Regional Science and Urban Economics 31 (2001) 453–470
regional SCIENCE & urban ECONOMICS
www.elsevier.nl/locate/econbase

Should diesel cars in Europe be discouraged?

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Abstract

This paper examines the rationale for the different tax treatment of gasoline and diesel cars currently observed in Europe. First, we analyse possible justifications for a different tax treatment: pure tax revenue considerations, externality considerations and constraints on the tax instruments used for cars and trucks. Next, an applied general equilibrium model is used to assess the welfare effects of revenue-neutral changes in the vehicle and fuel taxes on diesel and gasoline cars. The model integrates the effects on tax revenue, environmental externalities, road congestion, accidents and income distribution. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Taxation; Externalities; Gasoline and diesel cars

JEL classification: H2; H23; R41; D58

1. Introduction

In Europe, the share of diesel cars has been growing strongly. In the UK, diesel cars accounted for 3% of the car stock in 1990. They will represent almost 15% of the car stock in 2000. The market share of diesel cars varies strongly over the different countries. In 1995 it was smaller than 10% in Finland and in Greece, while in Belgium and France, it amounted to 39 and 28%, respectively (Auto-oil programme, 1999).

The relative taxation of diesel and gasoline cars is one of the most important

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0166-0462/01/$ – see front matter
PII: S0166-0462(00)00082-X

policy variables in passenger transport. This paper analyses positive and normative aspects of the tax treatment of diesel and gasoline. We start with a comparison between different EU countries of the market share of diesel cars. This is put in relation to the differences in the tax treatment. We show that the relative share of diesel cars can be explained principally by tax variables. The next section examines the theoretical prescriptions for the relative taxation of diesel and gasoline cars.[1] Three aspects are analysed: pure tax efficiency, environmental damage and the link with the use of diesel by trucks. The final section of the paper uses an applied general equilibrium model to assess the welfare effects of revenue-neutral changes in the vehicle and fuel taxes on diesel and gasoline cars. This model integrates the different government objectives: raising tax revenue, environmental goals, transport policy goals and income distribution concerns.

The main result of the paper is that it is difficult to justify the present favourable treatment of diesel cars in the European Union. It is shown that a revenue-neutral shift, which consists of discouraging diesel cars and of favouring gasoline cars via a change in ownership taxes, can generate important welfare gains. This is explained by two reasons. First, even when the different external costs of the two car types are not considered, welfare can be improved by shifting taxation from gasoline to diesel cars. The tax on gasoline car use is very high in comparison to that on diesel car use. Reducing it makes it possible to achieve large welfare gains which are only partly undone by the distortions created by the higher diesel tax. Secondly, the environmental costs of diesel cars are much higher than those of gasoline cars. Diesel cars have high emissions of particulate matter, which have a high social cost.

The emphasis in this paper is on the relative taxation of two car types. The policy changes examined are limited to revenue-neutral changes using the existing tax instruments. Other promising tax reforms focussing on the substitution of fuel taxes by road pricing are not considered in this study.[2]

2. The growing share of diesel cars and their fiscal treatment

Table 1 shows that the share of diesel cars in the car stock differs strongly over EU countries. In Belgium and France, diesel cars are expected to have a share close to 40% in 2000. Taking into account the larger mileage of diesel cars, more passenger car miles will be driven by diesel car than by gasoline car. In some

[1] A related paper is De Borger (2000), which analyses optimal two-part tariffs in the presence of externalities within the framework of a discrete choice model and which looks at the implications for the optimal tax treatment of diesel and gasoline cars.

[2] See Proost and Van Dender (2001) and Mayeres (2000) for a comparison of the likely effects of different transport and environment policies on welfare.

Table 1
The share of diesel cars in the car stock[a]

	1990	1995	2000
Belgium	33	39	43
Finland	10	8	5
France	17	28	35
Germany	14	14	16
Greece	3	2	1
Ireland	9	12	14
Italy	20	14	11
Netherlands	12	11	11
Spain	17	17	16
UK	3	8	14
Europe	14	16	17

[a] Source: Auto-oil programme (1999) and own computations.

countries (UK, Ireland, France and Belgium) the diesel share is growing strongly, while in others, it is stable or falling.

The overall growth in the diesel share can be due to technological changes. The arrival of smaller and more performant diesel engines (turbo and direct injection) in the 1990s means that the performance of diesel cars and gasoline cars is almost the same. Given the fact that the producer prices of diesel cars have not dropped more than those of gasoline cars, this could explain the growing share with unchanged tax parameters. However, as more or less the same car models are offered on the different European car markets, the differences in the diesel share have to be explained by differences in preferences and/or differences in tax treatment. Table 2[3] gives an idea of the car ownership costs and the fuel costs in 1998 of the two types of vehicles, with and without taxes. Low diesel shares can be found in those countries where there is either a relatively higher tax on the ownership of diesel cars (Finland, The Netherlands, Greece) or where relatively high fuel taxes on diesel are present (UK and Ireland).

Table 1 shows changes in the share of diesel cars in the car stock. It is more instructive to analyse the changes in car sales. An econometric analysis of the share of diesel cars in total car sales in nine European countries over the period 1990–96, using a fixed effects logit model, shows that the lifetime cost of car use is the most significant determinant of the gasoline/diesel choice (Janssen, 1999).

[3]Table 2 makes a comparison between medium diesel cars (1400–2000 cc) and small gasoline cars (<1400 cc) because these two car types have corresponding engine power. These categories also form an important segment of the car market. The lifetime fuel costs are calculated using the following assumptions: an average lifetime of 10 years, an average fuel use of 6.9 1/100 km for diesel cars and 8.3 1/100 km for gasoline cars, an average annual kilometrage of 20000 km/year and a real interest rate of 4%.

Table 2
Price and tax differences between diesel and gasoline cars in 1998[a]

	Belgium	Finland	France	Germany	Greece	Ireland	Italy	Netherl.	Spain	UK
Car ownership costs (Euro)										
Medium diesel car										
Net price	11 832	15 592	13 245	13 058	13 308	11 613	14 285	12 028	13 689	13 689
Taxes	5188	24 112	3359	4237	6234	7972	5889	15 376	3735	3914
Small gasoline car										
Net price	8594	11 256	9294	9427	8893	9559	9546	9678	9504	9504
Taxes	2991	14 288	2241	2065	3421	6256	2667	7951	2841	4642
Lifetime fuel costs (Euro)										
Medium diesel car										
Net fuel costs	2465	2695	1930	1984	1885	2781	2443	2539	2294	1884
Taxes	4644	4959	5648	4642	3533	5321	5945	5131	3991	9594
Small gasoline car										
Net fuel costs	2980	2960	2453	2572	2989	3208	3278	3400	2983	2314
Taxes	9272	10 271	10 515	8603	5908	7187	9606	10 112	6458	11 260
Cost difference: medium diesel — small gasoline (Euro)										
Car ownership										
Net price	3238	4336	3951	3631	4415	2054	4739	2350	4185	4185
Taxes	2197	9824	1118	2171	2813	1716	3222	7424	894	−728
Total	5435	14 160	5069	5802	7228	3770	7961	9774	5079	3457
Lifetime fuel costs										
Net fuel costs	−515	−264	−523	−588	−1104	−427	−835	−862	−689	−430
Taxes	−4628	−5312	−4866	−3961	−2374	−1866	−3661	−4981	−2468	−1666
Total	−5143	−5576	−5389	−4549	−3478	−2293	−4496	−5842	−3156	−2096
Break-even average annual km for diesel	21 136	50 789	18 812	25 511	41 562	32 886	35 415	33 462	32 179	32 987

[a] Source: Auto-oil programme (1999) and own computations.

The fixed effects represent the differences in preferences between different European countries.

A more thorough analysis of Table 2 shows that the car manufacturers absorb part of the tax advantages of diesel cars by adjusting their sales prices accordingly. Verboven (1996) examined the price setting behaviour on the monopolistic European car market and found that the manufacturers adjusted the pre-tax prices in function of the overall taxation level and of the gasoline–diesel tax differential. This implies that the relation between relative tax levels and relative user prices is not one to one. The price discrimination on the different national markets was possible because car manufacturers made parallel imports from other countries very difficult. In the future, the possibilities for price discrimination will decrease because of a reinforced European competition policy.

3. What is the appropriate tax treatment of diesel and gasoline cars?

This question has many aspects and is probably too difficult to grasp in one simple theoretical model. We therefore proceed in three steps. We first give the main intuition using a simple model for the optimal taxation of private passenger car transport in the presence of fiscal revenue requirements and different types of external costs. In the second step, we discuss the appropriate tax treatment of professional car use. In the final step, we discuss different complications that may arise in an open economy when there are restrictions on the available tax instruments.

3.1. Optimal taxation of diesel and gasoline car use for consumption purposes

We use a simple model for a closed economy with N identical consumers. There are three commodities: car kilometres driven by gasoline car (x_G), car kilometres driven by diesel car (x_D) and a composite commodity, including all other commodities. The composite commodity is assumed to be untaxed. It serves as numéraire. Its marginal and average production cost equals unity and is assumed to be constant. The marginal and average production costs of gasoline and diesel kilometres are assumed to be fixed. They are denoted by p_G and p_D. It is assumed that all commodities are produced by perfectly competitive industries.

There are two types of externalities in the economy: those linked to total car km (congestion, accidents) and those linked to the type of fuel used (air pollution). The first category is represented by the total external cost function $EC(X)$ which is an increasing function of total car km $X = N(x_G + x_D)$. The second category is given by $EF_i(Nx_i)$ ($i = G, D$; $\partial EF_i / \partial x_i > 0$).

We assume furthermore that the government is interested in raising a given total

R of fiscal revenue from the use of cars.[4] The optimal taxation problem of the government is then to choose the taxes on x_G and x_D (t_G and t_D) such that the social welfare function (W) is maximised subject to the government budget constraint:

$$\begin{aligned}&\mathrm{Max}_{t_G,t_D} \quad W = NV(1, q_G, q_D, Y) - EC(X) - \sum_{i=G,D} EF_i(Nx_i)\\&\text{s.t.}\\&Nt_Gx_G + Nt_Dx_D \leq R \quad (\mu)\end{aligned} \tag{1}$$

q_i is the consumer price of commodity $i(q_i = p_i + t_i)$. $V(1, q_G, q_D, Y)$ is the consumer's indirect utility function, and Y denotes his income. μ is the Lagrange multiplier associated with the government budget constraint. In an interior solution, the optimal tax rates have to satisfy the following type of conditions[5] as well as the revenue requirement:

$$\frac{\left(t_i + \dfrac{MEC + MEF_i}{\mu/\lambda}\right)}{q_i} EL_{ii} + \frac{\left(t_j + \dfrac{MEC + MEF_j}{\mu/\lambda}\right)}{q_j} \frac{q_j x_j}{q_i x} EL_{ji} = \frac{1}{\mu/\lambda} - 1$$
$$i, j = G, D; i \neq j \tag{2}$$

MEC and MEF_i are defined as follows:

$$MEC = -(1/\lambda)(\partial EC/\partial X) \tag{3}$$

$$MEF_i = -(1/\lambda)(\partial EF_i/\partial X_i) \quad i = G, D \tag{4}$$

MEC stands for the marginal external cost of car km that is not related to fuel use. MEF_i is the marginal external cost related to the use of fuel i. λ represents the marginal private utility of income, so that μ/λ stands for the marginal cost of public funds, that is, the welfare cost of raising one more unit of tax revenue via taxes on the use of cars. EL_{ij} ($i,j = G, D$) stands for the uncompensated own-price and cross-price elasticities. We will now discuss the implications of (2) in more detail.

3.1.1. Optimal taxes in the absence of externalities

In the absence of externalities and in the absence of cross-price effects, (2) boils down to the traditional Ramsey rules that imply that the tax distortion (in percentage terms) should be inversely proportional to the own-price elasticity:

[4] It is assumed that R does not enter the utility function, or equivalently, that it enters separably. Mayeres and Proost (1997) study — in a more general framework — the implications when a public good enters the utility function in a non-separable way.

[5] For the derivation of these conditions, see Appendix A.

$$\frac{t_i}{q_i} = \left(\frac{1}{\mu/\lambda} - 1\right)\frac{1}{EL_{ii}} \quad i = G, D \tag{5}$$

If car kilometres driven by diesel and gasoline cars both have the same price elasticity, an identical tax rate (in percentage terms) would be optimal. The level of the tax rates would be determined by the revenue requirement via the marginal cost of public funds, μ/λ.

In the absence of externalities but with cross price effects the Ramsey tax expression becomes less straightforward. When there are strong substitution possibilities between diesel and gasoline, any difference in tax treatment generates high welfare losses because consumers make efforts to save taxes and this is inefficient. To see this more clearly, we can analyse the marginal welfare cost of raising one extra unit of government revenue via an increase in the tax on gasoline km (MCF_G). It is given by:

$$MCF_G = \frac{\lambda N x_G}{N x_G\left(1 + \frac{t_G}{q_G} EL_{GG} + \frac{t_D}{q_D}\frac{x_D q_D}{x_G q_G} EL_{DG}\right)} \tag{6}$$

The numerator is the social welfare cost of increasing the consumer price of gasoline km.[6] The denominator gives the effect on government revenue of an increase in t_G.[7] When diesel and gasoline km are good substitutes, which is a realistic case, the cross-price effect of gasoline prices on diesel km is large and positive. In that case a large tax on diesel car use implies smaller welfare losses of raising one extra unit of government revenue via a higher tax on gasoline car use. Note that a similar expression holds for t_D and that in the optimum the welfare cost of raising revenue by means of t_G and t_D should be equal.

3.1.2. Optimal taxation in the presence of externalities

When externalities are introduced, expression (2) shows that the optimal tax rules change. The tax on car km now consists of two components: a revenue raising component and an externality component. The revenue raising component is governed by similar considerations as in the case without externalities. The externality component on both types of car use consists of two parts: a part related to the air pollution externality (MEF_i) and a part related to the other externalities (MEC). The MEC is identical for both car types and this implies that in this case an identical externality charge per kilometre is called for. If fuel is used as tax base, this means that the tax that covers the congestion and accident externalities

[6] Differentiate the first term of W w.r.t. t_G and use Roy's identity.

[7] Differentiate government revenue ($Nt_G x_G + Nt_D x_D$) w.r.t. t_G and rearrange, using the definition of EL_{ij}.

should be inversely proportional to the fuel consumption per kilometre. A proportional tax per litre or an identical excise per litre is then not optimal.

The optimal tax expressions also tell us that the externality component of the tax on car km becomes less important vis à vis the revenue raising component when the marginal cost of public funds (μ/λ) increases. This is the case when the revenue needs to finance public goods or transfers to the poor become more important.

The model used here is a simple model with only three commodities and a fixed amount of government revenue R that needs to be raised from private car transport. This simple model is sufficient to discuss the relative taxation of the two types of cars when we adopt the following two assumptions. The first assumption is that gasoline and diesel car km stand in the same complementary relationship with other consumption goods and in particular with labour supply. If this assumption is not satisfied, reducing the tax rate on the good that is more complementary with labour reduces the efficiency losses of the labour tax. The second assumption is that both types of cars are used in the same proportion by the different income classes.[8]

3.2. Optimal taxation of the commercial use of gasoline and diesel cars

An important share of total car km is for commercial purposes. In the absence of externalities, and if taxes on labour and consumption can be set optimally, Diamond and Mirrlees (1971) show that taxes on intermediate goods should equal zero, so that productive efficiency is preserved. Therefore, commercial car use should not be taxed at all in the absence of externalities.

When externalities are present and have the same dual structure as in the previous section, the optimal externality tax equals the marginal external cost and the marginal cost of public funds plays no role (Mayeres and Proost, 1997).

3.3. Restrictions on the use of tax instruments

The tax treatment of gasoline and diesel cars may be restricted by several constraints. Three main types of constraints should be taken into account. First, there is the impossibility to tax car use directly, such that only inputs for car use can be taxed. Secondly, there is the difficulty to distinguish between the private and the commercial use of cars. Moreover, it can be difficult to know whether diesel fuel is used for commercial car use or for use in trucks. Finally, due to the proximity of borders in Europe, cars and trucks can fuel abroad, which limits the possibilities to use the fuel tax instrument.

At present electronic road pricing does not yet exist so that the taxation of road

[8] One can consult Atkinson and Stiglitz (1980, lecture 12) for a more detailed treatment of this problem.

use means a combination of taxes on ownership (including registration taxes, circulation taxes, taxes on insurance, etc.) and taxes on fuel use. Fuel use is probably a better tax basis for externality taxes than the ownership of a car. Nevertheless, fuel taxes have a number of shortcomings. Too high fuel taxes will lead to too much fuel saving efforts by car users. Moreover, fuel taxes cannot be differentiated according to time of day, location or the emission technology of the vehicle. Some of these shortcomings can be remedied partly by the use of ownership taxes. An ownership tax offers extra discrimination possibilities since it can be differentiated as a function of the location of the owner (more or less congested area) or as a function of the air pollution characteristics of the car (the presence or absence of a catalytic converter, etc.).

The second type of restrictions has to do with the fact that it is costly for the tax authorities to observe the type of use that is made of a car and of the fuel. The largest problem exists for the tax on diesel fuel, since it is used both by cars and trucks. In addition, it is difficult to distinguish between private and professional car use and fuel consumption. Table 3 summarises three administrative tax differentiation possibilities for diesel fuel and diesel cars.

In case A, full discrimination is possible. In case B, no discrimination is possible according to who uses the fuel. Firms use diesel fuel for their trucks and cars. Diesel cars are driven both for professional and for private purposes. The tax authority cannot distinguish between the three uses. With a constant mileage per vehicle and if there was strict complementarity in the use of car km and fuel consumption, this would offer the same tax possibilities as case A. However, this is not very realistic. The implication is that taxing only one of the two inputs at its ideal rate is less efficient. In case B the price of diesel fuel is therefore an instrument that is used as externality tax instrument for cars and for trucks.

Case C arises when it is difficult to distinguish between car ownership and car use for private and for commercial purposes. Whenever commercial use is taxed less, it pays for consumers to represent private ownership and use as business use.

Cases A, B and C have been presented as well-defined cases, while in fact it is more a matter of balancing costs and benefits. In reality, discrimination between

Table 3
Tax discrimination possibilities for diesel fuel and diesel cars

Commodities and their use	A	B	C
Vehicle ownership			
Diesel car, households	t_1	t_1	t_1
Diesel car, production sectors	t_2	t_2	t_1
Diesel truck, production sectors	t_3	t_3	t_3
Fuel consumption			
Diesel car, households	t_4	t_4	t_4
Diesel car, production sectors	t_5	t_4	t_4
Diesel truck, production sectors	t_6	t_4	t_4

different uses is possible but this requires large monitoring and inspection resources from the tax authorities and generates the use of many resources by citizens for tax evasion and tax fraud. Both types of waste have to be balanced against economic efficiency gains through better taxation.

Limitation of tax discrimination possibilities between different uses leads to two policy prescriptions. First, vehicle ownership taxes are the principal instrument to differentiate the taxation between car and truck use. Secondly, it is difficult to use revenue raising taxes on private car ownership and use when the distinction between private and commercial use is difficult.

The third source of restrictions is the possibility of fuel tourism, mainly by trucks. This can have important implications. First, in small countries with a lot of transit truck transport, the maximisation of tax revenue becomes an important objective besides the internalisation of external costs. Consideration of the revenue raising objective will it make attractive for the government to undercut slightly the taxes of neighbouring countries (see Kanbur and Keen, 1993). Secondly, it means that fuel becomes an even less interesting tax base for cars.

The conclusion of this section therefore is that ownership taxes on diesel cars are an important instrument in the presence of restrictions on the tax instruments.

4. Tax reform analysis

This section investigates numerically the possibilities for welfare improving changes in the taxation of gasoline and diesel vehicles and fuel. The analysis focuses on revenue-neutral marginal tax reforms. It proceeds as follows. First, we use an applied general equilibrium model to calculate the marginal costs of public funds (*MCF*) of three types of instruments: the vehicle ownership tax on gasoline and diesel cars, and the excise and the VAT on gasoline and diesel fuel. In a next step, the *MCF* of these instruments are compared. From the tax reform literature (see Mayeres and Proost, 2001), we know that in the optimum the *MCF* should be equal for all tax instruments available to the government. If this is not the case, and if, for example, $MCF_i > MCF_j$ $(i \neq j)$, then welfare can be improved marginally by increasing the tax on commodity j and cutting simultaneously the tax on commodity i, such that government revenue is unaffected.

The exercise is performed for Belgium, using an applied general equilibrium model. The model is described in a detailed way in Mayeres (1999). It is a model for small open economy, calibrated to the situation in Belgium in 1990. It includes four categories of economic agents: non-identical consumers (corresponding with the quintiles of the Belgian household budget survey), fourteen production sectors, the government and the rest of the world. Several transport commodities are considered in the model. It makes a distinction between passenger and freight transport, between three transport modes (road, rail and inland navigation), between vehicle types and, for road transport, between peak and off-peak transport. The model considers three types of transport externalities: congestion, air pollution, and accidents. The model assumes that air pollution and accidents affect the consumers' welfare, but not their behaviour. Congestion also has a negative impact on the consumers' welfare, but in addition it affects the transport choices of the consumers.[9]

4.1. A description of the simulations

The simulations are of the balanced-budget incidence type: we introduce a small increase in government expenditure[10] and assume that it is accompanied by a change in a tax instrument such that government budget balance is maintained. The following tax instruments are considered:

(a) *The vehicle ownership tax:* this instrument consists of increasing the vehicle ownership tax to be paid annually by the owners of gasoline or diesel passenger cars. Both households and production sectors are subject to the tax increase.

(b) *The fuel excise:* the excise on gasoline or diesel fuel is raised. The fact that the excise rather than the VAT is raised, makes that both the consumers and the domestic producers face a higher tax on the use of these fuels. Foreign road transport users are not subject to the tax increase, since the model assumes that they buy their fuel abroad. The tax rate on fuel used by rail transport and inland navigation is kept constant.

(c) *The VAT rate on fuel:* the VAT rate on diesel or gasoline is increased. Only the households are subject to this tax increase.

For each instrument g, the marginal cost of public funds is calculated. It is defined as the marginal cost in terms of social welfare of raising an additional unit of government revenue by means of each instruments g. It is given by the negative of the ratio between the monetary value of the change in social welfare ($\mathrm{d}W_g$) and the change in government revenue ($\mathrm{d}REV_g$) brought about by instrument g. The change in government revenue takes into account the effect on the tax revenue from all taxed commodities.

$$MCF_g(\varepsilon) = -\frac{\mathrm{d}W_g(\varepsilon)}{\mathrm{d}REV_g} = -\frac{\sum_{i=1}^{5} a^i SG_g(\varepsilon)}{\mathrm{d}REV_g} \tag{7}$$

It depends on the degree of inequality aversion ε. A value of $\varepsilon = 0$ means that the social welfare function gives an equal weight to the welfare of individuals belonging to different consumer groups. As the value of ε increases, society has a higher degree of inequality aversion. In expression (7) a^i is the number of

[9] In reality air pollution and accident risks also affect the consumption choices. Such feedback effects are not yet included in the model.

[10] We assume that the accompanying change in the level of government spending does not affect the behaviour of the consumers.

consumers in quintile *i*. SG_g is the social equivalent gain (King, 1993) associated with an increase in instrument *g*. It is defined as the sum of money which, if equally distributed to all individuals in the initial equilibrium, would produce a social welfare equal to that obtained after the change in the tax system.

For reasons of comparability it is assumed that each instrument generates an equal real yield.

The findings of the model are compared with the *MCF* calculations for a model which is identical to the first one, except that it assumes the speed of road transport, the emissions and the accidents to remain constant at the level of the initial equilibrium. It can be interpreted as a model without externalities. The *MCF* calculated by this model is referred to by MCF^*.

The MCF calculations are made for the existing tax system in the benchmark year 1990. In that year the marginal labour income tax was 45% and the capital income tax rate was 24%. Together they raised 66% of government revenue. The VAT, vehicle ownership taxes and other indirect taxes raised another 24% of government revenue. In 1990 government spending amounted to approximately 50% of GDP.

4.2. The marginal external costs of transport and the taxes in the reference equilibrium

The simulations start from the situation in Belgium in 1990. Table 4 gives an estimate of the various marginal external costs associated with car and truck

Table 4
The marginal external costs and the tax in the reference equilibrium

	Gasoline car			Diesel car			Truck		
	Peak	Off-peak	Weighted average[a]	Peak	Off-peak	Weighted average[a]	Peak	Off-peak	Weighted average[a]
Marginal external costs (Euro/vkm)									
Congestion	0.23	0.04		0.23	0.04		0.46	0.09	
Air pollution	0.01	0.01		0.03	0.03		0.10	0.10	
Accidents	0.03	0.03		0.03	0.03		0.02	0.02	
Total	0.27	0.08	0.15	0.29	0.11	0.17	0.57	0.20	0.27
Tax (Euro/vkm)									
Private[b]	0.10 (36%)	0.10 (118%)	0.10 (65%)	0.06 (21%)	0.06 (58%)	0.06 (35%)			
Business[b]	0.04 (14%)	0.04 (47%)	0.04 (26%)	0.02 (8%)	0.02 (23%)	0.02 (14%)	0.12 (21%)	0.12 (60%)	0.12 (45%)

[a] Weighted average of peak and off-peak marginal external costs and taxes. The share of peak vkm in total vkm is 65% for cars and 20% for trucks.

[b] The figures within brackets give the tax as percentage of the marginal external costs.

transport in Belgium in the reference equilibrium. They are expressed in Euro per vehicle km (vkm). The figures presented are averages for Belgium. The simulations will consider only spatially undifferentiated transport policies. For more details on the derivation of the marginal external congestion and accident costs, see Mayeres (1999). The air pollution costs take into account the costs of the emissions of NO_x, SO_x, NMVOC, CO, CO_2 and $PM_{2.5}$. Table 4 is constructed using for each vehicle type emission factors for an average vehicle in 1998. The emission factors are based on European Commission (1999). The monetary valuation of the transport emissions in Belgium of all pollutants except CO_2 is taken from De Nocker et al. (2000) who apply the ExternE methodology to Belgium.[11] The ExternE study uses the impact pathway methodology, which undertakes the following steps for calculating the costs of emissions: simulation of atmospheric dispersion, impact assessment with dose–response functions and monetary valuation of the impacts. The effects on health are the dominant impacts. The monetary valuation of CO_2 emissions (14.55 Euro/tonne CO_2) is based on Fankhauser (1995).

The table compares the marginal external costs with the tax paid per vkm. The tax contains taxes on the ownership of vehicles, as well as fuel excises and VAT (for households).[12] Since this paper only presents simulations for transport instruments which cannot be differentiated according to the period of travel, the table also compares the tax per vkm with a weighted average of the marginal external costs in the peak and the off-peak period.

The first conclusion that we can draw from Table 4 is that the marginal external costs of diesel cars are higher than those of gasoline cars. This is due to the high air pollution damage attributed to particulate emissions in the ExternE methodology. Diesel cars emit more $PM_{2.5}$ per vkm than gasoline cars. Diesel cars have lower emissions of CO_2 and CO but the damage that is attributed to these pollutants is relatively small.

The second conclusion is that the difference in marginal external costs is not reflected in the relative tax rates. At least for business uses, diesel car use should be taxed more than gasoline use, as their taxes should approximate marginal external costs, if the government can make use of perfect instruments. We see that the reverse holds (for example, in the peak period the tax amounts to only 8% of the marginal external costs). Also for diesel trucks the tax is smaller than the marginal external costs. For consumptive uses, there is an even larger gap between

[11] De Nocker et al. (2000) present values for 2000. They are converted to 1990 by using an elasticity of 0.3 for the marginal willingness-to-pay for a reduction in emissions w.r.t. income and combining this with the annual income growth rate between 1990 and 2000. This gives the following costs per unit of emissions (in prices of 1998): 200.2 EURO/kg $PM_{2.5}$, 8.4 Euro/kg SO_x, 1.1 Euro/kg NO_x, 1.5 Euro/tonne CO and 1.5 Euro/kg NMVOC.

[12] The AGE model is a static general equilibrium model and models the effects of transport policies on both vehicle ownership and vehicle use. This explains why the ownership taxes are included in the tax per vkm.

the tax treatment of diesel and gasoline cars: the tax on diesel car use is 0.04 Euro/vkm lower than that on gasoline car use.

A third conclusion is that taxes on car and truck use are in general too low to cover marginal external costs (except for off-peak gasoline cars). This is also the case when we compare the tax with the weighted average of the marginal external costs in the peak and the off-peak.

4.3. The simulation results

Table 5 summarises the simulation results for the efficiency case ($\varepsilon = 0$). The results for higher degrees of inequality aversion are not significantly different from those presented in Table 5.[13] Therefore they are not reproduced here.

It should be noted that the marginal welfare costs of the fuel taxes are likely to be underestimated. The AGE model does not yet take into account the possibility to switch to more fuel efficient vehicles or the existence of fuel tourism. Taking into account these two aspects can be expected to increase the MCF of the excise and VAT on fuels.

Table 5 shows that even when one does not consider the transport externalities, welfare can be improved by increasing diesel taxation and by using the revenue to reduce gasoline taxation. This is the case for the three tax instruments considered here. Diesel use by road transport is undertaxed. For example, a higher vehicle ownership tax on diesel cars accompanied by a lower vehicle ownership tax on gasoline cars, together revenue neutral, yields a welfare gain of Euro 0.06

Table 5
The marginal cost of public funds

	AGE model without externality $MCF*$	AGE model with externalities			
		MCF	MCF^A	MCF^B	MCF^C
Vehicle ownership tax					
Gasoline car	1.21	1.07	1.09	0.00	−0.02
Diesel car	1.15	0.81	0.97	−0.11	−0.04
Excise					
Gasoline	1.29	1.05	1.07	0.00	−0.03
Diesel	1.11	0.71	0.90	−0.15	−0.04
VAT					
Gasoline	1.32	1.05	1.09	0.00	−0.03
Diesel	1.23	0.68	0.91	−0.16	−0.06

[13] The 1995–96 household budget survey for Belgium shows that the distribution of the consumption of car fuels over the quintiles is very similar for diesel and gasoline.

(=1.21–1.15) per Euro of shift in government revenue from one source to the other. So, following a pure Ramsey rule, it would be beneficial to increase the vehicle ownership taxes on diesel cars and to cut these taxes on gasoline cars. The relatively high *MCF** for the taxes on gasoline can be explained by the high tax rate on gasoline transport in the reference equilibrium. This means that even with a moderate own price elasticity for gasoline car ownership or car use, the taxes on gasoline should be increased by more in order to raise a given amount of government revenue, compared with the case of a lower initial tax rate. This leads to larger distortions. It should also be noted that in the case of diesel taxation, the *MCF** is smaller for the excise on diesel fuel than for the two other instruments. This is explained by the relatively large tax base of this instrument, which implies that the excise has to be raised less in order to finance the same increase in government spending.

Note that — ceteris paribus — the *MCF** of a tax on car ownership or use will be higher if the demand for these commodities becomes more sensitive to its own price. A higher own-price elasticity implies that large distortions are generated when raising a given amount of revenue. On the other hand, given the fact that gasoline and diesel are substitutes, a higher cross-price elasticity entails — ceteris paribus — a lower *MCF**. In that case, raising the tax on gasoline has a larger positive effect on the demand for taxed diesel, such that a given amount of revenue can be obtained with less distortions.

In the model with externalities the discrepancy between the *MCF* of gasoline and diesel becomes larger than in the model without externalities. The second part of Table 5 gives the results in this case. The table also decomposes the marginal cost of public funds into three terms.

$$MCF_g = MCF_g^A + MCF_g^B + MCF_g^C \tag{8}$$

The first term (MCF_g^A) is defined as the *MCF* when the emissions of air pollutants and the number of accidents are assumed to remain at the reference level. However, it takes into account the effect of the change in the congestion level. The second term (MCF_g^B) presents the marginal welfare impact associated with the change in emissions. The last term (MCF_g^C) is the marginal welfare impact of the change in accidents caused by the tax reform.

When externalities are taken into account, it is even more interesting to increase diesel taxation and to cut gasoline taxation. For example, consider an increase in the vehicle ownership tax on diesel cars, accompanied by an equal revenue cut in the same tax on gasoline cars. The benefit in the presence of externalities is Euro 0.26 (=1.07–0.81) per Euro of government revenue in the presence of externalities. The difference with the model without externalities is explained mainly by the welfare impact of the change in emissions caused by the tax reform, which equals Euro 0.11 (=0.00+0.11) per Euro of government revenue. The main reason is that diesel cars have higher emissions of particulate matter, which has a

Table 6
The effect of the tax reforms on the traffic flow

	Traffic flow: % change w.r.t. the reference equilibrium	
	Peak (%)	Off-peak (%)
Vehicle ownership tax		
Gasoline car	−0.06	−0.14
Diesel car	−0.09	−0.20
Excise		
Gasoline	−0.12	−0.18
Diesel	−0.12	−0.20
VAT		
Gasoline	−0.13	−0.20
Diesel	−0.18	−0.29

high social cost. The imposition of stricter emission standards for particulate matter could in the future reduce the environmental costs of diesel cars. Note, however, that our results show that even in the absence of externalities the relative taxation on diesel should increase.

Each instrument (vehicle ownership tax, excise and VAT) has more or less the same effect on congestion[14] and accidents whether it is applied to gasoline or diesel. In the model both external costs are determined mainly by the traffic flow. Table 6 gives the effect of the six tax reforms on the traffic flow. For the vehicle ownership tax and the VAT the effect of the tax on diesel is somewhat larger than for the tax on gasoline. This is because the tax base is smaller for these instruments and the tax on diesel needs to be raised more than that on gasoline in order to raise the same amount of real government revenue.

Note that the effect on the three externalities can be expected to be lower as the own-price elasticity of car ownership and use falls. Moreover, raising the tax on diesel will have less effect on pollution if the cross-price elasticity of the demand for gasoline with respect to diesel is higher.

5. Conclusions

In this paper we have studied the tax treatment of diesel cars. Recent evidence on environmental damages shows that diesel cars are more polluting than gasoline

[14]The AGE model does not yet incorporate the complementary relationship between labour and commuting transport. Considering this relationship would mean that the MCF of the transport instruments considered here will be somewhat lower than in Table 5. The beneficial effect of the instruments on congestion imply that the time costs of travelling to work are reduced and that at the margin labour supply will be higher than if this effect is not taken into account. This effect is considered explicitly by Parry and Bento (1999) and Calthrop et al. (2000).

cars. The obvious policy response would be to correct the relative taxation of diesel and gasoline cars to reflect this new information.

The fuel taxes and vehicle ownership taxes have to fulfil many objectives ranging from revenue raising to second best congestion tolls for cars and trucks. In the presence of large congestion externalities and in the absence of a road toll, the theoretical prescription is that taxes on diesel car use should be higher on a per km basis than taxes on the use of gasoline cars. This is an important change compared to the present practice that is closer to an equal percentage tax rule.

From a tax administration point of view, the change in the vehicle ownership taxes is the easiest way to alter the relative taxation of both types of cars. With a numerical model we show that a revenue neutral increase of diesel ownership taxes brings about important environmental as well as total welfare benefits.

Acknowledgements

The research reported in this paper was financed by the Fund for Scientific Research — Flanders, and the Sustainable Mobility Program initiated by the Belgian State — OSTC (project MD/DD/008). We thank Alain Henry for the provision of AUTO-OIL data and Leo De Nocker and Luc Int Panis for the provision of the ExternE results for Belgium. Valuable comments by the editor of this issue, by an anonymous reviewer and by participants at seminars in Leuven, Copenhagen and Crete (EAERE) are gratefully acknowledged. Any errors are the sole responsibility of the authors.

Appendix A

Using Roy's identity $((\partial V/\partial q_i) = -\lambda x_i)$, the F.O.C. for t_i can be written as:

$$
\begin{aligned}
& -\lambda N x_i - N\left(\frac{\partial EC}{\partial X} + \frac{\partial EF_i}{\partial (Nx_i)}\right)\frac{\partial x_i}{\partial t_i} - N\left(\frac{\partial EC}{\partial X} + \frac{\partial EF_j}{\partial (Nx_j)}\right)\frac{\partial x_j}{\partial t_i} \\
& + \mu N\left(x_i + t_i\frac{\partial x_i}{\partial t_i} + t_j\frac{\partial x_j}{\partial t_i}\right) = 0 \\
& i, j = G, D; i \neq j
\end{aligned}
$$

Using expressions (3) and (4), dividing by N, μ and x_i, and using the definitions of the own-price and the cross-price elasticities EL_{ij}, one obtains (2).

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