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MARGINAL TAX REFORM, EXTERNALITIES AND INCOME DISTRIBUTION
(Revised version)

by

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Abstract

The paper examines welfare improving and revenue neutral directions marginal policy reforms for an economy with nonidentical individuals and an externality that has a feedback effect on the consumption of taxed goods. It considers three types of policy instruments: the indirect taxes, the uniform poll transfer and public abatement. This extends the framework set up by Ahmad and Stern (1984), Bovenberg and de Mooij (1994) and Schöb (1996). The theoretical model is illustrated for a specific externality, namely congestion caused by peak car transport.

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1. Introduction

In recent years, it has been argued that a shift in taxes towards externalities and away from labour can be justified given the greening of preferences. Bovenberg and de Mooij (1994) and Bovenberg and van der Ploeg (1994) have studied analytically the effects of marginal shifts between labour taxes and externality taxes. These insights have been illustrated numerically using AGE-models by Bovenberg and Goulder (1996) and others. However, these contributions fail to include income distribution concerns in their models while this is an important element of the policy problem. First of all, new environmental taxes will be accepted more easily if they constitute an improvement for most agents. This will depend on their respective shares in the consumption of dirty goods, their share in the consumption of goods for which taxes are decreased and finally of their relative valuation of the improved environmental quality. Secondly, the income distribution dimension is at the heart of the existing distortionary tax structure. Indeed, in models with identical individuals the optimal tax structure consists of a head tax combined with a Pigouvian tax. Consequently, determining the direction of marginal tax reform becomes trivial.

This paper wants to bridge this gap and studies the marginal green tax reform question for an economy with nonidentical individuals. In addition, two other extensions are made. These consist of the introduction of externalities that are nonseparable from the consumption of private goods and of the introduction of a poll tax and public abatement as extra policy instruments. The model used is an extension of the Ahmad and Stern (1984) model, widely used for the study of the equity-efficiency trade-off in an economy without externalities. Schöb (1996) has extended this model to include environmental quality. He concentrates on the separable case and does not focus on income distribution issues.

The structure of the paper is as follows. Section 2 briefly presents the model. We assume throughout our analysis that the simplifying assumptions of the Ahmad and Stern framework (a Walrasian economy with fixed producer prices and fixed and untaxed factor incomes) continue to hold[1]. Section 3 discusses a methodology for evaluating revenue neutral marginal tax reforms. It is shown how the total welfare cost of a marginal tax change can be decomposed into a direct welfare cost and an externality impact and that distributional considerations play an important role in both components. Next, we make the link with the double dividend literature and extend the analysis to policy reforms involving a change in public abatement investments. The paper ends with a numerical illustration of the theory to the congestion externality caused by road passenger transport (section 4). Section 5 presents the conclusions.

2. The Model

We consider a single period model for a closed economy. There are I nonidentical *consumers* (indexed i=1, . . . ,I) who differ in their preferences and their earning capacity e^i. There are M goods (indexed m=1, . . . ,M). Goods 1 to K are normal consumption goods. Goods K+1 to M are goods whose consumption leads to the externality Z. The consumption vector of consumer i is $x_H^i=(x_{H1}^i, \ldots, x_{HM}^i)$, where x_{Hm}^i denotes his consumption of good m ($x_{Hm}^i > 0$). Leisure (l_H^i) is the numeraire good and is taken to be untaxed. With T denoting total time available and P the uniform poll transfer, each consumer faces the following budget constraint:

$$\sum_{m=1}^{M} q_{Hm}\, x_{Hm}^{i} \leq e^{i}\,(T - l_H^{i}) + P \qquad \forall i \tag{1}$$

In this expression q_{Hm} represents the consumer price of good m. It is the sum of the producer price p_m and the indirect tax t_{Hm}. The direct utility function of consumer i is given by:

$$U^{i} = U^{i}\,(x_{H1}^{i}, \ldots, x_{HM}^{i}, l_H^{i}, Z) \tag{2}$$

[1] Drèze (1985), Wibaut (1989), Marchand et al. (1989) and Van de gaer et al. (1992) applied the approach in a non-Walrasian setting,

The utility function U^i is strictly quasi-concave in x_{Hm}^i and twice continuously differentiable. The externality Z is an external diseconomy ($\partial U^i/\partial Z < 0$). It is assumed that Z enters preferences in a non-separable way. The individual consumer chooses his consumption bundle x_H^i and his consumption of leisure l_H^i such that his utility is maximized subject to his budget constraint. We assume that when doing this he ignores his own impact on the externality: he considers himself to be small compared to the economy. We assume that differentiable demand functions exist and that they are of the form:

$$l_H^i = l_H^i (q_H , P , Z) \qquad \forall i \tag{3}$$

$$x_{Hm}^i = x_{Hm}^i (q_H , P , Z) \qquad \forall m,i \tag{4}$$

Demand is a function of the consumer prices, the poll transfer and the level of the externality. The externality is thus characterized by a feedback effect: its level affects the demand for the different commodities and for leisure. A typical example is road congestion: an increase in congestion can induce a substitution to public transport. Other examples are noise and drinking water quality where the consumers may engage in defensive expenditures to lower the negative effects of the externality. Aggregate consumption of good m is denoted by X_{Hm}. The maximum utility individual i can achieve when facing the price vector q_H, externality Z and the poll transfer P is given by the indirect utility function $V^i(q_H,P,Z)$.

The level of the *externality* is determined by the total use of the externality-generating goods K+1 to M. Each externality-generating good m may have a different contribution to Z. The government can reduce the level of the externality by undertaking investments in public abatement (R). The externality is thus given by:

$$Z = Z \left(X_{H(K+1)} , \, . \, . \, . \, . \, , X_{HM} , R \right)$$
$$\frac{\partial Z}{\partial X_{Hm}} > 0 \quad \text{for } m=K+1,...,M; \qquad \left.\frac{\partial Z}{\partial R}\right|_{X_H} < 0 \tag{5}$$

The *production side* of the economy is modeled in a simple way. We suppose that the externality has no impact on production. Nor does the production sector contribute to the externality. We assume that producer prices are fixed and that there are constant returns to scale so that increases in taxes are reflected as consumer price increases and that there are no pure profits.

The *government* provides a level of public abatement (*R*) at a unit cost of p_R. It collects taxes from the individuals and distributes uniform poll transfers. The government requires resources (*B*) and thus public revenue for a number of exogenous activities which are kept constant throughout the analysis. It faces the following budget constraint:

$$\sum_{m=1}^{M} t_{Hm} X_{Hm} - p_R R - I P \geq B \tag{6}$$

It can be shown that all allocations that are derived from indirect utility functions and that satisfy the government budget constraint (6), will satisfy the production possibilities constraints (Walras law combined with fixed producer prices).

The government maximizes social welfare *W* which is represented by a Bergson-Samuelson type of social welfare function.

$$W = W\left(V^1\left(q_H, P, Z\right), \ldots, V^I\left(q_H, P, Z\right)\right) \tag{7}$$

3. Evaluating a Tax Reform in the Presence of Externalities

The government can make use of three policy instruments: indirect taxes t_{Hm}, the poll transfer *P* and the level of public abatement *R*. Our aim is to offer a methodology for evaluating marginal policy reforms in the presence of externalities when distributional considerations are taken into account. We build upon the analysis of Guesnerie (1977), Ahmad and Stern (1984), Schöb (1996) and Mayeres and Proost (1997). We want to evaluate whether a revenue neutral marginal policy reform is welfare improving or not when starting from an arbitrary tax system and from an arbitrary level of public abatement. In a first instance the analysis concentrates on marginal reforms of the tax system. Later, we show how the methodology can be transposed to the evaluation of policy reforms involving investments in public abatement.

3.1. The Welfare Cost of a Marginal Tax Change

The question is: how does welfare change if we increase the tax on a good *m* by an amount sufficient to raise one unit of government revenue while at the same time we reduce the tax on another good *k* ($k \neq m$) by an amount sufficient to lose one unit of public revenue. The effect on welfare of such a tax change is given by:

$$dW = \frac{\partial W}{\partial t_{Hk}} dt_{Hk} + \frac{\partial W}{\partial t_{Hm}} dt_{Hm} \tag{8}$$

where

$$dB = 1 = \frac{\partial B}{\partial t_{Hm}} dt_{Hm} = - \frac{\partial B}{\partial t_{Hk}} dt_{Hk} \tag{9}$$

Defining the *marginal cost in terms of social welfare of raising one additional unit of government revenue via the tax on good m* as:

$$MCF_m = - \frac{\partial W / \partial t_{Hm}}{\partial B / \partial t_{Hm}} \tag{10}$$

we find

$$dW \gtreqless 0 \quad \Leftrightarrow \quad MCF_m \lesseqgtr MCF_k \tag{11}$$

So welfare is increased (reduced) when the tax with the highest marginal welfare cost per additional unit of government revenue is reduced (increased) and when simultaneously the tax with the lowest marginal welfare cost per additional unit of government revenue is raised (reduced).

A similar analysis can be applied to a marginal tax reform involving the poll transfer. In this case it can be shown that a revenue neutral marginal tax reform which consists of increasing the tax on good *m* and recycling the revenue through the poll transfer has a positive, neutral or negative impact on welfare if and only if

$$MCF_m \quad \begin{matrix} < \\ = \\ > \end{matrix} \quad MCF_P \tag{12}$$

with

$$MCF_P = - \frac{\partial W}{\partial P} \Big/ \frac{\partial B}{\partial P} \tag{13}$$

In (10) and (13) MCF_m and MCF_P are defined as a ratio of two components. In the case of MCF_m the numerator consists of the effect on social welfare of a marginal change in the tax on good *m* (m=1,...,M). Starting from (7) this is given by:

$$\frac{\partial W}{\partial t_{Hm}} = \sum_{i=1}^{I} \frac{\partial W}{\partial V^i} \frac{\partial V^i}{\partial t_{Hm}} + \sum_{i=1}^{I} \frac{\partial W}{\partial V^i} \frac{\partial V^i}{\partial Z} \frac{\partial Z}{\partial t_{Hm}} \tag{14}$$

Expression (14) can be transformed by using Roy's identity and defining the direct social marginal utility of income accruing to individual *i* as

$$\beta^i = \frac{\partial W}{\partial V^i} \lambda^i \qquad \forall i \tag{15}$$

where λ^i is the private marginal utility of income. Moreover, we define the individual marginal willingness to pay for a reduction in the externality ζ^i as

$$\zeta^i = - \frac{\partial V^i}{\partial Z} \Big/ \lambda^i \tag{16}$$

This allows us to rewrite the expression for $\partial W/\partial t_{Hm}$:

$$\frac{\partial W}{\partial t_{Hm}} = - \left[\sum_{i=1}^{I} \beta^i x_{Hm}^i + \sum_{i=1}^{I} \beta^i \zeta^i \frac{\partial Z}{\partial t_{Hm}} \right] \qquad m=1,\ldots,M \tag{17}$$

The first term corresponds to what is found in the literature on marginal tax reform in the absence of externalities. The second term gives the evaluation, in terms of social welfare, of the change in the externality brought about by the marginal tax change. It is important to see that this term should be taken into account not only when evaluating a change in an externality tax, but also when looking at changes in other taxes as long as those other taxes affect the demand for the externality generating goods. The term $\partial Z/\partial t_{Hm}$ stands for the full effect of a marginal tax change on the externality. It is obtained from (5) using demand functions (4):

$$\frac{\partial Z}{\partial t_{Hm}} = \xi \sum_{k=K+1}^{M} \frac{\partial Z}{\partial X_{Hk}} \left. \frac{\partial X_{Hk}}{\partial t_{Hm}} \right|_Z \qquad \forall m \tag{18}$$

In this expression ξ stands for the externality feedback parameter. It is defined as:

$$\xi = \frac{1}{1 - \sum_{k=K+1}^{M} \frac{\partial Z}{\partial X_{Hk}} \frac{\partial X_{Hk}}{\partial Z}} \qquad 0 \leq \xi \leq 1 \tag{19}$$

The full effect of a change in taxation on the externality level is thus obtained by multiplying the first round effect by the externality feedback parameter ξ. For externalities which enter preferences in a separable way, the externality feedback parameter reduces to unity.

The denominator of (10) equals the effect on government revenue of a marginal change in the tax on good *m*. It can be written as:

$$\frac{\partial B}{\partial t_{Hm}} = X_{Hm} + \sum_{k=1}^{M} t_{Hk} \left. \frac{\partial X_{Hk}}{\partial t_{Hm}} \right|_{Z} + \sum_{k=1}^{M} t_{Hk} \frac{\partial X_{Hk}}{\partial Z} \frac{\partial Z}{\partial t_{Hm}} \qquad \forall m \tag{20}$$

Here we take into account that a change in the level of the externality may have an impact on government revenue. This term is known as the "Pigou-effect" in the literature on the optimal provision of public goods [Atkinson and Stiglitz (1980)]. So if the tax change causes a change in the externality which leads to an increase in the consumption of taxed commodities, then expression (10) and (20) tell us that, ceteris paribus, the MCF_m will be lower and thus it is more attractive to increase the tax on good *m*.

Using equations (17) and (20) the marginal welfare cost of raising one additional unit of government revenue via the tax on good *m* can be written as:

$$MCF_m = \frac{\sum_{i=1}^{I} \beta^i x_{Hm}^i + \sum_{i=1}^{I} \beta^i \zeta^i \frac{\partial Z}{\partial t_{Hm}}}{X_{Hm} + \sum_{k=1}^{M} t_{Hk} \left. \frac{\partial X_{Hk}}{\partial t_{Hm}} \right|_{Z} + \sum_{k=1}^{M} t_{Hk} \frac{\partial X_{Hk}}{\partial Z} \frac{\partial Z}{\partial t_{Hm}}} \qquad \forall m \tag{21}$$

Expression (21) contains the results of Ahmad and Stern (1984) and Schöb (1996) as special cases. If there are no externalities, the last term of both the numerator and the denominator drops out and expression (21) reduces to the familiar expression of Ahmad and Stern (1984). If, on the contrary, there are externalities in the economy but they are not characterized by a feedback effect, the last term in the denominator drops out and the externality feedback parameter in the expression for $\partial Z/\partial t_{Hm}$ equals unity. In that case we get an expression similar to that of Schöb (1996). However, our analysis still differs from that of Schöb because we consider an economy with nonidentical individuals whereas he focuses mainly on identical individuals.

In an analogous way we find that the marginal welfare cost of raising one additional unit of government revenue by changing the uniform poll transfer, is given by:

$$MCF_P = \frac{-\sum_{i=1}^{I} \beta^i + \sum_{i=1}^{I} \beta^i \zeta^i \frac{\partial Z}{\partial P}}{-I + \sum_{m=1}^{M} t_{Hm} \frac{\partial X_{Hm}}{\partial P}\Big|_Z + \sum_{m=1}^{M} t_{Hm} \frac{\partial X_{Hm}}{\partial Z} \frac{\partial Z}{\partial P}} \qquad (22)$$

3.2. The Direct Welfare Cost and the Externality Impact of a Marginal Tax Change

As in Schöb (1996) the MCF_m and MCF_P can be split into two components. First, we consider the marginal welfare cost of a change in the indirect tax on good *m* (*m*=1, . . . ,*M*). The first component of the MCF_m is called the *direct welfare cost* of a marginal change in the tax on good *m* and is defined as:

$$MCF_m^d = \frac{\sum_{i=1}^{I} \beta^i x_{Hm}^i}{\partial B / \partial t_{Hm}} \qquad (23)$$

The second component of the MCF_m is the *marginal externality impact* of a change in t_{Hm} which is defined as

$$MEI_m = \frac{\sum_{i=1}^{I} \beta^i \zeta^i \frac{\partial Z}{\partial t_{Hm}}}{\partial B / \partial t_{Hm}} \qquad (24)$$

In contrast to Schöb (1996) both cost components contain income distribution weights and the feedback effect of the externality on the consumption of taxed goods.

The marginal cost in terms of social welfare of one additional unit of government revenue raised via the tax on good *m* can therefore be rewritten as:

$$MCF_m = MCF_m^d + MEI_m \qquad (25)$$

Based on (11) and using (25) we see that for an increase in the tax on good *m* accompanied by a decrease in the tax on good *k*

$$dW \gtreqless 0 \quad \Leftrightarrow \quad MCF_m^d - MCF_k^d \lesseqgtr MEI_k - MEI_m \tag{26}$$

The left hand side of the second expression presents the direct welfare cost of the revenue neutral tax reform. The right-hand side gives the externality cost of the tax reform[2]. It has a positive value if the tax reform causes a net reduction in the level of the externality. Suppose the increase in the tax on good *m* reduces the externality. Then from the definition of MEI_m and $\partial Z/\partial t_{Hm}$ we know that the overall effect on the externality of increasing t_{Hm} and decreasing t_{Hk} will certainly be negative (i.e. the externality is reduced) if all the externality generating goods are substitutes for or neutral with respect to good *k*. But if some of the externality generating goods are substitutes for good *k* while others are complements, the tax reform will only lead to a net reduction in the externality level if the following condition is satisfied:

$$\frac{\partial Z/\partial t_{Hk}}{\partial Z/\partial t_{Hm}} > \frac{\partial B/\partial t_{Hk}}{\partial B/\partial t_{Hm}} \qquad \forall k,\ m \qquad k \neq m \tag{27}$$

This condition is derived from the definition of the marginal externality impact of a tax change [equation (24)]. So, in this case, the marginal tax reform only results in a net reduction of the

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[2] In analogy with Schöb (1996) we can introduce the concept of the *critical value* of the marginal social willingness to pay for a reduction in *Z*. It shows the value that the social marginal willingness to pay for a lower Z should take before a policy becomes attractive. It may be a useful concept if the direct welfare effect and the externality impact of the marginal tax reform do not suggest the same direction of tax reform. For the particular tax reform we have considered here, it is defined as:

$$\left(\sum_{i=1}^{I} \beta^i \zeta^i \right)_{m,k}^{C} = \frac{MCF_m^d - MCF_k^d}{MZ_k - MZ_m}$$

In this expression MZ_m stands for the change in the externality brought about by increasing the tax on good *m* by an amount sufficient to raise one unit of government revenue.

$$MZ_m = \left(\partial Z \,/\, \partial t_{Hm} \right) / \left(\partial B \,/\, \partial t_{Hm} \right)$$

externality if the ratio of the full effect on *Z* of the marginal tax change for good *k* to that of the marginal tax change for good *m* is larger than the ratio of the associated marginal revenue changes.

Up to now we have only considered policy reforms involving indirect taxes. However, in an analogous way, we can define the the marginal direct welfare cost of a change in the uniform poll transfer *P* (MCF_P^d) and the marginal externality impact of a change in *P* (MEI_P) as follows:

$$MCF_P^d = - \frac{\sum_{i=1}^{I} \beta^i}{\partial B / \partial P} \tag{28}$$

$$MEI_P = \frac{\sum_{i=1}^{I} \beta^i \, \zeta^i \, \frac{\partial Z}{\partial P}}{\partial B / \partial P} \tag{29}$$

The sum of these two components equals the MCF_P.

$$MCF_P = MCF_P^d + MEI_P \tag{30}$$

Finally, from (12) we find

$$dW \gtreqless 0 \quad \Leftrightarrow \quad MCF_m^d - MCF_P^d \lesseqgtr MEI_P - MEI_m \tag{31}$$

3.3. The Importance of Distributional Considerations

An important dimension of our analysis is that we consider an economy with nonidentical individuals. Distributional considerations are present in both components of MCF_m and MCF_P. For MCF_m this can be made clear when we rewrite expressions (23) and (24). Following Ahmad and Stern (1984) the direct welfare cost of a marginal change in the tax on good *m* can be transformed into:

$$MCF_m^d = \frac{r_m \, \bar{\beta}}{el_{Bm}} \, \frac{X_{Hm} \, t_{Hm}}{B} \qquad \text{where} \quad \bar{\beta} = \sum_{i=1}^{I} \beta^i \Big/ I \tag{32}$$

where el_{Bm} denotes the elasticity of government revenue with respect to the tax on good m and r_m stands for the *distributional characteristic of good m*. It is defined as [Atkinson and Stiglitz (1980)].

$$r_m = \frac{\sum_{i=1}^{I} \beta^i \, x_{Hm}^i}{\bar{\beta} \, \overline{X_{Hm}} \, I} \tag{33}$$

The distributional characteristic has a high value if good m is consumed proportionally more by people with a high social welfare weight. A higher value of the distributional characteristic implies that, ceteris paribus, the MCF_m will be higher and that therefore, it is less attractive to increase the tax on good m.

The second component of MCF_m, namely MEI_m, can be rewritten in a similar way. We define r_Z as *the distributional characteristic of the externality Z*

$$r_Z = \frac{\sum_{i=1}^{I} \beta^i \, \zeta^i}{\bar{\beta} \, \bar{\zeta} \, I} \qquad \text{where} \qquad \bar{\zeta} = \sum_{i=1}^{I} \zeta^i \Big/ I \tag{34}$$

r_Z has a higher value if a decrease in the externality is valued proportionally more by people with a high marginal social welfare weight. Moreover, we define el_{Zm} as the elasticity of the externality with respect to the tax on good m. This gives us

$$MEI_m = \frac{r_Z \, el_{Zm}}{el_{Bm}} \; \frac{\bar{\beta} \, Z \sum_{i=1}^{I} \zeta^i}{B} \tag{35}$$

A higher (lower) value of the distributional characteristic of the externality makes it more attractive to increase (decrease) the tax on good m in as far as this tax is effective in reducing the externality (large and negative el_{Zm}).

Since distributional considerations are present in both terms of MCF_m, their impact will be determined by the confrontation of the two. If increasing the tax on good m reduces the externality, then, ceteris paribus, a low (high) value of r_m and a high (low) value of r_Z make it more attractive to increase (decrease) the tax on good m. In this case the two components of MCF_m reinforce each other and suggest the same welfare improving direction of tax reform. An example can be found in the field of energy taxes. Energy use leads to the emission of CO_2 which is one of the greenhouse gases. Energy is consumed proportionally more by poor people while these people give a relatively lower value to CO_2 reduction than rich people. If the government has a high degree of inequality aversion, an increase in the tax on energy is less likely given the distributional considerations (everything else being equal). However, if r_m and r_Z are both high or low, there is a trade-off between the distributional considerations of the two components of MCF_m and one cannot predict beforehand which one will dominate. Such a trade-off is likely to occur in the case of congestion caused by road transport. We assume that increasing the tax on road transport reduces congestion. Road transport is consumed proportionally less by poor people (low value of the distributional characteristic of road transport) while these people value a reduction in congestion relatively less than rich people (low value of r_Z). Whatever the inequality aversion of the government, in this case one cannot state beforehand that distributional considerations point out a particular welfare improving direction of tax reform.

As can be expected, in the case of a marginal tax reform involving the poll transfer, distributional considerations are also present. From (29) and using (34) we know that

$$MEI_P = \frac{r_Z \; el_{ZP}}{el_{BP}} \; \frac{\bar{\beta} \; Z \sum_{i=1}^{I} \zeta^i}{B} \tag{36}$$

In this expression el_{BP} stands for the elasticity of net tax revenue and el_{ZP} for the elasticity of the externality w.r.t. the poll transfer. It is clear that if an increase in the poll transfer increases the externality and $el_{BP}<0$, a higher distributional characteristic of Z implies, everything else equal, a lower value of MEI_P and thus a lower value of MCF_P which makes it less attractive to increase the poll transfer.

3.4. The Link with the Double Dividend Literature

The link can be made with the double dividend literature [see e.g., Bovenberg and de Mooij (1994), Bovenberg and van der Ploeg (1994), Goulder (1995)]. The double dividend literature analyzes revenue neutral environmental tax reforms which consist of increasing the tax on the externality generating good and of recycling the revenue obtained this way either by increasing the lump sum transfer or by reducing existing distortionary taxes. The welfare effects of such tax reforms are split into two categories. The first category is termed the first dividend and is related to the net reduction in the negative externality brought about by the tax reform. The second category of welfare effects consists essentially of the increase or decrease of gross welfare (i.e. without taking into account the welfare impact of the change in the externality). A similar analysis can be carried out by using our model. However, compared to the double dividend literature our model is more general because we consider externalities that affect the consumption of taxed goods and because we incorporate distributional considerations.

Suppose that t_{Hm} is a tax on an externality generating good (m=K+1,...,M) while t_{Hk} is a tax on any of goods 1 to K which do not contribute to the externality. We also assume that the revenue neutral tax reform which consists of increasing t_{Hm} and reducing t_{Hk} causes a net reduction in the level of the externality. In our model this corresponds with MEI_k - MEI_m > 0. In terms of the double dividend literature a first dividend is realized. In order to check whether a second dividend is realized, it is necessary to compute the so-called gross marginal welfare cost of each instrument. This corresponds with the marginal welfare cost for a constant level of the externality and is denoted by MCF^*. For a given level of the externality expression (21) for the MCF of the tax on good m reduces to:

$$MCF_m^* = \frac{\sum_{i=1}^{I} \beta^i x_{Hm}^i}{X_{Hm} + \sum_{k=1}^{M} t_{Hk} \left. \frac{\partial X_{Hk}}{\partial t_{Hm}} \right|_Z} \qquad \forall m \tag{37}$$

A similar expression can be found for MCF_P^*. The gross marginal welfare cost (MCF^*) differs from the direct marginal welfare cost (MCF^d) because the latter cost category takes into account the impact of the change in the externality on government revenue.

A *weak double dividend* is now said to be realized if in terms of our model

$$MCF_m^* - MCF_k^* < MCF_m^* - MCF_P^* \tag{38}$$

This means that there is a smaller (higher) gross welfare cost (gain) if the public revenue raised by a marginal increase in the externality tax, is recycled by reducing a distortionary tax than if instead it is recycled by increasing the poll transfer. Alternatively, one can also say that a weak double dividend is present if

$$MCF_k^* > MCF_P^* \tag{39}$$

Whether this is the case or not, depends to a large extent on distributional considerations. E.g., if the inequality aversion is low and if rich people consume proportionally more of good *k* a weak double dividend is more likely to occur.

A *strong double dividend* is said to be present if the use of the externality tax revenue for the reduction of existing distortionary taxes compensates fully the "gross distortionary costs" of the externality tax. So if the marginal tax reform leads to a net gross welfare gain (i.e., $MCF_m^* - MCF_k^* < 0$), we can say that a strong double dividend is realized. Here also distributional considerations are important. A strong double dividend is present if the marginal tax reform analysis for a constant level of the externality shows that it is welfare improving to reduce t_{Hk} and to increase t_{Hm}. In other words, a strong double dividend will result if it is welfare improving to carry out the proposed tax reform even if one does not consider its effect on the level of the externality.

3.5. Applying the Methodology for the Evaluation of Marginal Tax Reforms to the Analysis of Investments in Public Abatement

In the previous sections we have focused our attention on marginal reforms of the tax system. However, apart from tax instruments, the government can also use another instrument: it can change the level of investment in public abatement. We can apply a similar methodology as before to determine whether a change in public abatement is welfare improving or not. We concentrate on the following problem: what is the effect on welfare if public abatement is increased by an amount sufficient to lose one unit of government revenue, while at the same time the tax on good *m* (*m*=1, . . . ,M) is increased such that one unit of public revenue is raised? In a similar way as before, we can derive that

$$dW \gtreqless 0 \quad \Leftrightarrow \quad MCF_m \lesseqgtr MCF_R \tag{40}$$

Since in our model public abatement is only valued by people in so far as it reduces the level of the externality, there is no direct welfare gain associated with a marginal increase in public abatement. As a result, the total welfare cost of a marginal change in public abatement equals the marginal externality impact of that change, or:

$$MCF_R = - \frac{\partial W}{\partial R} \bigg/ \frac{\partial B}{\partial R} = \left(\sum_{i=1}^{I} \beta^i \zeta^i \frac{\partial Z}{\partial R} \right) \bigg/ \frac{\partial B}{\partial R} = MEI_R \tag{41}$$

where

$$\frac{\partial Z}{\partial R} = \xi \left. \frac{\partial Z}{\partial R} \right|_{X_H} \tag{42}$$

4. A Numerical Illustration of the Theoretical Model - The Congestion Externality Caused by Road Passenger Transport

In this section we present a simple illustration of the methodology developed in the previous sections. The illustration starts from the Belgian tax system in 1986. It focuses on one specific externality, namely congestion caused by car passenger transport during the peak period. We make the simplifying assumption that road congestion is caused only by passenger transport and that it has no effect on freight transport. This assumption is more realistic in an urban setting than for interregional transport. If the assumption cannot be held, the producer prices can no longer be assumed to be fixed and a different approach should be used for the evaluation of marginal policy reforms [see e.g., Van de gaer et al. (1992)].

In our application there are 5 consumer groups which differ in their earning capacity. They correspond with the quintiles of the 1986-87 budget survey. There are four goods and one factor. Good 1 is a composite non-transport consumption good, good 2 is peak car transport use which generates congestion, good 3 is off-peak car transport use and good 4 is public transport use. The last two passenger transport modes are assumed not to cause any congestion. Labour is given as total time available (T) minus leisure. It is taken as untaxed numeraire[3]. Each consumer receives a uniform poll transfer. The congestion externality is a positive function of the total use of peak car transport and a negative function of the level of road capacity (R).

In order to apply the methodology of section 3, we rewrite (21) so that it can be operationalized more easily[4]

[3] When there are no other sources of income, we can use the homogeneity of degree zero property so that the taxes on labour can be translated into equal increases of the taxes on all goods other than leisure.

[4] We start from (21). Both the numerator and the denominator are multiplied by q_{Hm}. The last term of the numerator and the denominator is multiplied and divided by Z. The last two terms of the denominator are multiplied and divided by q_{Hk} and X_{Hk}. Using the following definitions: $el_{Zm} = (\partial Z/\partial t_{Hm})\, q_{Hm}/Z$, $el_{km}|_Z = (\partial X_{Hk}/\partial t_{Hm})|_Z\, t_{Hm}/X_{Hk}$ and $el_{kZ} = \partial X_{Hk}/\partial Z\; Z/X_{Hk}$, we obtain (43).

$$MCF_m = \frac{\sum_{i=1}^{I} \beta^i \left(x_{Hm}^i \; q_{Hm} \right) + \sum_{i=1}^{I} \beta^i \; \zeta^i \; Z \; el_{Zm}}{X_{Hm} \; q_{Hm} + \sum_{k=1}^{M} \frac{t_{Hk}}{q_{Hk}} X_{Hk} \; q_{Hk} \left(el_{km} \big|_Z + el_{kZ} \; el_{Zm} \right)} \tag{43}$$

el_{Zm} stands for the aggregate elasticity of the externality with respect to the price of good *m*. The aggregate uncompensated elasticity of the demand for good *k* with respect to the price of good *m* for a given level of the externality is given by $el_{km}|_Z$. Finally, el_{kZ} refers to the aggregate elasticity of demand for good *k* with respect to the externality. Similar expressions can be derived for marginal policy reforms involving the poll transfer and the level of public abatement.

$$MCF_P = \frac{- P \sum_{i=1}^{I} \beta^i + \sum_{i=1}^{I} \beta^i \; \zeta^i \; Z \; el_{ZP}}{- I \; P + \sum_{k=1}^{M} \frac{t_{Hk}}{q_{Hk}} X_{Hk} \; q_{Hk} \left(el_{kP} \big|_Z + el_{kZ} \; el_{ZP} \right)} \tag{44}$$

$$MCF_R = \frac{\sum_{i=1}^{I} \beta^i \; \zeta^i \; Z \; el_{ZR}}{- p_R \; R + \sum_{k=1}^{M} \frac{t_{Hk}}{q_{Hk}} X_{Hk} \; q_{Hk} \; el_{kZ} \; el_{ZR}} \tag{45}$$

$el_{kP}|_Z$ is the elasticity of the demand for good *k* with respect to the poll transfer (for constant *Z*). el_{ZP} and el_{ZR} stand for the elasticity of the externality with respect to the poll transfer and the road capacity respectively.

The implementation of (43)-(45) requires four categories of information. The data are summarized in Tables 1 to 5. For a description of the data sources we refer to the Appendix. The first three categories of information correspond with those needed in a marginal tax reform analysis without externalities [see e.g. Decoster and Schokkaert (1989)]. They consist of information on (i) economic variables, (ii) welfare weights and (iii) the aggregate income and uncompensated price elasticities of the demand for the taxed commodities. The economic variables include the tax rates (t_{Hm}/q_{Hm}), the poll transfer (P), the spending on taxed commodities of the different consumer groups ($q_{Hm}x_{Hm}^{i}$), aggregate spending on these goods ($q_{Hm}X_{Hm}$), and total public spending on road capacity ($p_R\ R$). The incorporation of transport externalities requires additional information which is grouped in the fourth information category. This category consists first of all of information on the level of congestion (Z). In addition, one needs to know the aggregate elasticity of the externality with respect to the price of each taxed good (el_{Zm}), w.r.t. the poll transfer (el_{ZP}) and the level of road infrastructure (el_{ZR}). One also needs the aggregate elasticity of demand for each taxed good n with respect to the externality. Finally, one needs information on the individualized value of a decrease in the externality. Summarizing, it can be concluded that the data requirements for analyzing marginal tax reforms in the presence of externalities are much more stringent because individual valuation data on the decrease in the externality are now required.

Table 1: The Government Instruments

Tax rates	Observed tax rates (% of producer price)	Normalized tax rates[a] (% of consumer price)
Labour	40.49%	0.00%
Composite commodity	11.89%	46.82%
Peak car transport	43.20%	58.45%
Off peak car transport	43.20%	58.45%
Public Transport	-69.53%	-95.30%
Public spending	**Observed (% of total tax income)**	**Normalized (% of total tax income)**
Poll transfer	47.71%	60.53%
Road infrastructure	2.85%	2.15%

[a] The tax rates and the poll transfer are normalized such that labour is the untaxed good

Table 2: Information on the Quintiles

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	Total
Spending (% of total spending by quintile)	100%	100%	100%	100%	100%	100%
Composite commodity	90.59%	89.58%	89.01%	89.18%	90.23%	89.72%
Peak car transport	3.66%	4.11%	4.91%	4.82%	4.52%	4.53%
Off peak car transport	5.13%	5.75%	5.54%	5.46%	4.87%	5.26%
Public transport	0.62%	0.56%	0.54%	0.55%	0.39%	0.49%
Valuation of reduction in the externality (quintile 1 = 1)	1	1.12	1.55	1.55	2.02	

Table 3: Welfare Weights

	Degree of inequality aversion			
	$\varepsilon = 0$	$\varepsilon = 1$	$\varepsilon = 5$	$\varepsilon = 10$
β^1	1	1	1	1
β^2	1	0.87	0.50	0.25
β^3	1	0.78	0.29	0.09
β^4	1	0.66	0.12	0.02
β^5	1	0.44	0.02	0.00

Table 4: Demand Elasticities

	Prices					Income	Externality
	Leisure	Comp. comm.	Peak car tp	Off peak car tp	Public tp		
Leisure	-0.23	0.15	-0.03	-0.02	0.00	0.99	-0.01
Comp. comm.	1.03	-1.16	-0.01	0.00	0.00	1.00	0.00
Peak car tp	0.14	-0.15	-0.20	0.05	0.01	1.10	-0.25
Off peak car tp	0.56	-0.15	0.04	-0.60	-0.02	1.20	0.05
Public tp	0.47	0.10	0.12	-0.18	-0.50	0.00	0.27

Table 5: The Elasticity of the Externality with respect to its Determinants

Elasticity of the externality w.r.t.	
Price composite commodity	-0.11
Price peak car transport	-0.14
Price off-peak car transport	0.04
Price public transport	0.01
Poll transfer (increase)	0.11
Road infrastructure capacity (increase)	-0.69

Using the information summarized in Tables 1 to 5, we can calculate the total marginal welfare costs (i.e., the sum of the direct marginal welfare cost and the marginal externality impact) of the different government instruments when taking into account the presence of the congestion externality. The results are presented in Tables 6 and 7. The marginal tax reform exercise has been repeated for different degrees of inequality aversion to test the sensitivity of the results to this parameter. A value of $\varepsilon = 0$ means that the social welfare function gives an equal weight to all income groups. As the value of ε increases, society has a higher degree of inequality aversion.

The first part of Table 6 gives the total marginal welfare cost of the different policy instruments. To get a better overview, the second part of Table 6 presents the ranking of the policy instruments in terms of their marginal welfare cost. For the pure efficiency social welfare function ($\varepsilon = 0$) it is welfare improving to increase capacity, to increase the tax on public transport and on peak car transport and to decrease the poll transfer, the tax on the composite commodity and the tax on off-peak car transport. A first important empirical result is that the policy recommendations do depend on the degree of inequality aversion. As society becomes more inequality averse the overall ranking is changed. First of all, there is a reversal in the ranking of the tax on peak car transport and that on public transport. With a higher degree of inequality aversion a higher tax on public transport becomes a more costly instrument to raise government revenue compared to the tax on peak car transport. Secondly, as society becomes more averse to inequality, financing an increase in government revenue by lowering the poll transfer becomes less attractive.

Table 6: The Total Marginal Welfare Costs (MCF) of the Different Government Instruments

		Degree of inequality aversion			
		$\varepsilon = 0$	$\varepsilon = 1$	$\varepsilon = 5$	$\varepsilon = 10$
MCF					
Indirect tax on comp. comm.	t_{H1}	2.22	1.45	0.52	0.30
Indirect tax on peak car tp	t_{H2}	1.01	0.65	0.22	0.12
Indirect tax on off peak car tp	t_{H3}	1.56	1.03	0.37	0.21
Indirect tax on public tp	t_{H4}	0.85	0.58	0.23	0.13
Poll transfer (decrease)	P	1.28	0.96	0.50	0.35
Road capacity (decrease)	R	4.74	2.95	0.90	0.46
Ranking					
Low MCF		t_{H4}	t_{H4}	t_{H2}	t_{H2}
		t_{H2}	t_{H2}	t_{H4}	t_{H4}
		P	P	t_{H3}	t_{H3}
		t_{H3}	t_{H3}	P	t_{H1}
		t_{H1}	t_{H1}	t_{H1}	P
High MCF		R	R	R	R

Table 7 gives more information on the composition of the total marginal welfare costs. It shows that the ranking for the tax instruments and the poll transfer in terms of their MCF is determined mainly by the direct marginal welfare costs (MCF^d). This is the second important empirical result. However, the marginal externality impact does explain why the ranking between the tax on peak car transport and that on public transport is reversed for larger values of ε. Moreover, the inclusion of the marginal externality impact significantly changes the policy conclusions regarding the road capacity. While on the basis of the direct welfare costs it is optimal to raise revenue by reducing the road capacity level and to recycle this revenue through a decrease in other taxes or an increase in the poll transfer, this is no longer the case if the marginal externality impact of the capacity instrument is taken into account. Indeed, if one incorporates the impact on congestion into the analysis, it becomes optimal to increase the level of road capacity and to finance this increase by increasing another indirect tax or by decreasing the poll transfer[5].

Table 7: The Components of the Total Marginal Welfare Cost

	Degree of inequality aversion			
	$\varepsilon = 0$	$\varepsilon = 1$	$\varepsilon = 5$	$\varepsilon = 10$
Indirect tax on comp. comm.				
MCF^d	2.23	1.45	0.52	0.30
MEI	-0.01	-0.01	0.00	0.00
Indirect tax on peak car tp				
MCF^d	1.15	0.74	0.25	0.133
MEI	-0.14	-0.09	-0.03	-0.01
Indirect tax on off peak car tp				
MCF^d	1.52	1.00	0.36	0.20
MEI	0.04	0.03	0.01	0.00
Indirect tax on public tp				
MCF^d	0.81	0.55	0.22	0.129
MEI	0.05	0.03	0.01	0.00
Poll transfer (decrease)				
MCF^d	1.30	0.98	0.50	0.35
MEI	-0.02	-0.01	0.00	0.00
Road capacity (decrease)				
MCF^d	0.00	0.00	0.00	0.00
MEI	4.74	2.95	0.90	0.46

In order to assess the possibility of realizing a double dividend, we need to know the marginal welfare cost of the different instruments obtained for a constant level of the externality. Table 8 presents the value of the MCF^* for different degrees of inequality aversion and the ranking of the instruments from low to high MCF^*. The ranking in terms of MCF^* corresponds completely with that in terms of MCF^d, though the value of the two measures is different. This is because, in the presence of

[5] It should be noted that capacity only enters the utility function of the consumers because it determines the level of congestion. The model does not take into account the environmental or disruptive costs of expanding road capacity. Including these effects would make an increase in road capacity less attractive than it is now. Depending on the magnitude of the environmental effects and on the consumers' valuation of them, the ranking of the capacity instrument w.r.t. the other instruments could in some cases be reversed.

a nonseparable externality, MCF^d takes into account the impact of a change in the externality on government revenue. We consider marginal policy reforms which consist of an increase in the tax on peak car transport and several alternative ways of recycling the extra revenue it generates. Table 8 shows that for low degrees of inequality aversion ($\varepsilon = 0$ and $\varepsilon = 1$) the gross welfare gain that can be obtained by returning the externality tax revenue through lower distortionary taxes (t_{H1} or t_{H3}) is higher than when it is redistributed through a higher poll transfer. This means that in these cases a weak double dividend can be realised. For $\varepsilon = 5$ this is the case only when the tax on the composite commodity (t_{H1}) is lowered. But since this is the most representative distortionary tax, this is still a positive result. However, for very high degrees of inequality aversion ($\varepsilon = 10$) there is no more possibility for a weak double dividend.

Table 8: The Total Marginal Welfare Costs (MCF^*) of the Different Government Instruments for a Constant Level of the Externality

		Degree of inequality aversion			
		$\varepsilon = 0$	$\varepsilon = 1$	$\varepsilon = 5$	$\varepsilon = 10$
MCF^*					
Indirect tax on comp. comm.	t_{H1}	2.24	1.45	0.52	0.30
Indirect tax on peak car tp	t_{H2}	1.18	0.76	0.25	0.14
Indirect tax on off peak car tp	t_{H3}	1.51	1.00	0.36	0.20
Indirect tax on public tp	t_{H4}	0.80	0.55	0.22	0.13
Poll transfer (decrease)	P	1.31	0.98	0.51	0.35
Road capacity (decrease)	R	0.00	0.00	0.00	0.00
Ranking					
Low MCF^*		R	R	R	R
		t_{H4}	t_{H4}	t_{H4}	t_{H4}
		t_{H2}	t_{H2}	t_{H2}	t_{H2}
		P	P	t_{H3}	t_{H3}
		t_{H3}	t_{H3}	P	t_{H1}
High MCF^*		t_{H1}	t_{H1}	t_{H1}	P
Weak double dividend test: is $MCF_{tH1}^* > MCF_P^*$?		yes	yes	yes	no
Strong double dividend test is $MCF_{tH2}^* < MCF_{tH1}^*$?		yes	yes	yes	yes

From Table 8 it is also clear that for all values of ε a strong double dividend can be realized: the revenue neutral substitution of the tax on peak car transport for a representative or typical distortionary tax (such as the tax on the composite commodity) leads to a gross welfare gain. Indeed, the MCF* of t_{H2} is always smaller than that of t_{H1}. This can also be observed for the less representative tax on off peak car transport. So, even without considering the externality effects, these policy reforms are welfare improving. All other policy reforms are characterized by a trade-off between the impact on direct welfare and that on the externality.

5. Conclusions

The paper contributes in three ways to the existing theory on marginal tax reform in the presence of externalities. The analysis looks at a general type of externalities, namely those which have a feedback on private consumption. It is shown that for a correct evaluation of marginal tax reforms one should not only take into account the impact of the tax reform on the externality level but also the possibility that a change in the level of the externality may have an impact on the consumption of taxed commodities. Secondly, the importance of distributional considerations is demonstrated. These should be considered when analyzing both the direct welfare costs and the externality impact of a marginal tax change. Thirdly, it is shown that the analysis of tax reforms may be extended to the analysis of marginal changes in other policy instruments, such as public abatement, which have an effect on the government budget balance. The theoretical model is illustrated for a specific externality, namely congestion caused by peak car transport. It is shown that the data requirements for carrying out the analysis in that context are more difficult than for the traditional marginal tax reform analysis. The present approach can be extended in several ways. The model could incorporate externalities in the production sector (freight transport) and one could use more elaborated representations of travel behaviour and congestion phenomena.

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Appendix: Description of the Data Sources for the Marginal Tax Reform Illustration

a.. The tax rates and the poll transfer

The data for the tax rates and the level of the poll transfer are found in Van Dongen et al. (1993), OECD (1992), Evrard (1993a,1993b) and Vanneste (1992). They normalized tax rates are calculated such that labour is the untaxed good. The underlying marginal tax rate on labour is 40.50%.

b. Spending on the taxed commodities

In the household budget survey of 1986-87 information is found on the spending on taxed commodities of the different consumer groups ($q_{Hm}\, x_{Hm}{}^{i}$) and aggregate spending on these goods (q_{Hm} X_{Hm}). However, no distinction is made between peak and off-peak car transport use. For this we have as a first approximation extrapolated findings for Brussels [Stratec (1992)] to the rest of Belgium.

c. Total public spending on road capacity

Due to a lack of suitable data, we have approximated total spending in Belgium on road capacity by using information for the Netherlands. van der Bij et al. (1994) have found a value of 57.7% for the ratio of spending on car passenger transport infrastructure to taxes collected from passenger transport. This ratio has been applied in our exercise.

d. The welfare weights

The welfare weights are constructed using a similar procedure as in Decoster and Schokkaert (1989). The welfare weight given to consumer *i* is defined as

$$\beta^i = \left(y_E^i \Big/ y_E^1 \right)^{-\varepsilon}$$

y_E^i is defined as the total expenditure per adult equivalent in consumer class *i*. It is approximated by the total expenditure per capita.

e. The congestion function

The congestion function is based on work by Kirwan et al. (1995). They have found that for a city the overall relation between the time needed for a km of travel and the total number of vehicle km can be described as

$$Z = \alpha_1 + \alpha_2 \, e^{\alpha_3 X_{H2} / 4}$$

X_{H2} is the number of vehicle km driven in the 4-hour peak period. In De Borger et al. (1997) a similar relationship has been used for interregional transport. From the confrontation of total spending on the use of private transport [Belgium, N.I.S. (1992)] with the total number of vehicle km per year [based on FEBIAC (1987) and De Borger (1987)] we have derived an average price per km which is applied to the data of the budget survey to find the corresponding no. of vehicle km in the peak and off-peak period. The congestion function is calibrated such that at the initial peak car transport level average speed is 60 km/h, freeflow speed is 85 km/h and speed decreases to 50 km/h at traffic levels 20% higher than the initial peak car traffic level.

e. The valuation of a reduction in the externality

The value of a marginal decrease in the congestion externality is based on a study carried out for the Netherlands by Hague Consulting Group (1990). That study has derived values for a marginal time saving in transport activities for different income groups.

f. Elasticities

Several types of elasticities have to be discerned. First of all we need aggregate income and uncompensated price elasticities of the demand for the different taxed commodities. For the transport goods these are based on the transport literature ['t Hoen et al. (1991), De Borger et al. (1996), Peirson et al. (1994), Dodgson and Topham (1987)]. The other elasticities are derived such all properties of Hicksian and Marshallian demand functions are satisfied [Deaton and Muellbauer (1980)]. The average own price elasticity of the labour supply is 0.35, a value which is close to the one found in Hansson & Stuart (1985).

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