both the production function (1), $wl = x + y + g$, and the revenue–neutrality condition $\hat{g} = 0$.

After some rearrangements one gets

$$\hat{l} = -\frac{\epsilon \sigma \alpha_x \alpha_y (\tau_x - \tau_y)(\hat{\tau}_x - \hat{\tau}_y)}{1 - \alpha_g(\epsilon + 1)} . \tag{24}$$

This immediately leads to[17]

Proposition 4: *Suppose (R.1) with $\epsilon > 0$ and (R.2) hold. Then an ETR implies $\hat{l} \gtrless 0 \Leftrightarrow \tau_x \gtrless \tau_y$.*

Proposition 4 tells us that with assumption (A.3), $\tau_x > \tau_y$, the ETR increases labor supply. A higher labor supply leads to a higher labor income which tends to increase consumer demand of x and y as (17) and (18) show. Generally, a higher labor supply (income) works against a lower demand for the dirty good y and therefore against an environmental dividend. If τ_x and ϵ are sufficiently high, i.e. $\tau_x \epsilon > 1$ (see (22)), the tax revenue recycling effect from the decreased clean tax more than compensates the consumer for the increased emission tax. Intuitively, an increase in the emission tax rate reduces the consumption of the dirty good because of a) the substitution effect, b) the own price

[16]This might suggest that only the difference between the two tax rates matters, but note that the tax rates should not be "to high" in order to ensure revenue–increasingness in (R.2) above.

[17]Note that from (23) a neccesary condition for τ_x to be revenue–increasing is that $1 - \alpha_g(\epsilon + 1) > 0$ and that (R.2) ensures $\hat{\tau}_x < 0$.

induced income effect, and c) the income effect induced by lower labor supply (see (17")). Concerning the government budget the positive revenue effect from the higher emission tax rate comes along with the negative tax base erosion effect. Simultaneously, the cross price relation implies that substitution leads to increasing demand for the clean good which is in contrast to the impact of the income effects induced by the higher emission tax rate (see (18")). If now the resulting (marginal) tax revenues from the increase in the emission tax are large there is wide scope to reduce the clean tax. With low marginal tax revenues T^x the clean tax rate can be sufficiently reduced which through the income effects does not only allow for higher x and labor, but also for higher y. In this case the "first round" demand decreasing income effects due to the higher tax rate on the dirty good are dominated by the "feedback" demand increasing income effects due to the lower tax rate on the clean good and the increased labor supply.[18] That means we cannot exclude that the ETR worsens environmental quality and therefore fails to yield an environmental dividend although our point of departure seemed to ensure a double dividend in any case.[19]

5.3 Efficiency of taxation ignoring environmental distortions

The analysis above allows us to calculate the non-environmental part of the welfare effects of an ETR. In other words: we can study the effects of an ETR from an optimal taxation viewpoint which highlights the tax efficiency dividend used by Bovenberg and de Mooij (1994a). This is done by inserting (21) and (22) in (15) for $\delta := U_q Q_y/\lambda = 0$:

$$\hat{\beta}|_{\delta=0} := du/\lambda wl|_{\delta=0} = \tau_x \alpha_x \hat{x} + \tau_y \alpha_y \hat{y} \,.$$

After rearrangement of terms this gives us (assuming that (R.2) holds)

$$\hat{\beta}|_{\delta=0} = \frac{\sigma \alpha_x \alpha_y (\tau_y - \tau_x)}{D} \hat{\tau}_y \quad \gtreqless \quad 0 \quad \Leftrightarrow \quad \tau_x \quad \gtreqless \quad \tau_y \,.$$

[18]It should be noted that the tax reform (i.e. each tax rate change) induces substitution effects which tend in the same direction whereas the income effects of each tax rate change are opposed to each other.

[19]Conversely, one can show that in the present model with (A.2), $\tau_y > \tau_x$, it cannot be excluded that a double dividend according to proposition 1 occurs.

The term $\sigma\alpha_x\alpha_y(\tau_y - \tau_x)$ represents the distortion caused by the non–uniform tax system.[20] If we treat this expression as the non–environmental dividend an ETR starting at $\tau_x > \tau_y$ obiously reduces the excess burden of the tax system by increasing τ_y and decreasing τ_x. Conversely, if the ETR starts at $\tau_y > \tau_x$ an increased emission tax rate clearly increases the tax wedge (assumed that (R.2) holds).[21]

It's useful to consider how $\hat{\beta}|_{\delta=0}$ changes if labor supply changes in case of an ETR. Using either (20) in (19) or (21), (22) in $\hat{l} = \alpha_x\hat{x} + \alpha_y\hat{y}$ gives a slight variation of (24) as

$$\hat{l} = -\frac{\epsilon\sigma\alpha_x\alpha_y(\tau_x - \tau_y)}{D}\hat{\tau}_y \,.$$

Combining $\hat{\beta}|_{\delta=0}$ and $\hat{l}$ then yields

$$\frac{\hat{l}}{\hat{\beta}|_{\delta=0}} = \epsilon \quad \Leftrightarrow \quad \hat{\beta}|_{\delta=0} = \hat{l}/\epsilon \,. \tag{25}$$

That means, an ETR reduces the excess burden of the tax system (including the emission tax) if and only if labor supply increases (for a positive wage elasticity of labor supply).

This result is closely related to Sadka (1977) who shows in a model without externalities that the following statements are equivalent: (a) a uniform tax on all consumer goods is optimal; (b) a uniform tax on all consumer goods maximizes the supply of labor. In view of this result (25) shows that if the tax system approaches the second–best value ($\hat{\tau}_y > 0$ and $\hat{\tau}_x < 0$) labor supply approaches the maximum value simultaneously (see also (24)). This result also corresponds with that of Corlett and Hague (1953) who show in a similar model that "whenever this tax changes makes the consumer work harder, he will reach a higher indifference surface" (p. 21).

To show the importance of the initial tax mix of different models assume that each tax rate consists of a part τ equal for both tax rates and a further component θ_i, $i = x, y$, i.e. $\tau_x = \tau + \theta_x$ and $\tau_y = \tau + \theta_y$. Then the government budget (2) is

[20] Compare the proposition of Sandmo (1974), p. 8.

[21] This is in line with Hatta's (1986) condition (eq. (16)) for a welfare improvement of a tax reform, $\sigma_{cf}(\tau_x + t_l)/(1 + \tau_x) \geq \sigma_{cf}(\tau_y + t_l)/(1 + \tau_y)$, with t_l as a labor tax rate, which in the present model simplifies to $\tau_x \geq \tau_y$.

$$(\theta_x + \tau)x + (\theta_y + \tau)y = g$$

which can be shown to be equivalent to

$$\frac{\tau}{1+\tau}wl + \frac{\theta_y}{1+\tau}y + \frac{\theta_x}{1+\tau}x = g\,,$$

where the tax rates of the latter equation are those of the Bovenberg–de Mooij model. They study a tax reform with $\theta_x = 0$, $d(\theta_y/(1+\tau)) > 0$ and $d(\tau/(1+\tau)) < 0$. This directly implies $\hat{l} = \epsilon\hat{\beta}|_{\delta=0} < 0$ because of $\theta_x < \theta_y$ and therefore indicates a welfare loss which is in contrast to the result obtained under assumption (A.3), $\tau_x > \tau_y$.

The question may arise if there are differences in applying the two different concepts of tax efficiency dividends. The following table compares the results under the two definitions for propositions 2 and 3:

Case of Prop. 2/3	Version 1 (Pethig) $\hat{x} = -\frac{\sigma\alpha_y(1-\tau_y\epsilon)}{D}\hat{\tau}_y$	Version 2 (Bovenberg/de Mooij) $\hat{\beta}\|_{\delta=0} = \frac{\sigma\alpha_x\alpha_y(\tau_y-\tau_x)}{D}\hat{\tau}_y$
1	>0 *win*	>0 *win*
2	>0 *win*	>0 *win*
3	<0 *lose*	<0 *lose*
4	<0 *lose*	<0 *lose*
5	$\mathbf{>0}$ **win**	$\mathbf{<0}$ **lose**
6	>0 *win*	>0 *win*
7	<0 *lose*	<0 *lose*
3*a*)	$=0$	$=0$
3*b*)	$\mathbf{>0}$ **win**	$\mathbf{=0}$
3*c*)	>0 *win*	>0 *win*

Table 1: Comparison of the two tax efficiency dividends

As one can see there are two cases indicating not the same tax efficiency dividends. The first one may arise if the ETR produces adverse tax revenue effects such that condition (R.2) is violated and $D > 0$ follows (case 5 of proposition 2). The second one comes into being if the ETR starts from a tax system which is efficient from a non–environmental point of view. In this case a (marginal) ETR doesn't result in a tax efficiency dividend according to Bovenberg and de Mooij, but indicates a win–situation applying the dividend according to Pethig (case 3b of proposition 3).

To summarize, Bovenberg and de Mooij confirm (under the same qualifications) the environmental dividend because labor supply and (therefore unambiguously) the demand of the dirty good decreases but reject the tax efficiency dividend (in both definitions but with a labor tax instead of the tax on the clean good). In contrast, by assuming $\tau_x > \tau_y$ we confirm the tax efficiency dividend (in both definitions, too) but cannot guaranty that the demand of the dirty good decreases to reap an environmental dividend (case 2 of proposition 2).

6 Concluding remarks

In this paper we analyzed the effects of an ETR starting from a tax system that from a partial equilibrium point of view appears to be a favorable starting–point for yielding a double dividend. Under some standard hypotheses on the labor supply and the tax revenue function a double dividend may, but need not occur. We showed in a fairly simple model based on Bovenberg and de Mooij (1994a) that an ETR can, in principle, produce positive or **negative** environmental quality effects although induced substitution effects from a higher emission tax rate and a lower tax rate on the clean consumption good seems to give an unambiguous environmental dividend. This kind of second–best result is in line with the traditional tax reform analysis which states that "policy changes which appear to be steps in the right direction, but stop short of attaining the full optimum, can actually reduce welfare" (Dixit (1975), p. 103).[22] To sum up, the initial tax mix

[22]There are several studies which deal with tax reform as a special field of second–best policy; among others see Corlett and Hague (1953), Feldstein (1976), Guesnerie (1977), Pazner and Sadka (1981).

plays an important role in ETR–analysis but even "favorable" preconditions of the tax system are not sufficient to reap a double dividend in general equilibrium. Moreover, the initial tax system and the choice of taxes used in an ETR allow for opposite dividends: reducing a labor tax rate (under the present conditions equivalent to a uniform tax rate on both consumer goods and therefore second–best) fails to reap the tax efficiency dividend, but ensures the environmental dividend (the Bovenberg–de Mooij–case). Reducing a (relatively high and distortionary) tax rate on the clean consumption good may lead to the opposite case and therefore makes possible an "ecological paradox" of an ETR (our case). Additionally, different concepts of dividends may indicate different welfare gains.

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