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# Ecological Tax Reform and Efficiency of Taxation:

## A Public Good Perspective

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# Ecological tax reform and efficiency of taxation: A public good perspective[1]

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## 1. Introduction

Taxing the emission of pollutants has been recommended as an 'economic' instrument of pollution control ever since economists approached environmental disruption as a problem of negative externalities in the *Pigouvian tax-subsidy paradigm*. Such emission taxes were shown to reduce the allocative distortions of environmental externalities caused by the market system's failure of correctly accounting for the scarcity of environmental resources. Such an efficiency enhancing externality taxation is in stark contrast to the results of modern taxation theory which shows that in a world without lumpsum taxation and without externalities taxes carry an excess burden thus diminishing allocative efficiency.

These two lines of argument demand for being interlinked: Suppose government is asked to collect a given amount of total tax revenue by levying both an emission tax and a distortionary labor tax. Isn't it then an obvious conclusion that changing the tax mix by rising the emission tax rate reduces both the externality inefficiency and the excess burden of the labor tax? Indeed, such a taxation strategy, called *'ecological tax reform'*, promises a *double dividend* (Pearce 1991) by improving the quality of the environment and reducing the tax system's excess burden at the same time.

In recent years the theoretical foundations of ecological tax reform and its implications have been scrutinized in a number of contributions (Ulph 1992; Bovenberg and de Mooij 1994a, 1994b; Parry 1995; Schöb 1995) relating to some extend the tax reform issue to the optimal tax cum externality literature (Atkinson and Stern 1974; Sandmo 1975). As a tendency, the theoretical investigations do not find much support for the tax efficiency dividend (Parry 1995) or even reject the double dividend hypothesis like Bovenberg and de Mooij (1994a, p. 1085) who conclude „that environmental taxes typically exacerbate, rather than alleviate, preexisting distortions - even if revenues are employed to cut pre-existing distortionary taxes“. This obvious *discrepancy* between informed common sense and theoretical analysis is intriguing. One may argue that the source of the discrepancy originates, perhaps, from our failure to understand the complexity of the third-best scenario of an ecological tax reform which involves two distinct inefficiencies, the externality and the distortionary taxation. Another reaction is to question the robustness of the theoretical conclusions, because carrying out conclusive comparative statics in general tax-distorted equilibrium models requires to employ very restrictive assumptions[2]. Yet another response - the one to be pursued in the present paper - is to suggest a different perspective of analyzing tax reforms in the presence of

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[1] Helpful comments by Daniel Weinbrenner are gratefully acknowledged. Remaining errors are the auther's sole responsibility.

[2] The (lack of) robustness of the results in the literature is a serious issue, since comparative static analysis in (simple) general equilibrium models does not yield conclusive results unless severe restrictions are introduced with respect to utility and production functions. Unfortunately, interdependence effects in general equilibrium analysis can support just about every pathological result as shown in Weinbrenner (1996).

externalities in an effort to obtain new insights into the expected benefits (dividends) of environmental policy in a world of distortionary taxation.

The basic focus of this paper is to look at ecological tax reform from a *public good perspective* rather than from a *Pigouvian externality cum tax reform perspective*. Our point of departure is the insight, aptly expressed by Heller and Starrett (1976, p. 10), e. g., that "one can think of externalities as nearly synonymous with non existence of markets". In their view an externality is "a situation in which the private economy lacks sufficient incentives to create a potential market in some good and the non existence of this market results in losses in Pareto efficiency" (ibid.). Thinking of externalities or rather public goods in terms of (non existing) markets requires, first of all, to identify the commodities traded on these fictitious markets. In our context these goods are *'environmental quality'* and *'nature's assimilative services'* the former being a public good and the latter a private good.

For reference purposes we build a simple model in which all disincentives of market creation are assumed to be absent: Nature's fixed endowment of assimilative services is privately owned and is sold to two different users, to the producer of environmental quality and to the consumption good industry. This fancy scenario of a *complete set of competitive markets* is known to constitute a first-best world with full internalization of the environmental externality. Government has no useful role to play since even the public good 'environmental quality' is privately provided in an efficient way - ignoring all the well-known problems of demand revelation and free riding.

Throughout the present paper, the first-best allocation in an economy with a full set of partly fictitious competitive markets is taken as the benchmark model of taxation and tax policy - in contrast to the public finance view of ecological tax reform (e. g. Bovenberg and de Mooij (1994a)) which takes as its benchmark the general competitive equilibrium in the absence of any pollution control and in the absence of harmful pollutants. To make our concept precise we assume that the government interferes with (fictitious) markets through taxes and subsidies for the purpose of fixing the market provision of environmental quality at a 'politically predetermined level'. It is shown that any (suboptimal) environmental quality standard can be tax-implemented in an efficient way. If this standard is inefficiently low, the corresponding taxation scheme includes an *emission subsidy (!)*, whereas what is conventionally identified as the 'emission charge' turns out to be the (subsidized) price of the productive factor 'assimilative services' used by industry. An obvious advantage of this perspective is that we do not study the effects of distortionary taxation in an externality-distorted world but rather view taxation as the only cause of allocative inefficiency.

The paper proceeds by investigating public policies to supply environmental quality *at no cost to the consumers.* On the assumption that the market for assimilative services is still working and *no lumpsum taxation or transfer* is viable, government now has to raise a *distortionary labor tax* to pay for the purchase of environmental quality. It is shown that implementing a predetermined environmental quality standard by such a policy is *equivalent* to establishing this standard in an economy with a complete set of markets where the externality was represented as a tax distortion.

In this setting, one may want to strengthen the environmental quality standard by changing the tax mix. Rather than carrying out a full-scale comparative statics analysis (see footnote 2) we characterize the set of possible results and form some plausible incidence hypotheses to conclude that the double dividend conjecture essentially amounts to arguing that government is able to buy more of a public good while expending less.

All considerations up to this point had been based on the assumption that assimilative services are privately owned so that the associated income from selling assimilative services (resource income, for short) is disposed of by the consumers. If this *resource income is publicly owned*, as in the real world, the regulator can implement any environmental quality standard *at minimum cost* when she replaces the labor tax by the non-distortionary resource income. In other words, the issue of distortionary taxation vanishes unless one introduces a second public good in addition to environmental quality that is also costlessly provided to the consumers and financed by government.

With this modification of the model we obtain, in fact, the framework of analysis chosen by the studies on ecological tax reform listed above. Hence in our perspective the ecological tax reform literature essentially aims at answering the following question: What happens to the efficiency of the tax system when the regulator provides environmental quality and another public good costlessly to the consumers at inefficient levels, when the purchase of these goods is financed partly by the revenue from distortionary taxes and partly by non-distortionary public resource income and when she wishes to strengthen the standard of environmental quality?

It is finally shown that paying for the increased provision of one out of two public goods with resource income and the revenue of a distortionary (labor) tax is qualitatively very similar to the simpler scenario (described above) of using labor tax revenue for purchasing an increment of environmental quality as the only publicly provided public good when assimilative services are privately owned. The set of possible results is again characterized along the same lines as in the scenario described above, and plausible incidence hypotheses lead to similar conclusions. Moreover, necessary conditions for the emergence of a double dividend turn out to be the existence of a private consumption good in addition to the 'dirty' good, if all production processes are linear, or the existence of a waste abatement technology. It is finally shown how the public good perspective of ecological tax reform is linked to the conventional analysis of ecological tax reform as in Bovenberg and de Mooij (1994a). A partial equilibrium illustration shows that it is the less likely that the emission tax revenue (conventionally defined) increases as a response to an increase of the emission tax rate, the more price elastic is industry's demand for assimilative services.

## 2. Tax representations of environmental externality

Consider an economy producing a (private) consumption good $Y$, with the help of labor, $\ell$, and assimilative services, $a_y$, by means of the linear homogeneous production function[3]

$$y = Y\left(\ell, a_y\right) \quad \text{with domain} \left\{ \left(\ell, a_y\right) | \, a_y \leq c\ell,\ c > 0 \text{ and const.} \right\}. \qquad (1)$$

The emission of pollutants by industry Y can be interpreted as that industry's demand for assimilative services so that $a_y$ measures both the use of assimilative services and the

[3] For more details see Pethig (1979)

industrial emission of pollutants. The flow of these emissions affects the state of the environment represented by an index of environmental quality, $q$, according to the strictly declining and concave function $\tilde{Q}$ where $q = \tilde{Q}(a_y)$ is the environmental quality resulting from industry's use of assimilative services (alias discharge of pollutants)[4]. Nature's limited assimilative capacity is modeled in a very stylized way: It is assumed that the environment is capable of assimilating or neutralizing small amounts of pollutants (per period) without irreversible damage. But once emissions exceed some *critical load*, say $\bar{a}$, then serious environmental disruption occurs rendering the development unsustainable. This implied „*sustainability constraint*" is formalized by $a_y + a_q = \bar{a} > 0$, $a_y \geq 0$ and $a_q \geq 0$, and it allows to transform $\tilde{Q}$ into a function $Q$ defined by

$$q = \begin{cases} Q(a_q) := \tilde{Q}(\bar{a} - a_y), & \text{if } a_y \in [0, \bar{a}]; \\ -\infty & \text{if } a_y > \bar{a}. \end{cases} \tag{2}$$

Clearly, $Q$ is increasing and concave, and sustainability requires environmental quality to stay at or above the critical environmental quality, $Q(0)$. Introducing the convention[5] $Q(0) = 0$ equation (2) is readily interpreted as an *ecological production function* for generating 'environmental quality' with the help of assimilative services, $a_q$. In this perspective the assimilative services are *private* factors for producing both environmental quality - which is a *public* good - and the *private* good $Y$. Observe, however, that the use of assimilative services is very different in both cases. Industry uses them for disposing of detrimental pollutants, whereas $a_q$ is demanded to prevent the environment from being polluted. In this way the environmental-economic allocation problem is characterized as the conflict between *competing uses* of scarce assimilative services: its use for 'producing' environmental quality versus its use for absorbing industrial pollutants.

Summing up the supply side of the economy, we recall that there are two productive factors: assimilative services in fixed supply and labor in endogenous supply; there are two consumption goods: environmental quality as a public good and the private consumption good $Y$. The former is produced with assimilative services only and the latter requires both inputs for its production.

The description of the model is completed by introducing the representative consumer's strictly quasi-concave utility function

$$u = U(y, f, q) \tag{3}$$

where $f := 1 - \ell$ represents leisure.

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[4] Even though we will use a very simple *static* model in the subsequent analysis, $Q(a_y)$ will be interpreted as a *longterm stationary* environmental quality that is maintained when the steady flow $a_y$ of pollutants is emitted into the environment. For the relationship between dynamic paths of adjustment (ignored in the present paper) and stationary states see Pethig (1994).

[5] Conceptually, the scale of the quality index $q$ can be chosen arbitrarily, but in view of the above interpretations, we consider $Q(0) = 0$ as a natural normalization.

We now embark on the thought experiment of investigating the above model as a *private ownership market economy with a complete set of competitive markets*, one for each of the four commodities with market clearing prices in general competitive equilibrium.[6] Being the owner of assimilative services, the representative consumer[7] sells these services to the producers of good $Y$ and of environmental quality. Such a market for assimilative services differs from markets in tradeable emission permits as usually discussed in the literature, because in the latter permits are not purchased for the purpose of *preventing* the emission of pollutants which is precisely the reason why the producer of environmental quality demands assimilative services in the model of the present paper. This producer runs a profit-maximizing and price-taking private firm and thus forms the link between the markets for assimilative services and environmental quality.

Denote by $p_y$ the price of good $Y$, by $p_q$ the price of environmental quality, by $p_a$ the price of assimilative services, and by $w$ the wage rate. Let $t$ be the labor tax rate, $\theta$ the tax rate on the consumption of environmental quality, and $\tau$ the tax rate on the use of assimilative services. The tax rate $t$ is assumed to be non-negative, but $\theta$ and $\tau$ are unrestricted in sign[8]. Since we want to consider the possibility of applying different tax rates to different uses of assimilative services, we allow for splitting $\tau$ into a tax rate $\tau_y$ levied on the use of assimilative services by industry and a tax rate $\tau_q$ levied on the use of these services by the producer of environmental quality.

At equilibrium prices, maximum profit is zero in both sectors if the production functions $Y$ and $Q$ are linear homogeneous[9]. With this simplifying assumption the *consumer's budget constraint* is

$$(w-t)\ell + p_a \overline{a} + \sigma = p_y y + (p_q + \theta) q \cdot \tag{4}$$

In (4), $\sigma$ is a *lumpsum transfer* (or tax, if negative) from the government to the consumer which will be explicitly set zero when appropriate. Consequently, the *government budget constraint* is

$$\theta q + \tau_q a_q + \tau_y a_y + t\ell - \sigma = 0 . \tag{5}$$

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[6] The marketability of environmental quality is clearly questionable since it encounters all the well-known problems of establishing a market for non-excludable public goods. The principal reason why markets for assimilative services rarely emerge in practical pollution control seems to be the difficulty and/or political reluctance of delineating and enforcing appropriate private property rights.

[7] It would be possible (but is not pursued in the present paper) to distinguish between the assimilative capacity, $\overline{a}$, and an endowment $a_0 \le \overline{a}$ privately owned which the owner can sell to the producers $(a_y + a_q \le a_0)$. If $a_0 < \overline{a}$ then $Q(a_q = 0) = \widetilde{Q}(\overline{a} - a_0) > 0$ would be the lowest possible environmental quality. The amount $\overline{a} - a_0 > 0$ of assimilative services is then commonly owned by the pollutees.

[8] Unless it is particularly interesting to refer to $\theta < 0$ or $\tau < 0$ as rates of subsidy we usually call $\theta$ and $\tau$ tax rates whether they are positively or negatively valued.

[9] Strict concavity of $Q$ appears to be realistic in some empirical applications (Fiedler 1995). But here we stick to linear $Q$ for expository convenience.

Disregarding corner solutions, for given $\theta$, $\tau_q$, $\tau_y$ and $t$ the equilibrium allocation is given by the equations (1) - (5) combined with the following first-order conditions of profit and utility maximization, respectively:

$$p_y Y_\ell(\ell, a_y) = w \tag{6a}$$

$$p_y Y_a(\ell, a_y) = p_a + \tau_y \tag{6b}$$

$$p_q Q_a(a_q) = p_a + \tau_q \tag{6c}$$

$$p_y U_f(y, f, q) = (w - t) \cdot U_y(y, f, q) \tag{6d}$$

$$p_y U_q(y, f, q) = (p_q + \theta) \cdot U_y(y, f, q) \tag{6e}$$

Let us first recall the conditions under which a full market equilibrium is Pareto efficient:

**Proposition 1:** *(a) A general competitive equilibrium allocation is Pareto efficient, if and only if* $t = \theta = 0$ *and* $\tau_q = \tau_y \geq 0$.
*(b) A Pareto efficient competitive equilibrium exhibits* $p_a = p_q Q_a(a_q) > 0$ *if* $U_q > 0$, $U_y > 0$, $Q_a > 0$ *over the set of feasible allocations and if* $Y_a(\ell, c\ell) = 0$ *for all* $\ell \in [0, 1]$.

Excluding corner solutions, proposition 1a follows immediately from the Lagrangean

$$U(y, f, q) + \lambda_y [Y(\ell, a_y) - y] + \lambda_q [Q(a_q) - q] + \lambda_a (\bar{a} - a_y - a_q) + \lambda_\ell (1 - f - \ell) \tag{7}$$

by determining the first-order conditions of an interior solution and assigning $\lambda_\ell = w$, $\lambda_y = p_y$, $\lambda_q = p_q$ and $\lambda_a = p_a + \tau$. The resultant equations coincide with the equations (6a) - (6e), if and only if $t = \theta = 0$ and $\tau_q = \tau_y = \tau \geq 0$.

Proposition 1a states the obvious: In a world with a full set of competitive markets *the best tax-subsidy policy is no policy*. The government has no meaningful role to play. With all tax rates being zero the equations (6a) - (6e) readily imply the (Samuelson) condition of Pareto optimal public good provision[10]

$$\frac{U_q}{U_y} = \frac{Y_a}{Q_a}. \tag{8}$$

In (8), $U_q / U_y$ is the marginal willingness-to-pay for environmental quality of the representative consumer (marginal pollution damage), $Y_a / Q_a$ is the marginal production cost

[10] The property of the Samuelson condition of summing over the marginal willingness-to-pay of *all* individuals is missing here, because by assumption there is only a single (representative) consumer in the present model.

of environmental quality in terms of good $Q$ (marginal abatement cost), and $Y_a$ is the marginal abatement cost in terms of good $Y$.

Proposition 1b lists necessary conditions for environmental quality and assimilative services to be free goods $\left(p_a = 0,\ p_q = 0\right)$. Since Pareto efficient situations where $p_q = p_a = 0$ do not involve serious pollution problems, they will be ignored in what follows. It is worth emphasizing that the scarcity price of assimilative services $\left(p_a > 0\right)$ required to secure efficiency *is by no means a distortionary input tax*. On the contrary, environmental disruption rather occurs, if and only if government interferes with market prices through taxes or subsidies. The reason why uniform taxation of assimilative services does not cause allocative distortions is, of course, that the supply of assimilative services is completely inelastic.

Additional information on the allocative effects of differential taxation of assimilative services is obtained in

**Proposition 2:** *Except for corner solutions, the allocative impact of $\tau_q$ and $\tau_y$ exclusively depends on the difference $\tau_q - \tau_y$.*

To see this suppose that the quantity vector $h(\delta) := \left(a_q, a_y, \ell, q, y\right)$ and the price vector $p(\delta) := \left(p_a, p_q, p_y, w\right)$ constitute a competitive equilibrium for given tax rates $\delta := \left(\tau_q, \tau_y, \theta, t\right)$. Then it follows from the equations (1) - (6e) that for small $|\Delta\tau|$ there is

$$\delta' := \left(\tau_q' = \tau_q + \Delta\tau,\ \tau_y' = \tau_y + \Delta\tau,\ \theta' = \theta,\ t' = t\right) \quad \text{and}$$
$$p(\delta') := \left(p_a' = p_a - \Delta\tau,\ p_q' = p_q,\ p_y' = p_y,\ w' = w\right)$$

such that $p(\delta')$ and $h(\delta') = h(\delta)$ constitute an equilibrium for the tax rates $\delta'$. Note that $\Delta\tau$ used in defining $\delta'$ and $p(\delta')$ above may be positive or negative, but it must be sufficently small in absolute value to avoid corner solutions. Setting $\Delta\tau = -\tau_q$ demonstrates that it is no loss of generality when the analysis is restricted to taxing (or subsidizing) the industrial emission of pollutants only $\left(\tau_q = 0,\ \tau_y \neq 0\right)$.

**Proposition 3:** *In a general competitive equilibrium with $t \geq 0$ environmental quality is*

$$\left\{\begin{array}{l}\textit{underprovided}\\ \textit{efficiently provided}\\ \textit{overprovided}\end{array}\right\} \qquad \textit{if and only if} \qquad \theta\, Q_a + \tau_q - \tau_y \left\{\begin{array}{c}>\\=\\<\end{array}\right\} 0 .$$

Proposition 3 is straightforward from observing that (6b), (6c) and (6e) yield

$$\frac{U_q}{U_y} - \frac{Y_a}{Q_a} = \frac{\theta Q_a + \tau_q - \tau_y}{p_y Q_a} \tag{8'}$$

while (8) is required for Pareto efficiency. It is an interesting implication of proposition 3 that the 'internalization gap', represented by the term on the RHS of (8'), is uniquely determined by $\theta$, $\tau_q$ and $\tau_y$ and does not depend on $t \geq 0$. Note also that equal changes of $\tau_y$ and $\tau_q$ $\left(d\tau_q = d\tau_y\right)$ do not affect the allocation.

The welfare impact of small changes in tax rates is readily spelled out in

**Proposition 4**: *Suppose that any of the tax rates $\delta = \theta, \tau_y, \tau_q, t$ is marginally changed. The resultant change in utility is given by*

$$\frac{du}{\lambda\, d\delta} = t\frac{d\ell}{d\delta} + \tau_y \frac{da_y}{d\delta} + \tau_q \frac{da_q}{d\delta} + \theta \frac{dq}{d\delta} \tag{9}$$

*where $\lambda$ is the Lagrange multiplier (marginal utility of income) associated to the problem of maximizing (3) subject to (4).*

To derive (9), we first form the total differential of (3) and then substitute the first-order conditions $U_\ell = -\lambda(w-t)$, $U_y = \lambda p_y$, and $U_q = \lambda p_q + \lambda\theta$ which are implied by maximizing utility subject to (4). This yields

$$du = -\lambda(w-t)d\ell + \lambda p_y dy + \lambda p_q dq + \lambda \theta d\underline{q}.$$

This equation is turned into (9) by totally differentiating (1) and (2) and making use of (6a) - (6c) and $da_q = -da_y$.

Proposition 4 tells us that whenever one of the tax rates is positive in the initial situation, its increase $(d\delta > 0)$ exacerbates the tax distortion to the extend that it erodes the base of prevailing taxes. To obtain information on the sign of the terms $d\ell/d\delta$, $da_y/d\delta$ and $dq/d\delta$ in (9) it is necessary to carry out a full-scale comparative statics analysis which is beyond the scope of the present paper, however.

## 3. Tax implementations of environmental quality standards in an economy with a full set of competitive markets

The observation that $\theta$, $\tau_q$ and $\tau_y$ determine the internalization gap (proposition 3) motivates the idea to turn the argument around as follows: Suppose the government aims at securing a certain - somehow politically determined - level of environmental quality, called *environmental quality standard*, $q_s$, hereafter. Are there tax rates $\theta$, $\tau_q$ and $\tau_y$ to support any standard $q_s$ which the government may wishes to implement? The affirmative answer is formalized as follows:

**Proposition 5:** *Let $q_s \in [0, Q(\bar{a})]$ and let $\alpha(q_s) := (a_{qo}, a_{yo}, \ell_o, q_s, y_o)$ be the allocation that is Pareto efficient relative to $q_s$.*
*(a) $\alpha(q_s)$ is implemented by any tax policy $(\tau_q, \tau_y, \theta, t, \sigma)$ satisfying (5), $t = 0$ and $(\tau_q, \tau_y, \theta) \in M(q_s)$, where*

$$M(q_s) := \left\{ (\tau_q, \tau_y, \theta) \left| \frac{U_q(\ell_o, q_s, y_o)}{U_y(\ell_o, q_s, y_o)} = \frac{Y_a(a_{yo}, \ell_o)}{Q_a(a_{qo})} + \frac{\theta Q_a(a_{qo}) + \tau_q - \tau_y}{p_{yo} Q_a(a_{qo})} \right. \right\}$$

*(b) Consider the tax policies characterized by $t = 0$ and, respectively, $\tau_q = \tau_y = 0$, $\theta$ free* ***(policy A)*** *or $\tau_q = \theta = 0$, $\tau_y$ free* ***(policy B)****. Assume that $Q$ is a linear function*[11] *and suppose $q_s \in [0, Q(\bar{a})]$ is implemented by policy A with $(\theta_A, \sigma_A = \theta_A q_s)$. Then there is policy B with $(\theta_B = 0, \tau_{yB} = -\theta_A Q_{aA}, \sigma_B = -\tau_{yB} a_{yA})$ which is equivalent to policy A in the sense that it also implements $q_s$ and exhibits the same equilibrium allocation.*

To validate the efficiency claim of proposition 5a we add the terms "$+\lambda_{so}(q - q_s) + \lambda_{su}(q_s - q)$" to the Lagrangean (7) and then determine the first-order conditions of an interior solution. The assignment of terms

$$\lambda_\ell = w,\ \lambda_y = p_y,\ \lambda_q = p_q,\ \lambda_a = p_a \text{ and } \theta = \lambda_{su} - \lambda_{so}$$

(implying $\tau_q = \tau_y = t = 0$) secures an efficient implementation of the quality standard $q_s$. It is straightforward that any $(\tau_q, \tau_y, \theta) \in M(q_s)$, $(\tau_q, \tau_y, \theta) \neq (0, 0, \lambda_{su} - \lambda_{so})$ also implements $q_s$ efficiently.

To prove proposition 5b we recall that, by definition, policy A is characterized by $w_A = p_{yA} Y_{\ell A}$, $p_{aA} = p_{qA} Q_{aA}$, $p_{aA} = p_{yA} Y_{aA}$ and $p_{yA} U_{qA} = (p_{qA} + \theta_A) U_{yA}$. We now define $p_{qB} := p_{qA} + \theta_A$ so that $p_{aA} = p_{qA} Q_{aA}$ can be rewritten as

$$p_{aA} = (p_{qB} - \theta_A) Q_{aA} \text{ or } p_{aA} + \theta_A Q_{aA} = p_{qB} Q_{aA}.$$

Define also $p_{aB} := p_{aA} + \theta_A Q_{aA}$ and $\tau_{yB} := -\theta_A Q_{aA}$ to obtain $p_{aA} = p_{aB} + \tau_{yB}$. The claim is that with $w_A = w_B$, $p_{yB} = p_{yA}$ and $\theta_B = 0$ the equilibrium allocation under policy A is also supported by $w_B, p_{yB}, p_{aB}, p_{qB}$ when the producers' price of assimilative services is $p_{aB}$ in the production of environmental quality and $p_{aB} + \tau_{yB}$ in sector $Y$. All tax parameters with subscript B clearly constitute a policy B as defined above. The equilibrium quantities $a_{qA}, a_{yA}, \ell_A$ and $y_A$ are compatible with (6a) - (6e) if all prices and tax rates with subscript A

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[11] It would be possible to construct a scheme for subsidizing emissions that extends proposition 6 to cases where the function $Q$ is strictly concave.

are appropriately substituted by those with subscript B. It remains to be shown that the consumer's budget equation

$$w_A \ell_A + p_{aA}\bar{a} + \sigma_A = p_{yA} y_A + \left(p_{qA} + \theta_A\right) q_s$$

is also satisfied for $\ell_A$ and $y_A$ when $w_A, p_{aA}, p_{yA}, p_{qA}, \theta_A$ is replaced by $w_B, p_{aB} + \tau_y, p_{yB}, p_{qB} - \theta_A, \theta_B = 0$, respectively. This substitution turns the budget equation into

$$w_B \ell_A + \left(p_{aB} + \tau_y\right)\bar{a} + \theta_A q_s = p_{yB} y_A + p_{qB} q_s,$$

which coincides with the budget equation under policy B (with $q = Q_a a_q$), indeed, since

$$\tau_y \bar{a} + \theta_A q_s = \tau_y \bar{a} - \frac{\tau_y}{Q_a} q_s = \tau_y \left(\bar{a} - a_q\right) = \tau_y a_y = \sigma_B$$

Therefore, under policy B the consumer chooses $\ell_B = \ell_A$ and $y_B = y_A$. In an analogous and straightforward way one can show that an equilibrium allocation under policy B can be supported by policy A with appropriate changes in prices and tax rates.

The important message of proposition 5a is that if, for whatever reason, the provision of environmental quality is to deviate from its Pareto efficient level this can be accomplished in a cost minimizing way by choosing an appropriate tax mix $\left(\tau_q, \tau_y, \theta\right) \in M\left(q_s\right)$ - provided that the total tax revenue is transferred back to the consumer in a lumpsum way.[12]

In essence, proposition 5a is a general *equivalence result*. However, of particular interest for our purposes are the special cases, defined as policies A and B in proposition 5b, to which we will restrict our attention in the subsequent analysis. The special *equivalence result* of proposition 5b is striking: If a predetermined environmental quality falling short of its Pareto efficient level is to be implemented in a cost minimizing way, *one can either tax consumer demand for environmental quality* (policy A) or *subsidize (!) the emission of pollutants* (policy B). It is also interesting to observe that there is a special case of policy B, namely $\tau_y = -p_a$ or $p_a + \tau_y = 0$ which, in conventional perspective, characterizes the absense of any pollution control (laissez-faire) or a polluter's rights regime. The state of 'policy inactivity' emerges here as the result of a particular form of policy B which, by the way, implements the corresponding environmental quality efficiently!

Figure 1 provides a partial equilibrium illustration of implementing the standard $q_{so}$, alternatively, by policy A (as indicated by $q_{so}, a_{yo}, p_{ao}, p_{qo}/p_{qo} + \theta$) or policy B (as indicated by $q_{so}, \tilde{a}_y, \tilde{p}_a + \tau_y/\tilde{p}_a, \tilde{p}_q$ ). To be supported from the supply side, (lower parts of Figure 1) the

[12] Our conjecture is that if implemented by a tax mix $(0, 0, \theta)$, the standard $q_s$ varies inversely with $\theta$. To prove this conjecture one would have to carry out a full-scale comparative static analysis, however.

standard $q_{so}$ requires the demand $a_{yo} = \tilde{a}_y$ for assimilative services by industry $Y$ which is generated, in turn, when the price for assimilative services is $p_{ao} = \tilde{p}_a + \tau_y$. On the other hand, the demand-side price of the environmental quality standard $q_{so}$ is $\tilde{p}_q = p_{qo} + \theta$ (upper right part of Figure 1). Since profit maximizing production of environmental quality (with production function $q\, c_{aq} = a_q$) requires $p_q = p_a\, c_{aq}$, the tax rate $\theta$ drives a wedge between the consumer's price, $p_{qo} + \theta$, and the producer's price, $p_{qo}$, of environmental quality. Correspondingly, $\tau_y$ drives a wedge between the price for assimilative services faced by producers of good $Y$, $\tilde{p}_a + \tau_y$, and the price faced by the producer of environmental quality, $\tilde{p}_a$. Observe also that if in figure 1 $q_s^*$ happened to be the standard to be implemented, then one would have $\theta = 0$ in case of policy A and $\tau_y = 0$ in case of policy B implying that $q_s^*$ is Pareto efficient.

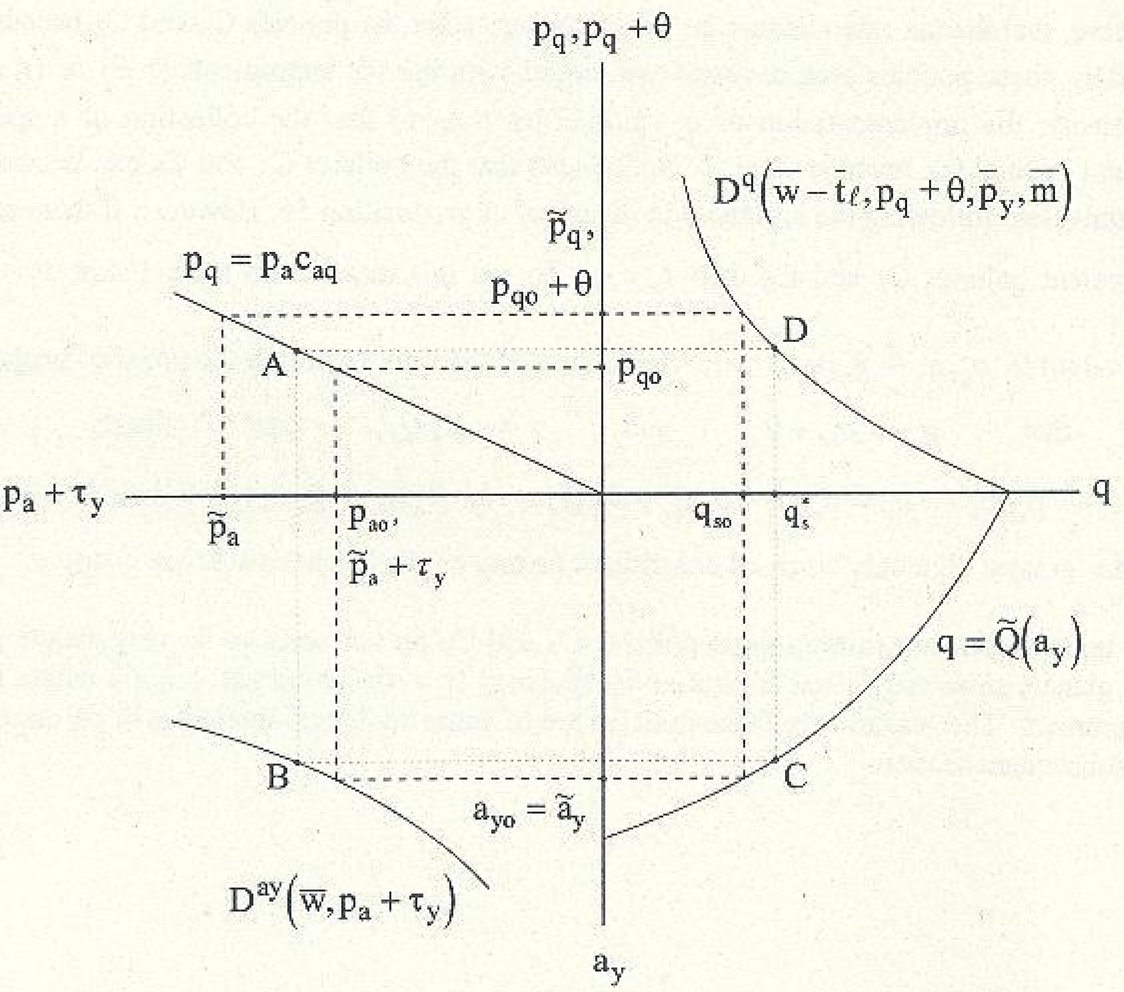


**Figure 1**: Equivalence of subsidizing emissions and taxing environmental quality

The policies A and B characterized above are chosen to form the basis of our further investigations of a gallery of tax policies designed to implement predetermined levels of environmental quality. Our aim is to proceed from the full-scale market model to the conventional price-and-standard approach in an effort to improve the understanding of the latter by studying the former. Table 1 provides an overview of all tax policies to be scrutinized. Since $\tau_q \equiv 0$ in the remainder of this paper we write $\tau_y = \tau$ in what follows for notational convenience. The policies $C_A$ and $C_B$ still presuppose the working of *all* competitive markets, as do the policies A and B, while the policies D to G have in common that the environmental quality is costlessly provided to the consumers. Another distinctive criterion is that policies A to D assume private ownership of assimilative services, while theses services are publicly owned in case of the policies E to G.

Before concluding subsection 3 with its scenario of a complete set of competitive markets we briefly consider the policies $C_A$ and $C_B$ in table 1 that are extended versions of the policies A and B, respectively, in that they include labor taxation and place, in addition, a constraint on total tax proceeds (to be retransferred to the consumer).

Observe, that the tax rate $t$ cannot be freely chosen under the policies $C_A$ and $C_B$ because, essentially, these policies seek to reach two targets with the tax instruments $(t, \theta)$ or $(t, \tau)$, respectively: the implementation of $q_s$ (guided by $\theta$ or $\tau$) *and* the collection of a specified amount of total tax revenue $p_q\, q_s$.[13] Notice also that the policies $C_A$ and $C_B$ can be shown to be equivalent following the argument in the proof of proposition 5b. However, if there are two equivalent policies $C_A$ and $C_B$ then $t_A < t_B$. To see this recall from table 1 that $t_A \gtreqless t_B$ is equivalent to $p_{qA}\, q_s \gtreqless p_{qB}\, q_s - \tau a_y$. Making use of the information in the proof of proposition 5b that $p_{qB} = p_{qA} + \theta_A$ and $\tau = -\theta_A Q_a$, one clearly obtains $p_{qA}\, q_s \gtreqless p_{qB}\, q_s - \tau a_y = p_{qA}\, q_s + \theta_A q_s + \theta_A Q_a a_y$ or $\theta_A \left(q_s + Q_a a_y\right) \lesseqgtr 0$ which is satisfied for the 'greater' sign only since all constituent factors on the left hand side are positive.

The taxing rules constituting these policies $C_A$ and $C_B$ do not seem to be very meaningful at first glance, since they cause allocative inefficiency $(t > 0)$ without assigning a useful role to government. The reason why these policies are of some analytical interest will be clarified in the subsequent section.

[13] Quite obviously, the policies $C_A$ and $C_B$ are difficult to handle for the regulator, because in order to collect the prescribed total tax revenue and to make the supply of environmental quality equal to $q_s$ she must engage in a trial and error process of adjusting, respectively, $(t, \theta)$ and $(t, \tau)$.

| type of policy*) | tax rates set zero | public transfer to consumers | government budget | implications |
|---|---|---|---|---|
| A | $t, \tau$ | $\theta q_s$ | $\sigma = \theta q_s$ | efficient implementation of $q_s$ |
| B | $t, \theta$ | $\tau a_y$ | $\sigma = \tau a_y$ | efficient implementation of $q_s$ |
| $C_A$ | $\tau$ | $\theta q_s + t\ell$ | $(p_q + \theta) q_s = \sigma =$ $= \theta q_s + t\ell$ | $p_q q_s = t\ell$ |
| $C_B$ | $\theta$ | $\tau a_y + t\ell$ | $p_q q_s = \sigma =$ $= \tau a_y + t\ell$ | $p_q q_s - \tau a_y = t\ell$ |
| $D_A$ | $\tau$ | 0 | $(\pi + \theta) q_s = \theta q_s + t\ell$ | $\pi q_s = t\ell$ |
| $D_B$ | $\theta$ | 0 | $\pi q_s = \tau a_y + t\ell$ | $\pi q_s - \tau a_y = t\ell$ |
| $E_A$ | $t, \tau$ | $p_a a_y$ | $(\pi + \theta) q_s + \sigma =$ $= \theta q_s + p_a \bar{a}$ | efficient implementation of $q_s$ |
| $E_B$ | $t, \theta$ | $(p_a + \tau) a_y$ | $\pi q_s + \sigma =$ $= \tau a_y + p_a \bar{a}$ | efficient implementation of $q_s$ |
| F | $t, \tau, \theta$ | $p_e a_y$ | $\sigma = p_e a_y$ | conventional efficient price-and-standard policy |
| $G_A$ | $\tau$ | 0 for $p_z z > p_a a_y$ | $(\pi + \theta) q_s + p_z z =$ $= \theta q_s + t\ell + p_a \bar{a}$ | $p_z z = t\ell + p_a a_y$ |
| $G_B$ | $\theta$ | 0 for $p_z z > (p_a + \tau) a_y$ | $\pi q_s + p_z z =$ $= \tau a_y + t\ell + p_a \bar{a}$ | $p_z z = t\ell + (p_a + \tau) a_y$ |

*) $\bar{a}$ is private property in policies A to D and public property in policies E to G

**Table 1**: A gallery of environmental tax policies

## 4. Costless provision of environmental quality

### 4.1 Private ownership of assimilative services

Suppose now that there is *no market for environmental quality* any more and the environmental quality is, instead, costlessly provided by the government at some level $q = q_s$. The consumer contends herself with the prevailing environmental quality at zero price. Since the producer of environmental quality cannot sell her output at positive prices she will be reluctant to demand positively priced assimilative services. In other words, the break-down of the market for environmental quality causes the market for assimilative services (as established in the previous model) to also collapse even though the assumption of private ownership of assimilative services is maintained. But rather than closing down both markets, we aim at designing an allocation procedure, as an intermediate step, that makes as much use as possible of allocative guidance by prices under the constraint, however, that environmental quality is provided to the consumer at no cost. Indeed, the breakdown of the market for assimilative services can be avoided (in an admittedly somewhat artificial way) by adopting an institutional arrangement which we refer to as policy D (table 1).

More specifically, an environmental quality standard, $q_s$, is said to be implemented by policy D[14], (i) if the regulator provides an estimate[15], $\pi$, of the consumer's marginal willingness-to-pay for $q_s$, (ii) if she offers the producer of environmental quality to pay $\pi q$ for the provision of any quantity $q$; and (iii) if she then chooses her tax instruments $\tau$ and $t$ so that

$$q = q_s, \quad \sigma = 0 \quad \text{and} \quad \tau a_y + t\ell = \pi q_s . \tag{10}$$

The common feature of the policies C and D is that both make use of $\tau \neq 0$ and $t \neq 0$. Profit maximizing behavior in both sectors is the same under these policies except that under policy D the output price for the producer of environmental quality is not the market price but rather the regulator's estimate. The principal difference between both policies is, however, that lumpsum taxation is denied in policy D but not in policy C. The model of policy D implies that the consumer chooses $\ell$ and $y$ as to maximize $U\left(1-\tilde{\ell},\, q_s,\, \tilde{y}\right)$ subject to

$$(w-t)\tilde{\ell} + p_a \bar{a} = p_y \tilde{y}\,, \tag{11}$$

whereas in the model of policy C the consumer chooses $\ell$, $y$ *and* $q$ to maximize $U\left(1-\tilde{\ell},\, \tilde{q},\, \tilde{y}\right)$ subject to

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[14] To promote our argument it suffices to restrict our attention to policy $D_B$. For notational simplicity we refer to the policies $C_B$ and $D_B$ as policies C and D, respectively, unless it is of interest to explicitly distinguish their types A and B.

[15] The concept of $\pi$ in the above description of policy D simply means that the regulator is asked to estimate the fictitious market price $p_q$. If we denote by $D^q\left(w-t,\, p_q,\, p_y,\, m\right)$ the consumer's demand for environmental quality in the full-fledged market model (with m for non-labor income and transfers), then the regulator's task is to elicit $\pi$ as implicitly determined by the equation $q_s = D^q\left(w-t,\, \pi,\, p_y,\, m\right)$. The informational requirement of obtaining a good estimate $\pi$ is very demanding, thus rendering this kind of pollution control fairly stylized. But on the other hand, if available valuation techniques should ever be applied systematically, $\pi$ is the kind of information one would like to obtain and use.

$$(w-t)\,\widetilde{\ell}+p_a\,\overline{a}+\sigma=p_y\,\widetilde{y}+p_q\,\widetilde{q} \qquad \text{with } \sigma=p_q q_s. \tag{11'}$$

Irrespective of these important differences, closer inspection of policies C and D reveals their *equivalence*:

**Proposition 6**: *The policies C and D are equivalent in the sense that the quantities and prices of the pertaining general competitive equilibria are the same, if the same environmental quality standard is implemented.*

To put proposition 6 into more formal terms, suppose that the environmental quality standard $q_s$ is implemented, alternatively, by policy C *or* policy D and characterize the respective results by the vector $h^*:=\left(p_a^*,\ p_q^*,\ p_y^*,\ w^*;\ \tau^*,\ t^*;\ a_q^*,\ a_y^*,\ \ell^*,\ y^*\right)$ for policy C and by the vector $h^\circ:=\left(p_a^\circ,\ \pi^\circ,\ p_y^\circ,\ w^\circ;\ \tau^\circ,\ t^\circ;\ a_q^\circ,\ a_y^\circ,\ \ell^\circ,\ y^\circ\right)$ for policy D. Then the claim of proposition 6 is that $h^*=h^\circ$. To prove this, consider first the case that $q_s$ is implemented by policy C so that $h^*$ prevails and one has $\sigma^*=p_q^* q_s=\tau^\circ a_y^*+t^\circ \ell^*$, in addition. We want to show that policy D implements $q_s$ at prices $\left(p_a^*,\ \pi^\circ=p_q^*,\ p_y^*,\ w^*\right)$ and tax rates $\left(\tau^*,\ t^*,\ \sigma^\circ=0\right)$. The pertaining profit maximizing productions are obviously $a_q^*$ and $\left(\ell^*,\ a_y^*\right)$, respectively. Under policy C the budget constraint satisfies

$$\left(w^*-t^*\right)\ell^*+p_a^*\,\overline{a}+\sigma^*=p_y^*\,y^*+p_q^*\,q_s \tag{12}$$

with $\sigma^*=p_q^* q_s=\tau^* a_y^*+t^* \ell^*$. Let $\left(\widetilde{\ell},\ \widetilde{y}\right)$ maximize $U\left(1-\ell,\ q_s,\ y\right)$ subject to (11) for $\left(p_a^*,\ \pi^\circ,\ p_y^*,\ w^*,\ t^*\right)$. Then $\left(\widetilde{\ell},\ \widetilde{y}\right)$ clearly satisfies

$$\left(w^*-t^*\right)\widetilde{\ell}+p_a^*\,\overline{a}=p_y^*\,\widetilde{y}. \tag{13}$$

If we add the term $'+\pi^\circ q_s'$ to both sides of (13), this modified equation coincides with equation (12). Hence $\left(\widetilde{\ell},\ \widetilde{y}\right)=\left(\ell^*,\ y^*\right)$ for $\pi^\circ=p_q^*$. The second part of the proof starts from $h^\circ$ (policy D) to demonstrate that $h^\circ$ with $\sigma=\pi^\circ q_s$ is also an implementation of $q_s$ by policy C. This can be shown along similar lines as above and is therefore omitted here.

The important message of proposition 6 is that *implementations of quality standards by policy D can be looked at as if these standards were implemented by policy C*. The analytical advantage being that all relevant scarcity indicating prices are available (to the analyst) and the allocative displacement effects originating either from the environmental externality or from distortionary labor taxes *are still uniformly treated as tax-induced distortions*.

The fact that the policy C as well as policy D employs two different taxes provides the regulator with the opportunity of *changing the tax mix* subject to the respective budget and transfer constraints. More specifically, suppose, an inefficiently low environmental quality standard $q_s$ is implemented by policy $C_B$ and assume the regulator aims at improving environmental quality. To this end she may want to consider $\tau$ as a discretionary policy instrument and raise the rate $\tau$ by $d\tau > 0$ leaving the change of environmental quality to the market forces which are supported by appropriate adjustments of $t$ for the purpose of keeping the government budget balanced. If $\tau < 0$ in the initial situation, the conjecture of 'normal reaction' is that the autonomous change $d\tau > 0$ (reduction of the emission subsidy) leads to a new equilibrium differing from the initial one by $dq > 0$ and $dt \neq 0$. Similarly, if an environmental quality standard $q_s$ had been implemented by policy $C_A$, the corresponding revenue neutral tax policy would be to set $d\theta < 0$ with the expectation that $dq > 0$.

These tax policies bear some similarity to *ecological tax reforms* as discussed in the literature because both approaches deal with tax induced pollution control when non-distortionary taxes are not available. But the differences are significant, since in the present approach assimilative services are privately owned and the tax rates $\tau$ and $\theta$, respectively, are policy instruments.

Moreover the tax policies described above are no tax reforms in the narrow sense because they violate revenue neutrality, in general. It is clearly viable, to carry out an exogeneous tax shift ($d\tau > 0$ or $d\theta < 0$) obeying the *government balanced-budget constraint* $\frac{d(\pi q)}{d\theta} = \frac{d(t\ell)}{d\theta}$ in case of policy $D_A$ or $\frac{d(\pi q)}{d\tau} = \frac{d(\tau a_y)}{d\tau} + \frac{d(t\ell)}{d\tau}$ in case of policy $D_B$. But *revenue neutrality* (being a constitutive property of a conventional tax reform) would require, in addition, $d\sigma = 0$ implying $\frac{d[(\pi_A + \theta)q]}{d\theta} = \frac{d(\pi_B q)}{d\tau} = 0$. Clearly, it is not feasible, in general, to simultaneously satisfy both the balanced government budget and revenue neutrality.

To gain additional insights into the nature of ecological tax reform we now investigate the impact of the above policies without the revenue neutrality contraint but with the requirement of balancing the government budget. In addition, motivated by the observation that the target of public policy is not a particular level of the subsidy rate $\tau$ or tax rate $\theta$ but rather the level of environmental quality provided, we now consider an initial quality standard $q_s$ implemented by policy $D_A$ or $D_B$ and use this policy again for implementing the new standard $q_s + dq > q_s$. More specifically, if $q$ is increased by $dq > 0$ the respective adjustments of the public budgets are, in view of table 1,

$$\frac{d\alpha}{dq} = \frac{d(t\ell)}{dq}, \qquad (14)$$

where $\alpha = \pi q_s$ in case of policy $D_A$ and $\alpha = \pi q_s - \tau a_y$ in case of policy $D_B$. Observe that moving from $q_s$ to $q_s + dq$ induces endogenous changes $d\tau$ and $d\theta$, respectively, as well as $dt$.[16] In view of (9) the welfare implications of such a policy are

[16] Such a policy of standard tightening by applying either policy $D_A$ or $D_B$ has a very broad interpretation beyond environmental policy: Essentially, we investigate the impact of a public policy of increasing the public (and costless) provision of *any* public good when the public good has to be paid for by the revenue from distortionary taxes.

$$\frac{du}{\lambda\, dq} = \theta + \tau \frac{da_y}{dq} + t \frac{d\ell}{dq} \tag{15}$$

where either $t > 0$, $\theta \neq 0$ and $\tau = 0$ (policy $D_A$) or $t > 0$, $\tau \neq 0$ and $\theta = 0$ (policy $D_B$). To fix our ideas we assume that in the initial situation an inefficiently low environmental quality standard $q_s$ is implemented. Then the *ecological dividend* of tightening the standard $(dq > 0)$ is $\theta > 0$ in case of policy $D_A$ and $\tau\left(da_y/dq\right) > 0$ in case of policy $D_B$. The decisive question is, however, which sign the term $t\left(d\ell/dq\right)$ has in (15). This partial welfare effect is clearly associated to the labor tax distortion (since it would vanish in case of lumpsum taxation $(t = 0)$) and is therefore interpreted as the tax efficiency impact of enhancing environmental quality. If $t\left(d\ell/dq\right) > 0$, then the policy of environmental quality improvement is said to exhibit a *double dividend*: the *ecological dividend* (which is realized by definition of the policy performed) and the *labor tax efficiency dividend*.

It is worth mentioning that the concept of dividends specified here differs from that introduced in Bovenberg and de Mooij (1994a). To see this observe that in case of policy $D_A$ (8') and (15) yield the welfare change

$$\frac{du}{\lambda\, dq} = \underset{(a)}{\underline{\theta}} + \underset{(b)}{\underbrace{t\frac{d\ell}{dq}}} = \underset{(c)}{\underbrace{\frac{p_y U_q}{U_y}}} + \underset{(d)}{\underbrace{\left[t\frac{d\ell}{dq} - \frac{t_e}{Q_a}\right]}}, \tag{15'}$$

where $t_e := p_y Y_a$ denotes the 'emission tax rate' in the conventional perspective (see also proposition 9 below) which is set equal to the marginal abatement cost by profit maximizing firms. Bovenberg and de Mooij (1994a) look at the tax rates $(t, t_e)$ as representing the tax system. Consequently they consider (d) in (15') as the efficiency-of-taxation dividend whereas (c) is the ecological dividend. In contrast, our market perspective suggests to look at the tax system as consisting of tax rates $(\theta, t)$ so that (a) *and* (b) in (15') gives us the overall efficiency-of-taxation effect with respect to $(\theta, t)$. Note that $\theta$ is clearly the ecological dividend which would still exist if the labor tax would be substituted by lumpsum taxation. Correspondingly, the term (b) in (15') is the change in efficiency of the labor tax, the labor tax efficiency dividend, for short. Observe finally, that while $\theta$ becomes negative in case of 'overinternalization', the ecological dividend (c) is always positive.

As a next step of the analysis it would be natural to provide the information about the sign of $d\ell/dq$ from a full-scale comparative statics analysis. However, a reasonably general comparative static analysis which avoids the preoccupation with special cases with its unknown potential for generalization tends to be inconclusive and intractable (see also footnote 2, above). We therefore contend ourselves with offering a classification of feasible results. Table 2 shows that there are four different constellations in which a double dividend or no double dividend occurs. Presumably each of these (eight) constellations can be generated in a sufficiently rich model. However, our "partial equilibrium intuition" suggests the following hypotheses to be plausible

(H1) If the rate $\delta$ of a tax with base $b$ is increased then its base erodes: $db/d\delta < 0$.

(H2) The revenue $\delta b$ of a tax with rate $\delta$ expands when the tax rate is increased: $d(\delta\, b)/d\delta > 0$ (i.e. the 'Laffer curve' is positively sloped in the relevant domain).

(H3) Providing a greater amount of environmental quality requires a (significant) increase in the expenditure for that good: $d\alpha/dq > 0$ with $\alpha = \pi q_s$ in case of policy $D_A$ and $\alpha = \pi q_s - \tau a_y$ in case of policy $D_B$.

In our view the hypotheses H3 is not artificial since even if general equilibrium effects are accounted for, common sense tells us that buying more of a good usually requires spending more money. To see that spending more is likely to be a necessary condition for H3 to hold in case of policy $D_B$ suppose environmental quality is underprovided in the initial situation ($\tau < 0$). Then

$$\frac{d(\tau a_y)}{dq} = \frac{d(\tau a_y)}{d\tau} \cdot \frac{d\tau}{dq} > 0$$

if H2 holds (implying $d(\tau a_y)/d\tau > 0$) and if firms are induced to pollute less by reducing the rate of emission subsidy in absolute terms ($d\tau/dq > 0$).

| policy: $dq > 0$ | | $\frac{d\alpha}{dq} > 0$ | | $\frac{d\alpha}{dq} < 0$ | |
|---|---|---|---|---|---|
| | | $\frac{d\ell}{dt} < 0$ | $\frac{d\ell}{dt} > 0$ | $\frac{d\ell}{dt} < 0$ | $\frac{d\ell}{dt} > 0$ |
| $\frac{d(t\,\ell)}{dt} > 0$ | $\frac{dt}{dq} > 0$ | 1 no DD*) | 2 DD | 3 infeasible | |
| | $\frac{dt}{dq} < 0$ | 4 infeasible | | 5 DD | 6 no DD |
| $\frac{d(t\,\ell)}{dt} < 0$ | $\frac{dt}{dq} > 0$ | 7 infeasible | | 8 no DD | 9 DD |
| | $\frac{dt}{dq} < 0$ | 10 DD | 11 no DD | 12 infeasible | |

*) DD = double dividend

**Table 2:** Impact of improving environmental quality (policy $D_A$)

shifted completely from the consumer to the government. In this institutional setting of policy E (table 1) the regulator chooses her tax instruments so that

$$p_a \bar{a} + \tau a_y + t\ell = \pi q_s + \sigma \quad \text{with} \quad \sigma = min\left[0,(p_a + \tau)a_y\right]. \tag{10''}$$

The consumer's budget constraint (11") is modified to read

$$\sigma + (w - t)\ell = p_y y. \tag{11'''}$$

Observe that policy E allows for positive transfers to the consumer (in contrast to policy D) for the purpose of avoiding the fancy implication of negative tax rates on labor income. The allocative consequences of this policy are straightforward:

**Proposition 8:** *If the environmental quality standard $q_s$ is implemented by policy $E_B$ and $p_a + \tau \geq 0$, then $t = 0$ and the resultant allocation is efficient (as under policy B).*

To see this, notice that the government budget constraint (10") can be rewritten as $\sigma = (p_a + \tau)a_y + t\ell$. The inequality $p_a + \tau \geq 0$ implies $t = 0$ and this policy implements $q_s$ in an efficient way. The condition $p_a + \tau \geq 0$ in proposition 8 is by no means restrictive, because $p_a + \tau = 0$ is the no-policy or laissez-faire state (see above). Clearly, $\sigma = (p_a + \tau)a_y \geq 0^-$ is the *government's residual resource income after paying for the standard $q_s$ and the emission subsidy.*

Recall that in all policies A to E discussed above we used the concept of politically determined and 'price implemented' environmental quality standard which plays an important role in environmental economics since Kneese and Bower (1968), Baumol and Oates (1971) and Dales (1972). But in contrast to those contributions we introduced a fictitious market for assimilative services in which these services are also demanded for the protection of the environment. To see how the approach of the present paper relates to conventional price and standard approaches consider policy F (table 1) that envisages a regulator issuing the amount $a_{ys} = Q^{-1}(q_s)$ of tradeable emission permits, selling them to industry Y at the market clearing price, $p_e$, and setting $\sigma = p_e a_{ys}$. Assimilative services used for the generation of environmental quality are not marketed anymore.

Obviously, the pollution control policy F works through establishing a (competitive) *market for emission permits* as discussed in the literature since Dales (1972). Such a market is, in fact, a partial substitute for the market of assimilative services as employed above. The producer of environmental quality is indifferent between any positive or zero production because she has neither costs $(p_a = 0)$ nor positive revenue $(p_q = \pi = 0)$. An alternative institutional arrangement equivalent to policy F at the level of abstraction applied here is, of course, the *charge and standard scheme* as suggested by Baumol and Oates (1971). In this scheme the regulator does not issue permits but she levies, instead, a charge on each unit of pollutants emitted. In a trial and error procedure this charge has to be adjusted until the standard $q_s$ is met.

**Proposition 9**: *(a) The implementation of any environmental quality standard $q_s$ by policy F is efficient.*
*(b) Let the standard $q_s$ be efficiently implemented, alternatively, either by policy E or policy F and denote the associated prices by $(p_{aE}, \pi_E, p_{yE}, w_E, \tau_E)$ in case of policy E and by $(p_{aF}=0, \pi_F=0, p_{yF}, w_F, \tau_F=0, p_e)$ in case of policy F. Then the equilibrium allocations are identical with $(p_{yF}, w_F)=(p_{yE}, w_E)$ and $p_e = p_{aE}+\tau_E$.*

Proposition 9 is straightforward. It provides the last 'missing' link between conventional price and standard environmental policy schemes and the world of fictitious markets discussed in the previous sections of this paper. Observe that with policy F the environmental quality standard $q_s$ is not only provided to the consumer at no cost but is also (seemingly) costless for the government. However, policy E with the pertaining public budget (10") reveals the costs of providing environmental quality. Looking at policy F from the 'market perspective' of policy E makes also precise that in Pigouvian language $p_a+\tau$ is interpreted as an *'emission charge'* and $\sigma=(p_a+\tau)a_y$ as the *proceeds from this emission tax*. This terminology amounts to mistaking a factor price $p_a$ net of subsidy $\tau$ as a tax rate!

After having introduced public property of assimilative services, we saw that the public resource income could be used to completely substitute the proceeds from the distortionary labor tax to pay for the provision of environmental quality. As a consequence, the problem of inefficient taxation being at the heart of the debate on ecological tax reform simply disappeared. To reintroduce it while maintaining the (realistic) assumption of public ownership, *a second public good* must be considered in the model (in addition to environmental quality) that is also costlessly provided in fixed supply and whose cost exceeds the excess resource income. In table 1 we denoted by policy G the implementation of an environmental quality standard when the amount $z_s$ of an additional public good Z is publicly provided. If policy G applies and the standard is to be exogeneously changed then balancing the public budget requires to satisfy the equation (14) with $\alpha=\pi q_s+p_z z_s-p_a\bar{a}$ in case of policy $G_A$ and with $\alpha=\pi q_s-\tau a_y+p_z z_s-p_a\bar{a}$ in case of policy $G_B$. With these specifications of $\alpha$ in H3, equation (14') and table 2 can be immediately applied to show that proposition 7 carries over for the policies $G_A$ and $G_B$. Observe that the only difference is the contents of hypothesis H3 through the different specifications of $\alpha$. More specifically the difference between H3 under policies D and G is the term

$$\frac{d(p_z z_s - p_a\bar{a})}{dq} \tag{16}$$

Since $z_s$ and $\bar{a}$ are constant, (16) differs from zero only as a consequence of general equilibrium price effects $(dp_z\neq 0,\ dp_a\neq 0)$. In fact, if environmental quality is taken as numeraire $(\pi=1)$ and the technology of producing environmental quality is linear $(p_a=const.)$ then (16) reduces to the term $z_s\cdot dp_z/dq$. If $p_z$ remains unchanged (because good $z$ is the numéraire or is linked to the numéraire by a linear technology) the basic difference is the impact of changing resource price $p_a$. A plausible sign of (16) is difficult to establish. In other words, except for some ambiguous general equilibrium price effects, the welfare impact of improving environmental quality in a model with two public goods and public ownership of assimilative services is very similar as in case of private ownership of assimilative services and environmental quality as the only public good (section 4.1).

***Proposition 10**: Suppose, the public goods Z and Q are publicly provided in fixed supply via policy $G_A$ or $G_B$ and the level of environmental quality is exogenously raised $(dq > 0)$*

*(a) Propositions 7a and 7b hold (with an appropriate modification of $\alpha$ in H3).*

*(b) Necessary conditions for a double dividend are*

*- the existence of private goods in addition to good Y if all production processes are linear*

*- or the existence of waste abatement technologies.*

Proposition 10a summarizes the arguments given above. To prove proposition 10b consider an economy producing environmental quality $Q$, the public good $Z$, the private good $Y$ and additional private goods $X_1 \cdots X_n$ $(n \geq 0)$. Denote by $c_{vw}$ the input of factor $V$ per unit of good $W$ produced. Then we have $c_{ay}\, da_y = da_y$, $c_{aq}\, dq = da_q$, $c_{\ell z}\, dz = d\ell_z$, $c_{\ell y}\, dy = d\ell_y$ and $c_{\ell xi}\, dx_i = d\ell_{xi}$ for $i = 1, \ldots, n$. Observe that $da_y = -da_q$ and $d\ell = d\ell_y + \sum_i d\ell_{xi}$ (owing to $dz = d\ell_z = 0$). This yields

$$\frac{d\ell}{dq} - \sum_i \frac{d\ell_{xi}}{dq} = c_{\ell y}\frac{dy}{dq} = -\frac{c_{\ell y}\, c_{aq}}{c_{aq}} < 0$$

implying $d\ell / dq < 0$ for $\sum_i (d\ell_{xi} / dq) \leq 0$. Hence in this model the policy of improving environmental quality does not yield a double dividend if $\sum_{i=1}^{n} \frac{d\ell_{xi}}{dq} \leq 0$. The least inequality trivially holds if there are no goods $X_1, \ldots, X_n$ $(n = 0)$ which proves the first part of proposition 10b. If $n > 0$, however, a double dividend $(d\ell / dq > 0)$ may emerge if the production of some of the goods $X_1$ to $X_n$ expands significantly which is conceivable in case of special relationships of substitutability or complementary between the goods $Q$, $Y$ and $X_1, \ldots, X_n$ (see e. g. Parry 1995). If $n = 0$, another possibility of obtaining $d\ell / dq > 0$ as a result of strengthening the environmental quality standard is to assume substitutional technology for good $Y$ as allowed for in the general formulation of the production function (1) implying intra-industrial waste abatement. If substitution between labor input and the use of assimilative services is feasible, industrial emissions $a_y$ are likely to be reduced with less than proportional reductions in output $y$ and labor input $\ell_y$. Using labor for waste abatement in addition to labor input in the production process proper may even increase total labor demand in industry $Y$ though its output shrinks owing to an increase in its relative price.

In concluding our tour d'horizon we return to the conventional analysis of ecological tax reform by demonstrating that the public goods perspective adopted here fits well into and smoothly extends the view of the prevailing literature:

***Proposition 11**: Suppose the technology of producing environmental quality is linear $(Q_{aa} = 0)$ and the expenditure for the public good is constant $[d(p_z z_s)/dq = 0]$. Under the regime of policy $G_B$ (where $\alpha = \pi q_s + p_z z_s - \tau a_y + p_a \bar{a}$) a policy change $dq > 0$ implies that* *the change in labor tax revenue is equal to but opposite in sign to the change in 'emission tax revenue', conventionally defined. In formal terms:*

$$\frac{d\alpha}{dq} = -\frac{d\left[(p_a+\tau)a_y\right]}{dq} = \frac{d(t\,\ell)}{dq}. \tag{14"}$$

This result is straightforward from observing that the government budget equation $p_z z_s + \pi q_s = \tau a_y + p_a \bar{a} + t\,\ell$ is equal to

$$p_z z_s = (p_a+\tau)a_y + t\,\ell \tag{17}$$

under the assumption that the technology of producing environmental quality is linear. When combined with the assumption $d(p_z z_s)/dq = 0$ this observation yields (14"). Interpreting $p_a+\tau$ as an 'emission tax rate' and $(p_a+\tau)a_y$ as the associated emission tax revenue, equation (17) shows, indeed, that *the problem of increasing the supply of one out of two public goods paid (good Q) for by public resource income and labor tax revenue has been transformed into the problem of costlessly supplying a fixed amount of a single public good (good Z) which is financed by two 'taxes': an 'emission tax' with rate $p_a+\tau$ and a labor tax.*

Equation (14") reflects, indeed, the conventional revenue-neutral ecological tax reform as investigated, e. g., by Bovenberg and de Mooij (1994a). Their calculations yield $dt < 0$, $d\ell < 0$ as well as $d\left[(p_a+\tau)a_y\right] > 0$ and $d(t\,\ell) < 0$. Observe that these results contradict both H1 and H3 while H2 is satisfied. For $\alpha = p_z z_s - (p_a+\tau)a_y$ (and $d(p_z z_s)/dq = 0$) the conclusions of Bovenberg and de Mooij correspond to the box 6 in table 2.

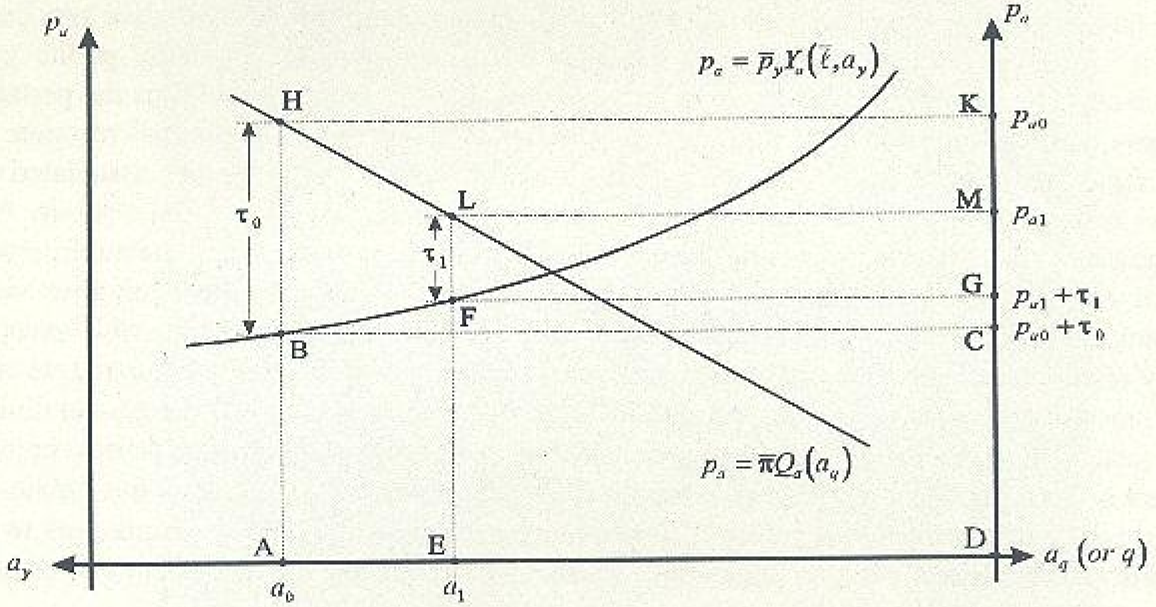


**Figure 2**: The market for assimilative services (policy $G_B$, partial equilibrium analyses)

According to the conventional view $d\left[(p_a+\tau)a_y\right]/dq>0$ (or $d\alpha<0$) means that the 'emission tax revenue' increases with $dq>0$. Figure 2 presents a partial equilibrium example for $d\left[(p_a+\tau)a_y\right]/dq<0$ presupposing the possibility of waste abatement in the course of producing the good $Y$. More specifically, suppose $q_0=\widetilde{Q}(a_0)$ is changed to $q_1=\widetilde{Q}(a_1)>q_0$. Then the 'emission tax revenue' decreases from $(p_{a0}+\tau_0)a_0$ (or (ABCD) to $(p_{a1}+\tau_1)a_1$ (or EFGD). At the same time the amount of the emission subsidy is reduced from $|\tau_0 a_0|$ (or BHKC) to $|\tau_1 a_1|$ (or FLMG). This result requires low abatement costs or a highly elastic demand of industry Y for assimilative services. It cannot be excluded, of course, that general equilibrium repercussions in $p_y$, $\pi$ and $\ell$ override this partial equilibrium effect.

## 5. Concluding remarks

This paper focused on the public provision of the public good 'environmental quality' using a benchmark model with a complete set of competitive markets and investigated various ways to finance that public good including subsidies, (distortionary) taxes and resource income from selling assimilative services. Raising the level of environmental quality in a full-scale market economy was related to the concept of ecological tax reform as discussed in the literature. In the first part of the paper, assimilative services had been assumed to be privately owned, but since public ownership is the empirically relevant case, a *second public good* (in addition to environmental quality) has finally been introduced that is also costlessly provided and whose cost exceed the excess resource income - following the theoretical literature on ecological tax reform.

In this scenario, government essentially provides fixed amounts of two different public goods and has two different sources to pay for them: resource income from assimilative services (in fixed supply) and labor tax revenue. To increase the supply of one of the public goods requires, under plausible conditions, to increase the labor tax proceeds and thus the pertaining excess burden, unless general equilibrium price effects override this 'normal' reaction. The principal analytical difficulty is that one deals with multiple inefficiencies associated with labor taxation and with the non-optimal predetermined quantities of two public goods. A full characterization of conditions under which labor supply will increase when the environmental quality standard is strengthened - which is the necessary and sufficient condition for an ecological tax reform to yield a second (positive) dividend - will hardly be possible except for very restrictive assumptions on preferences and technologies because the comparative statics become very messy even in simple models. But our analysis suggests that the double dividend conjecture (Pearce 1991) which can be considered as an 'informed common sense' conjecture is not necessarily sound on the basis of plausibility arguments emerging from our public good perspective of ecological tax reform: Buying more environmental quality may require to raise additional distortionary tax revenue with a tendency of increasing the inefficiency of taxation.

It should be emphasized that the analysis of the present paper does not challenge the validity of the results obtained in the conventional ecological tax reform studies. But it strongly suggests that applying the concept of tax reform from public finance to include 'Pigouvian taxes' on environmental externalities does not seem to handle the issue in a completely satisfactory way. We demonstrated that important insights into ecological tax reform are gained if it is studied in models that allow for more specific structure with regard to assimilative services as productive factors along with labor or other 'conventional' inputs and intra-industrial waste abatement. The concept of tax representation of public goods that are publicly and costlessly provided (at inefficient levels) turns out to be useful in looking at allocative distortions from externalities or public goods as being tax induced distortions and thus offers a uniform approach to tax reforms in third best worlds.

A final message of this paper is that our market approach to ecological tax reform yielded new insights about scarcity prices, tax rates and distortionary tax wedges. In our view the previous discussion on ecological tax reform suffered from mixing up resource prices, tax revenues, resource incomes and even emission subsidies and emission taxes. One may continue to use conventional notation, but it should be acknowledged that tax reforms in a world with environmental externalities have special features as compared to tax reforms in a world where zero taxation is Pareto efficient.

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