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Marginal tax reform, externalities and income distribution

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Abstract

The paper examines welfare improving revenue neutral marginal policy reforms for an economy with non-identical individuals and an externality with a feedback on the consumption of taxed commodities. The instruments considered are: indirect taxes, the uniform poll transfer and public abatement. This extends the framework of Ahmad and Stern [Journal of Public Economics, 25 (1984) 259–298], Bovenberg and de Mooij [American Economic Review, 84 (1994) 1085–1089] and Schöb [Oxford Economic Papers 48 (1996) 537–555]. The theory is illustrated for congestion caused by peak car transport. The desirability of a higher externality tax is shown to depend on: the efficiency effect of the revenue recycling, the externality benefit, the distributional characteristic of the commodities and the externality and the feedback effect. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

In recent years, it has been argued that a shift in taxes towards externality-generating commodities and away from labour can be justified given the greening

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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 applied general equilibrium 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 commodities, on their share in the consumption of commodities for which taxes are cut and finally on 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 non-identical individuals. Two other extensions are made. These consist of the introduction of externalities that are non-separable from the consumption of private commodities, 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 employed 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 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. Section 4 presents a numerical illustration of the theory to the congestion externality caused by road passenger transport. The section tries to assess whether the externality component, the feedback effect and the degree of inequality aversion are important empirically for the welfare ranking of the marginal tax reforms and the marginal changes in public abatement. Section 5 presents the conclusions.

¹Wibaut (1989) and Van de gaer et al. (1992) applied the approach in a non-Walrasian setting.

2. The model

We consider a single period model for a closed economy. There are I non-identical *consumers* (indexed $i = 1, \dots, I$) who differ in their preferences and their earning capacity e^i . There are M commodities (indexed $m = 1, \dots, M$). Commodities 1 to K are traditional commodities. The consumption of commodities $K + 1$ to M contributes to the externality Z . The consumption vector of consumer i is $x^i = (x_1^i, \dots, x_M^i)$. x_m^i denotes his consumption of commodity m ($x_m^i > 0$). Leisure (l^i) is the *numéraire* commodity and is taken to be untaxed. Each consumer faces his budget constraint:

$$\sum_{m=1}^M q_m x_m^i \leq e^i(T - l^i) + P \quad \forall i \quad (1)$$

T denotes total time available, P is the uniform poll (lump sum) transfer and q_m represents the consumer price of commodity m . It is the sum of the producer price p_m and the indirect tax t_m . The direct utility function of consumer i is given by:

$$U^i = U^i(x_1^i, \dots, x_M^i, l^i, Z) \quad (2)$$

U^i is strictly quasi-concave in its arguments 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. Each consumer chooses x^i and l^i such that his utility is maximized subject to his budget constraint. We assume that he ignores his own impact on Z and that differentiable demand functions exist:

$$l^i = l^i(q, P, Z) \quad \forall i \quad (3)$$

$$x_m^i = x_m^i(q, P, Z) \quad \forall m, i. \quad (4)$$

The externality is 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 road congestion can induce a substitution to rail 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. The aggregate consumption of commodity m is denoted by X_m . $V^i(q, P, Z)$ is the indirect utility function.

The level of the *externality* is determined by the total consumption of the externality-generating commodities $K + 1$ to M . Each of these commodities may have a different contribution to Z (e.g. per additional passenger kilometre a car contributes more to congestion than a public bus with a high occupancy rate). The government can reduce the level of Z by undertaking investments in public abatement (R). The externality is thus given by:

$$Z = Z(X_{K+1}, \dots, X_M, R) \quad (5)$$

$$\frac{\partial Z}{\partial X_m} > 0 \text{ for } m = K + 1, \dots, M; \quad \left. \frac{\partial Z}{\partial R} \right|_x < 0.$$

As regards the *production side* of the economy, we suppose that the level of Z has no impact on production. Nor does the production sector contribute to Z . 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 (B) for a number of exogenous activities. It faces the following budget constraint:

$$B = \sum_{m=1}^M t_m X_m - p_R R - I P \geq B^*. \quad (6)$$

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

The government maximizes a Bergson–Samuelson type of social welfare function:

$$W = W(V^1(q, P, Z), \dots, V^I(q, P, Z)). \quad (7)$$

3. Evaluating revenue neutral marginal policy reforms in the presence of externalities

The government can use three policy instruments: indirect taxes t_m , 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 to transpose the methodology to the evaluation of marginal changes in public abatement.

3.1. The welfare cost of a marginal tax change

The effect on welfare of a revenue neutral tax change which consists of increasing t_m and reducing t_k is given by:

$$dW = \frac{\partial W}{\partial t_k} dt_k + \frac{\partial W}{\partial t_m} dt_m \text{ with } dB = 1 = \frac{\partial B}{\partial t_m} dt_m = -\frac{\partial B}{\partial t_k} dt_k \quad (8)$$

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

$$MCF_m = -(\partial W / \partial t_m) / (\partial B / \partial t_m) \quad (9)$$

we find

$$dW \geq 0 \Leftrightarrow MCF_m \leq MCF_k. \quad (10)$$

So welfare is increased (reduced) when the tax with the highest *MCF* is reduced (increased) and when simultaneously the tax with the lowest *MCF* is raised (reduced).

In order to rewrite (9), we take the derivative of (6) and (7) with respect to t_m taking into account the endogenous nature of Z as specified in (5), we use Roy's identity and define λ^i as the private marginal utility of income, β^i ($\beta^i = (\partial W / \partial V^i) \lambda^i$) as the direct social marginal utility of income accruing to individual i and ζ^i ($\zeta^i = -(\partial V^i / \partial Z) / \lambda^i$) as the individual marginal willingness to pay (WTP) for a reduction in the externality. This way the MCF_m can be written as:

$$MCF_m = \frac{\sum_{i=1}^I \beta^i x_m^i + \sum_{i=1}^I \beta^i \zeta^i \frac{\partial Z}{\partial t_m}}{X_m + \sum_{k=1}^M t_k \frac{\partial X_k}{\partial t_m} \bigg|_Z + \sum_{k=1}^M t_k \frac{\partial X_k}{\partial Z} \frac{\partial Z}{\partial t_m}} \quad \forall m \quad (11)$$

with

$$\frac{\partial Z}{\partial t_m} = \xi \sum_{k=K+1}^M \frac{\partial Z}{\partial X_k} \frac{\partial X_k}{\partial t_m} \bigg|_Z \quad \forall m \quad (12)$$

in which ξ is the externality feedback parameter that translates the first round effect of a tax on Z (e.g. a higher tax on road transport reduces congestion) into the full effect of that tax on Z (the reduced congestion level attracts more traffic and this offsets part of the initial gain in speed). It is defined as:

$$\xi = 1 / \left(1 - \sum_{k=K+1}^M \frac{\partial Z}{\partial X_k} \frac{\partial X_k}{\partial Z} \right) \quad 0 \leq \xi \leq 1. \quad (13)$$

Expression (11) 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 (11) reduces to the familiar expression of Ahmad and Stern (1984). If, on the contrary, there are externalities but they are not characterized by a feedback effect, the last term in the denominator drops out and the externality feedback parameter in (12) equals one, as in Schöb (1996). The last term in the denominator of (11) is known as the ‘Pigou-effect’: the level of the externality affects the demand for the taxed commodities (Atkinson and Stiglitz, 1980).

In an analogous way we find the expression for the marginal welfare cost of raising one additional unit of government revenue by reducing the uniform poll transfer:

$$MCF_P = \frac{-\sum_{i=1}^I \beta^i + \sum_{i=1}^I \beta^i \zeta^i \frac{\partial Z}{\partial P}}{-I + \sum_{m=1}^M t_m \frac{\partial X_m}{\partial P} \bigg|_Z + \sum_{m=1}^M t_m \frac{\partial X_m}{\partial Z} \frac{\partial Z}{\partial P}} \quad (14)$$

3.2. Decomposing the welfare cost and the link with the double dividend literature

As in Schöb (1996) the MCF_m and MCF_P can be split into two components. The first component of the MCF_m is called the *direct welfare cost* of a marginal change in t_m and is defined as:

$$MCF_m^d = \left(\sum_{i=1}^I \beta^i x_m^i \right) / (\partial B / \partial t_m). \quad (15)$$

Following Ahmad and Stern (1984) this can be written in terms of the *distributional characteristic* r_m :

$$MCF_m^d = \frac{r_m \bar{\beta}}{el_{Bm}} \frac{X_m t_m}{B} \text{ with } \bar{\beta} = \sum_{i=1}^I \beta^i / I \quad (16)$$

where el_{Bm} denotes the elasticity of government revenue with respect to the tax on commodity m and

$$r_m = \left(\sum_{i=1}^I \beta^i x_m^i \right) / (\bar{\beta} \bar{X}_m I) \text{ with } \bar{X}_m = \sum_{i=1}^I x_m^i / I. \quad (17)$$

r_m has a high value if commodity m is consumed proportionally more by people with a high social welfare weight. A higher value of r_m implies that, ceteris paribus, the MCF_m becomes higher and that therefore, it is less attractive to increase t_m .

The second component of the MCF_m is the *marginal externality impact* of t_m and is defined as:

$$MEI_m = \left(\sum_{i=1}^I \beta^i \zeta^i \frac{\partial Z}{\partial t_m} \right) / (\partial B / \partial t_m). \quad (18)$$

It can be rewritten in a similar way as MCF_m^d , with r_Z as the *distributional characteristic of Z*

$$r_Z = \left(\sum_{i=1}^I \beta^i \zeta^i \right) / (\bar{\beta} \bar{\zeta} I) \text{ with } \bar{\zeta} = \sum_{i=1}^I \zeta^i / I. \quad (19)$$

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

$$MEI_m = \frac{r_Z el_{Zm}}{el_{Bm}} \frac{\bar{\beta} Z \sum_{i=1}^I \zeta^i}{B}. \quad (20)$$

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

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

In an analogous way, MCF_p can be decomposed into MCF_p^d and MEI_p , with:

$$MCF_p^d = - \left(\sum_{i=1}^I \beta^i \right) / (\partial B / \partial P) \quad (21)$$

$$MEI_p = \frac{\sum_{i=1}^I \beta^i \zeta^i \frac{\partial Z}{\partial P}}{\partial B / \partial P} = \frac{r_Z el_{ZP}}{el_{BP}} \frac{\bar{\beta} Z \sum_{i=1}^I \zeta^i}{B}. \quad (22)$$

el_{BP} and el_{ZP} stand for the elasticity of net tax revenue and of the externality with respect to P , respectively.

The overall welfare effect of a revenue neutral tax reform which consists of increasing t_m and reducing t_k can be decomposed into two effects:

$$dW \cong 0 \Leftrightarrow (MEI_k - MEI_m) + (MCF_k^d - MCF_m^d) \cong 0. \quad (23)$$

The first term between brackets is the net externality benefit of the tax reform. It is positive if there is a net reduction in the level of the externality. The second term

between brackets is the net direct welfare impact. It is negative if the tax reform leads to a net direct welfare cost.²

Expression (23) allows to make the link with the double dividend literature (see, e.g. Bovenberg and de Mooij, 1994; Bovenberg and van der Ploeg, 1994; Goulder, 1995).³ Suppose that t_m is a tax on an externality-generating commodity ($m = K + 1, \dots, M$) while t_k is a tax on any of commodities 1 to K which do not contribute to Z . We also assume that the revenue neutral tax reform which consists of increasing t_m and reducing t_k causes a net reduction in Z . The first term in brackets in (23) is therefore positive. This welfare effect is known in the double dividend literature as the *first dividend*. It corresponds with the welfare gain caused by the net reduction in Z . In our case the magnitude of the first dividend depends on the distributional characteristic of the externality, r_Z . From (20), the higher the WTP of the poor and the higher the inequality aversion, the higher is the social benefit of a reduction in Z . The possibility for obtaining a second dividend can be assessed on the basis of the second term within brackets in (23). This term depends on the relative distributional characteristics of commodities m and k and on the relative government revenue effects of t_m and t_k . The government revenue effect depends on the substitutability with the other commodities, including leisure, and on the feedback of the change in the externality on the consumption of the taxed commodities.

A *weak double dividend* occurs if the direct welfare gain of recycling the tax revenue via a cut in a distortionary tax is higher than the direct welfare gain of recycling it via a higher poll transfer P .⁴

$$MCF_k^d > MCF_P^d. \quad (24)$$

Distributional considerations can easily destroy this property: with a high

²In analogy with Schöb (1996) we can introduce the concept of the *critical value* of the marginal social WTP for a reduction in Z . It gives the value that the social marginal WTP for a lower Z should take for the policy reform to become welfare improving. It is a useful concept if the net direct welfare effect and the net 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:

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

in which MZ_m stands for the change in Z brought about by increasing t_m by an amount sufficient to raise one unit of government revenue

$$MZ_m = (\partial Z / \partial t_m) / (\partial B / \partial t_m).$$

³We use, as in most of the tax reform literature, labour as the untaxed commodity. However, most of the double dividend literature uses the clean consumption commodity as the untaxed commodity (see Bovenberg and de Mooij, 1997).

⁴One could also assess the presence of a double dividend on the basis of the gross marginal welfare costs (MCF^*). MCF^* differs from MCF^d because, unlike MCF^d , it assumes that the externality level is constant. Therefore, it does not take into account the impact of the change in the externality on government revenue.

inequality aversion and if rich people consume proportionally more of commodity k a weak double dividend is less likely.⁵

A *strong double dividend* is present if the use of the externality tax revenue for the reduction of existing distortionary taxes compensates fully the direct distortionary costs of the externality tax: if $MCF_m^d - MCF_k^d < 0$. We know from the tax reform literature that the distributional characteristic of both commodities plays a key role here.

3.3. Applying the methodology for the evaluation of marginal tax reforms to the analysis of investments in public abatement

We apply a similar methodology to determine whether a change in public abatement (R) financed by a tax raise on one of the commodities is welfare improving or not. Precision in the definition is required here. We want to analyse the effect on welfare if R is increased marginally such that it costs one unit of public revenue,⁶ and this is financed by a higher t_m ($\forall m$) which raises exactly one unit of public revenue. As there is no direct welfare gain associated with a marginal increase in R , the total welfare cost of a marginal change in R equals the marginal externality impact, or:

$$MCF_R = - \frac{\partial W}{\partial R} \bigg/ \frac{\partial B}{\partial R} = \left(\sum_{i=1}^I \beta^i \xi^i \frac{\partial Z}{\partial R} \right) \bigg/ \frac{\partial B}{\partial R} = MEI_R \quad (25)$$

where

$$\partial Z / \partial R = \xi(\partial Z / \partial R)|_X. \quad (26)$$

In a similar way as before, we can derive that it is interesting to increase public abatement only if the marginal welfare cost of one unit of revenue raised via a decrease in public abatement (MCF_R) is higher than the marginal welfare cost of raising one unit of revenue via a higher tax on commodity m (MCF_m):

$$dW \geq 0 \Leftrightarrow MCF_m \geq MCF_R. \quad (27)$$

4. A numerical illustration of the theoretical model — the congestion externality caused by road passenger transport

4.1. Assumptions and data

In this section we want to analyse the importance of the consideration of the feedback mechanism and the distributional values in the assessment of externality tax reforms. We have chosen road traffic congestion in the peak period as

⁵See Proost and Van Regemortel (1995) for an empirical illustration of this.

⁶Because of the feedback effect of the externality this is not the same as spending one additional unit of government revenue on public abatement.

externality. This has three advantages. Firstly, it is easier to determine the WTP for congestion than for pure environmental externalities (e.g. air pollution). Secondly, the feedback mechanism (impact of congestion on the consumption of private commodities) is relatively easy to track. Finally, congestion is one of the quantitatively most important transport externalities.⁷ 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.

We consider five consumer groups that differ in their earning capacity. They correspond with the quintiles of the 1986–1987 budget survey. There are four commodities and one factor. Commodity 1 is a composite non-transport consumption commodity, commodity 2 is peak car transport use which generates congestion, commodity 3 is off-peak car transport use and commodity 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 minus leisure. It is taken as untaxed *numéraire*.⁸ 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 (11) so that it can be operationalized more easily⁹

$$MCF_m = \frac{\sum_{i=1}^I \beta^i (x_m^i q_m) + \sum_{i=1}^I \beta^i \zeta^i Z el_{zm}}{X_m q_m + \sum_{k=1}^M \frac{t_k}{q_k} X_k q_k (el_{km|Z} + el_{kz} el_{zm})} \quad (28)$$

el_{zm} stands for the aggregate elasticity of the externality with respect to the price of commodity m . The aggregate uncompensated elasticity of the demand for commodity k with respect to the price of commodity 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 commodity k with respect to the externality. Similar expressions are

⁷This is typically the case in urban areas in Western Europe during the peak period. Emission regulation (e.g. catalytic converters, unleaded gasoline) has reduced the air pollution damage of cars, while the limited potential for road expansion gives rise to strong congestion effects (see, e.g. Mayeres et al., 1996). For tax reform exercises with different externalities, see, e.g., De Borger et al. (1997) and Mayeres (1999).

⁸When 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 commodities other than leisure.

⁹We start from (11). Both the numerator and the denominator are multiplied by q_m . 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_k and X_k . Using the following definitions: $el_{zm} = (\partial Z / \partial t_m) (q_m / Z)$, $el_{km|Z} = (\partial X_k / \partial t_m)|_Z (t_m / X_k)$ and $el_{kz} = (\partial X_k / \partial Z) (Z / X_k)$, we obtain (28).

derived for marginal policy reforms involving the poll transfer and the level of public abatement.

$$MCF_P = \frac{-P \sum_{i=1}^I \beta^i + \sum_{i=1}^I \beta^i \zeta^i Z el_{ZP}}{-IP + \sum_{k=1}^M \frac{t_k}{q_k} X_k q_k (el_{kP|Z} + el_{kZ} el_{ZP})} \quad (29)$$

$$MCF_R = \frac{\sum_{i=1}^I \beta^i \zeta^i Z el_{ZR}}{-p_R R + \sum_{k=1}^M \frac{t_k}{q_k} X_k q_k el_{kZ} el_{ZR}} \quad (30)$$

$el_{kP|Z}$ is the elasticity of the demand for commodity 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 data are summarized in Tables 1–5. For a description of the data sources we refer to Appendix A. The implementation requires four categories of information. The first three categories correspond with those needed in a marginal tax reform analysis without externalities (see, e.g. Ahmad and Stern, 1984). 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_m/q_m), the poll transfer (P), the spending on the taxed commodities of the different consumer groups ($q_m x_m^i$), aggregate spending on these commodities ($q_m X_m$), 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

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 revenue)	Normalized (% of total tax revenue)
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 commodity.

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
The 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

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 commodity (el_{Zm}), with respect to the poll transfer (el_{ZP}) and the level of road infrastructure (el_{ZR}). One also needs the aggregate elasticity of demand for each taxed commodity k with respect to the externality. Finally, one needs information on the individualized WTP for a decrease in the externality level.

Table 4
The demand elasticities

	Prices					Income	Externality
	Leisure	Comp. comm.	Peak car tp	Off peak car tp	Public tp		
Leisure	-0.11	0.01	-0.03	-0.01	-0.00	0.99	-0.01
Comp. comm.	0.88	-1.00	-0.00	-0.01	-0.00	1.00	0.00
Peak car tp	0.13	-0.15	-0.20	0.05	0.01	1.13	-0.25
Off peak car tp	0.59	-0.15	0.05	-0.60	-0.02	0.93	0.05
Public tp	0.41	0.10	0.10	-0.21	-0.50	0.70	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	0.11
Road infrastructure capacity	−0.69

One of the attractive properties of marginal tax reform analysis for private commodities is that it relies on easily obtainable aggregate data. When externalities or public goods are involved, we need their valuation by income group and their effect on the demand for private commodities. This type of information is much more difficult to gather.

4.2. The marginal welfare cost and the role of the degree of inequality aversion

Using the information summarized in Tables 1–5, we 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. 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 upper left part of Table 6 gives the total marginal welfare cost of the different policy instruments. To get a better overview, the lower left 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, e.g., raise the tax on public transport or that on peak car transport or to reduce the poll transfer and to use these funds to expand road capacity or to cut the tax on the composite commodity or that on off-peak car transport. However, the policy recommendations depend on the degree of inequality aversion. The most important effect is that, as society becomes more averse to inequality, financing an increase in government revenue by reducing the poll transfer becomes less attractive. The reason is that the poll transfer is an important redistributive instrument when only a linear income tax is available. In addition, 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,

Table 6

The total marginal welfare costs (*MCF*) of the various government instruments

		Degree of inequality aversion				$\varepsilon = 0$
		$\varepsilon = 0$	$\varepsilon = 1$	$\varepsilon = 5$	$\varepsilon = 10$	No feedback effect
<i>MCF</i>						
Indirect tax on comp. comm.	t_1	1.90	1.24	0.44	0.25	1.91
Indirect tax on peak car tp	t_2	0.99	0.64	0.22	0.12	1.06
Indirect tax on off peak car tp	t_3	1.70	1.12	0.41	0.23	1.70
Indirect tax on public tp	t_4	0.77	0.52	0.20	0.12	0.77
Poll transfer (decrease)	P	1.27	0.96	0.50	0.35	1.27
Road capacity (decrease)	R	4.74	2.95	0.90	0.46	3.28
Ranking						
Low <i>MCF</i>		t_4	t_4	t_4	t_2	t_4
		t_2	t_2	t_2	t_4	t_2
		P	P	t_3	t_3	P
		t_3	t_3	P	t_1	t_3
		t_1	t_1	t_1	P	t_1
High <i>MCF</i>		R	R	R	R	R

because public transport is consumed proportionally more by the poor. However, the reversal in ranking only occurs for values of ε equal to 10 and higher. A very strong inequality aversion is needed to compensate for the high revenue cost of subsidized public transport.

4.3. The decomposition of the marginal welfare cost, the feedback effect and the double dividend test

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 and less by the marginal externality impact. The marginal externality impact of peak and off-peak car transport and of public transport has the expected sign. 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 cut in other taxes or a higher poll transfer, this is no longer the case if the marginal externality impact of the capacity instrument is taken into account. Indeed, when incorporating the impact on congestion into the

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. (t_1)				
MCF^d	1.91	1.24	0.44	0.25
MEI	−0.01	−0.01	−0.00	−0.00
Indirect tax on peak car tp (t_2)				
MCF^d	1.13	0.73	0.25	0.13
MEI	−0.14	−0.09	−0.03	−0.01
Indirect tax on off peak car tp (t_3)				
MCF^d	1.65	1.09	0.40	0.22
MEI	0.04	0.03	0.01	0.00
Indirect tax on public tp (t_4)				
MCF^d	0.72	0.49	0.19	0.12
MEI	0.04	0.03	0.01	0.00
Poll transfer (P) (decrease)				
MCF^d	1.29	0.97	0.50	0.35
MEI	−0.02	−0.01	0.00	−0.00
Road capacity (R) (decrease)				
MCF^d	0.00	0.00	0.00	0.00
MEI	4.74	2.95	0.90	0.46
Weak double dividend test: is $MCF_{t_1}^d > MCF_P^d$?	Yes	Yes	No	No
Strong double dividend test is $MCF_{t_2}^d < MCF_{t_1}^d$?	Yes	Yes	Yes	Yes

analysis, it becomes optimal to increase the level of road capacity and to finance this increase by raising an indirect tax or by reducing the poll transfer.¹⁰

Our theoretical framework takes into account not only the direct impact of a policy change on the externality but also the feedback effect of the externality on the consumption of the commodities (see the feedback parameter ξ and the last term in the denominator of (11), (14) and (30)). In our case study the feedback effect turns out to be less important for all tax instruments. The last column of Table 6 reports the MCF computed without feedback effect and the associated

¹⁰It 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 with respect to the other instruments could in some cases be reversed.

ranking of the policy instruments for $\varepsilon=0$. As regards the tax instruments, the largest difference is found for the tax on peak car transport, where the feedback reduces the welfare cost of the tax by $\sim 6\%$. Increasing the tax on car use in the peak period reduces congestion, which makes heavily taxed car use again more attractive for consumers. The feedback effect for the taxes on the other commodities is much smaller. For road capacity the feedback effect is quite substantial: it increases the MCF_R by some 45%. The feedback effect reduces the public revenue cost of an increase in road capacity because less congestion attracts more (heavily taxed) car transport. This is the expected ‘Pigou-effect’ of public investments.

Table 7 can be used to assess the possibility of realizing a double dividend. 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. The lower part of Table 7 shows that for low degrees of inequality aversion ($\varepsilon=0$ and $\varepsilon=1$) the direct welfare gain that can be obtained by returning the externality tax revenue through lower distortionary taxes (t_1 or t_3) is higher than when it is redistributed through a higher poll transfer. This means that in these cases a weak double dividend can be realized. However, for higher degrees of inequality aversion ($\varepsilon=5$ and $\varepsilon=10$) there is no weak double dividend.

From Table 7 it is also clear that for all values of ε a strong double dividend can be obtained:¹¹ 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^d of t_2 is always smaller than that of t_1 . It can be explained by the low own price elasticity of peak car transport so that the efficiency losses of taxing car use are smaller than for other commodities (Ramsey rule). So, even without considering the externality effects, these policy reforms are welfare improving.¹² All other policy reforms are characterized by a trade-off between the impact on direct welfare and that on the externality.

4.4. The net welfare effect of revenue neutral marginal policy reforms

Table 8 summarizes the policy results for $\varepsilon=0$ and shows their sensitivity to the valuation of the externality. The first two columns present the net marginal welfare effect of a higher tax on peak road transport and an increase in road capacity, with various recycling or financing strategies. Each element of these two columns is constructed by taking the difference between two elements of Table 6. A negative

¹¹The same double dividend conclusions are obtained when MCF^* (see footnote 4) rather than MCF^d is used to assess the presence of a weak or strong double dividend.

¹²Obviously, these results depend on the presence of inefficiencies in the initial tax structure. Moreover, a given initial tax structure is generally only optimal for one degree of inequality aversion. When other ε -values are considered, it is not surprising to find welfare improving tax reforms.

Table 8

The net marginal welfare effect of policy reforms involving t_2 and R and its sensitivity to the valuation of the externality ($\varepsilon=0$)

		Net marginal welfare effect		Marginal social WTP for a reduction in congestion:	
		Increase t_2	Increase R	critical value/actual value	
				Increase t_2	Increase R
Revenue recycled/instrument financed by:					
Indirect tax on comp. comm.	t_1	0.91	2.83	–5.9	0.4
Indirect tax on peak car tp	t_2		3.74		0.2
Indirect tax on off-peak car tp	t_3	0.70	3.04	–2.8	0.4
Indirect tax on public tp	t_4	–0.23	3.97	2.3	0.2
Poll transfer	P	0.28	3.47	–1.3	0.3
Road capacity	R	3.74		0.2	

value corresponds with a welfare loss. The first column shows that a higher tax on peak car transport increases welfare when its revenue is used to cut the taxes on most other commodities, to raise the poll transfer or to expand road capacity. The highest welfare gain is obtained when road capacity is expanded. This is explained by the high welfare gain of a net reduction in congestion which outweighs the net direct welfare loss of the policy reform. As can be seen from the second column of Table 8, road capacity expansion is always welfare improving whatever the way in which it is financed. Again, this conclusion depends on the too low initial level of road capacity and on a correct calculation of the social cost of infrastructure. The net welfare gain of the revenue neutral substitution of the tax on peak car transport for a tax on the other commodities (except that on public transport) can be traced back to the relatively low price elasticity of peak car transport and the welfare gain associated with the lower congestion level. Using the revenues of t_2 to increase the subsidy on public transport is not interesting because the welfare impact of the lower congestion level is offset by the high tax revenue cost of stimulating the consumption of strongly subsidized public transport.

4.5. The sensitivity to the measurement of the externality benefits

Measuring the marginal social WTP for a lower congestion level is difficult.¹³ Therefore, the last two columns of Table 8 report by how much the valuation of congestion can change and still leave the policy conclusions for a particular tax reform or a public abatement operation unaltered. The columns present the ratio

¹³ Besides the uncertainty about the marginal social WTP for less congestion one can also point to the uncertainty about the technical relationship (the speed-flow relationship) that links the road congestion level to the consumption of peak car transport.

between the critical value (the policy reversion value as defined in footnote 2) and the actual value of the marginal social WTP for a reduction in congestion. The marginal social WTP actually has to be negative in order to make the revenue neutral substitution of the tax on peak car transport for most other taxes (except that on public transport) an uninteresting policy option. The reason is the dominance of the positive net direct welfare impact. Recycling the peak car tax revenue through higher subsidies for public transport only becomes welfare improving when the value attributed to a reduction in congestion is 2.3 times the actual value. Road capacity expansion financed by higher commodity taxes or by a cut in the poll transfer is worthwhile undertaking even if the value of the marginal social WTP for a reduction in congestion is lower than the actual value (e.g. if the road capacity expansion is financed by a higher tax on peak car transport, a net welfare gain still results if the marginal social WTP is 20% of the actual value or higher).

5. Conclusions

The paper contributes in three ways to the existing theory on marginal tax reform in the presence of externalities. It 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. The data requirements for carrying out the analysis in that context are shown to be more difficult than for the traditional marginal tax reform analysis. It is demonstrated how the net welfare effect of an increase in the congestion tax depends on four factors: the efficiency effect of the tax revenue recycling, the externality benefit, the distributional characteristic of the consumption commodities and of the externality benefits and the feedback effect of the externality on the consumption of the taxed commodities. Among these factors the feedback effect is found to be less important, except for the welfare cost of public abatement.

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 A. Description of the data sources for the marginal tax reform illustration

A detailed description of the data is presented in Mayeres, (1999, Chapter III).

(a) The tax rates and the poll transfer.

The data for the tax rates and the level of the poll transfer are taken from a combination of sources. The normalized tax rates are calculated such that labour is the untaxed commodity. The underlying marginal tax rate on labour is 40.50%.

(b) Spending on the taxed commodities.

In the household budget survey of 1986–1987 information is found on the spending on taxed commodities of the different consumer groups ($q_m x_m^i$) and aggregate spending on these commodities ($q_m X_m$). This is combined with transport data.

(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.

(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

$$\beta^i = (y_E^i / y_E^1)^{-\varepsilon}.$$

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 O’Mahony et al. (1997). 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

$$Z = \alpha_1 + \alpha_2 e^{\alpha_3 X_2/4}$$

X_2 is the number of vehicle km driven in the 4-h 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.

(f) 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.

(g) Elasticities.

The aggregate income elasticities of the demand for the taxed commodities are based on the Belgian household budget survey of 1986–1987. The uncompensated own price and cross price elasticities of the transport commodities are based on the transport literature. One typically finds (Goodwin, 1992) that the own price elasticity of car transport is smaller in the peak than in the off-peak period. The own price elasticity of public transport in the literature is close to -0.5 . The elasticity of car use with respect to congestion is based on Small (1983). As off-peak travel and public transport are substitutes to peak travel, the elasticity of these goods with respect to the externality should be positive but small. The own price elasticity of leisure is chosen such that the average own price elasticity of the labour supply is 0.16, a value which is close to the one used in the large computable general equilibrium models in the Shoven–Whalley tradition (see, e.g., Ballard et al., 1985). The other demand elasticities are derived such that all properties of Hicksian and Marshallian demand functions are satisfied. The elasticity of the externality with respect to its determinants follows from the assumptions on the demand elasticities and the congestion function.

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