Fiscal Instruments for Air Pollution Abatement in Road Transport

By Ian Crawford and Stephen Smith*

1. Introduction

Tax reform has become an important element of environmental policy in a number of European countries. A recent OECD study reported a wide range of environmental tax measures in member countries (OECD, 1993). Some of these, such as the carbon taxes introduced by five European countries, are new taxes that have an explicit environmental rationale. Elsewhere, the impact of environmental policy on the tax system has been through the injection of environmental considerations into policy decisions on the level and structure of existing taxes. In contrast to the emissions taxes of textbook theory, therefore, much of the recent policy interest has concerned the scope for restructuring the tax system, so as to discourage products or activities which cause environmental damage.

Road transport has been a major focus of recent initiatives to “green” the tax system in OECD countries. Road transport is already the subject of a number of different taxes levied on motor vehicles and on motor fuels in most OECD countries. There is therefore considerable scope for environmental objectives to be reflected through the restructuring of these existing taxes rather than the introduction of wholly new environmental taxes or charges. One of the most widespread fiscal measures undertaken with an explicitly environmental rationale has been an excise tax differential in favour of unleaded petrol. Also, the level of motor fuel taxes is increasingly being determined with reference to the environmental effects of road transport.

Formulating appropriate policies towards the taxation of road transport is, however, far from straightforward, due to the varied range of social costs (externalities) associated with road use (congestion, accidents, road and environmental damage), and the complex interactions between road transport, other modes of transport and issues of spatial development. Road transport taxes would thus have to reflect the combined (and, perhaps, interacting) effect of different externalities, and at the same time induce appropriate

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choices regarding the use of competing modes of transport, and regarding location decisions and spatial development. This complexity is amplified by the existence of significant "second-best" aspects in the use of existing fiscal instruments; taxes on vehicles and fuels are able to reflect the various externalities only approximately, and the optimal policy mix would generally require the use of a package of a number of instruments in combination, even where policy sought to address only one of the relevant externalities.

This paper considers the possible role of the taxation of road transport in policy on transport-related air pollution. Section 2 considers the theoretical framework for analysing the possible contribution of taxation to the regulation of transport-related externalities. Section 3 provides a brief summary of the existing structure of taxes on road transport in European countries. Section 4 considers the possible contribution that could be made to air pollution abatement by an increase in the general level of taxation on motor fuels, and Section 5 considers the impact of changes in the relative taxation of different motor fuels (for example, the differentials in favour of unleaded petrol and diesel fuel), and the possible contribution of differentials in taxation of motor vehicles in affecting technology diffusion. Section 6 draws some conclusions.

2. What Role Should Road Taxes Play?

2.1 Road taxes and social costs

In principle, the taxation of road transport might be used to address each of the principal forms of social cost involved in vehicle use: environmental costs including global and local air pollution, noise and aesthetic losses (Button, 1990, 1993); congestion costs and accident costs imposed on other road users (Newbery, 1990; Jones-Lee, 1990);\(^1\) and the otherwise uncharged costs of consumption of publicly-provided road infrastructure (Newbery, 1988).

It is desirable that these social costs should be reflected in the costs of road use faced by individual road users. The tax system may have an important role to play in achieving this. In practice, policy-makers have often been unclear about which — if any — of the various social costs are reflected in the high level of taxation on motor vehicles and vehicle fuels.

While the first-best policy might be for road users to be charged the full marginal social cost of marginal vehicle use, it is not possible to restructure existing taxes on vehicles or fuels so as to reproduce exactly the first-best structure of incentives. The various environmental costs differ in how closely they are related to the characteristics of vehicles or fuels. Some, such as the global warming potential of vehicle use, are closely (and broadly linearly) related to fuel consumption. Others, including the costs of smog-inducing emissions, particulate emissions and noise, are related to the location, and in some cases the time of day, of vehicle use. Fuel taxes would be a poor proxy for these components of the environmental costs.

The implication of this is that taxation of vehicles or motor fuels can only provide an

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\(^1\) See also the special issue of this Journal on Transport Safety edited by Andrew Evans (January, 1994).
approximate reflection of the marginal social costs incurred as a result of individual transport decisions. The available tax bases are only loosely linked to the various social and environmental costs which policy might aim to control. In such a "second-best" context, it will generally be appropriate to make use of a wide range of instruments, to produce the closest possible approximation of the tax incentives to the structure of the various social costs. However, theoretical analysis indicates that it will rarely be possible to provide a clear answer to the question of the appropriate relationship between the contribution of the various components. Second-best policy design is often complex,\(^2\) and can be counter-intuitive, so that the available data and models are rarely likely to be capable of identifying the optimal policy mix with any certainty.

2.2 Road taxes and revenues

Governments levy indirect taxes for the purposes of revenue-raising as well as in order to correct externalities. In broad terms, revenue-raising taxes should be levied over and above any level of taxes imposed for purposes of correcting externalities (Sandmo, 1976). Where significant revenues are raised from externality-correcting taxes, it will of course be possible to set lower rates of purely revenue-raising taxes. It has been suggested that this substitution of externality-correcting taxes in place of distortionary taxation may provide a "double dividend" (that is, with both environmental benefits and a lower welfare cost of raising public revenues) from environmental taxation.

Given the rule of Diamond and Mirrlees (1971) that (provided certain general conditions hold) intermediate goods should not be subject to revenue-raising taxes, it will be appropriate for vehicles and motor fuels used as production inputs to be taxed less heavily than vehicles and fuels used by final consumers. Any revenue-raising indirect taxes should apply to the latter, but not to the former. In the case of VAT, this is achieved automatically, by the provisions for VAT-registered businesses to deduct "input" VAT in computing "output" VAT liability; such businesses do not perceive VAT as a cost. Excises and vehicle registration taxes, however, are levied on sales to final consumers and to businesses alike. As a result, if goods which bear revenue-raising excises are used as intermediate inputs, the Diamond-Mirrlees rule will be violated. Two possible approaches might be taken to avoid this. One — which has not, in practice, been employed to any significant extent — would be to make excise duties refundable to business users of dutiable goods. The other would be to seek to distinguish between goods used predominantly as intermediate inputs, and goods used predominantly by final consumers. The differential taxation of diesel fuel and petrol in many European countries may be defended in this way, although the boundary between diesel fuel and petrol does not exactly match the boundary between intermediate and final consumption of motor fuels.

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\(^2\) Thus, for example, Wijkander (1985) considers tax policy in situations where direct externality taxes cannot be used, and externalities have to be corrected through taxes and subsidies to related activities. Such a case might be that of urban congestion. If direct congestion charging is impracticable, an approximation to its effects might be achieved by simultaneously taxing complementary activities to congested vehicle use (for example, urban parking spaces) and subsidising substitutes for congested vehicle use (for example, peak-hour urban public transport). However, "perverse" cases can arise where the contrary rule should hold — that is, where complements should be subsidised, and substitutes taxed.
3. The Level and Structure of Road Taxes in Europe.

3.1 Taxes and tax rates
This section provides a brief survey of the overall structure of taxes on road transport in western Europe. The principal taxes are those levied on vehicle purchase and initial registration, annual charges on vehicle use, and taxes on motor fuels; in addition, various European countries operate an assortment of miscellaneous taxes and tax provisions likely to influence individual road transport decisions. Existing vehicle-related taxes include:

(a) Sales taxes on new motor vehicles
These taxes are in many cases higher than on other goods, or are imposed in addition to the general sales tax. Thus, for example, in the United Kingdom motor cars are subject both to VAT at the standard rate of 17.5 per cent, and also to a special car tax at 5 per cent on five-sixths of the list price of a new car. In Belgium, new motor vehicles attract both the normal VAT and, in addition, a “taxe de mise en circulation”.

While sales taxes on new cars may reduce the rate at which the existing vehicle stock is replaced, some countries have seen environmental benefits in accelerating the replacement of older vehicles with new, less polluting vehicles. Greece operates a system of fiscal incentives to scrap old vehicles, which is designed to remove from circulation the most polluting elements of the existing vehicle stock.

(b) Recurrent annual charges
Such charges commonly take the form of fees for the registration or use of motor vehicles. In the case of motor cars, these may be an annual lump-sum tax (for example, the British Vehicle Excise Duty of £130 per annum), or may be related to certain characteristics of the motor vehicle, such as engine capacity. In most countries the taxes levied on commercial vehicle sales, ownership and use are higher and more complex than the taxes on private cars, reflecting amongst other things the greater variety in size and use amongst commercial vehicles. In the UK, for example, the Vehicle Excise Duty on commercial freight vehicles is substantially higher than that for cars, and is related to the number of axles and vehicle weight.

Possibilities exist for the differentiation of the tax on new cars and the annual charges for registration according to the “environmental” attributes of different vehicles. In some countries a tax incentive has been introduced for “clean” cars (such as cars meeting certain emissions standards, or fitted with catalytic converters). Germany and the Netherlands, for example, introduced tax incentives to accelerate the take-up of catalytic converters, ahead of the requirements stipulated in European Union legislation on vehicle emissions (Blum and Rottengatter, 1990; Vleugel, van Gent and Nijkamp, 1990). At least three countries in Europe (Austria, Iceland and Norway) have lower rates or provide tax exemptions for electric and/or gas-powered vehicles (OECD, 1993). Also, again for environmental reasons, a number of countries have recently begun to differentiate initial or annual vehicle taxes on private cars by engine size or other factors affecting fuel use.
(c) Tax treatment of company cars
OECD countries pursue a wide range of practices with regard to the fiscal treatment of cars provided by employers to their employees ("company cars"). Some of the benefit which employees derive from company cars may be treated, as in the UK, as a benefit in kind, and consequently taxed as if the benefit were provided in the form of income (Ashworth and Dilnot, 1987). Much of the public policy discussion of this issue has been concerned with achieving neutrality between the taxation of cash income and income in kind, but there are also potential environmental consequences of any fiscal subsidy to company cars, arising if the subsidy induces higher rates of vehicle ownership, greater mileages, or the purchase of larger vehicles than in the absence of subsidy.

(d) Tax treatment of commuting expenses
There is similar variety in the tax treatment of expenditures incurred by private individuals in the course of commuting to work. Some European countries, including Germany and the Netherlands, allow tax deductibility of such commuting costs. There has recently been growing awareness that tax deductibility for commuting costs may encourage excessive commuting distances, or commuting using certain modes of transport — especially, using private cars — rather than other, less environmentally-damaging, modes. Blum and Rottengatter (1990) estimate that in 1986/87 the German tax relief for car commuters could have been responsible for additional accident costs of some DM 0.9 billion per annum, and additional air pollution costs of some DM 0.4 billion to DM 1.1 billion per annum.3

(e) Motor fuel taxes
The majority of countries in Europe levy specific excise duties upon motor fuels, in the form of a fixed amount per litre of fuel rather than a percentage of the price. In addition, the Value Added Tax is generally applied over and above the excise duty; under European Union rules, EU Member States have been required since the start of 1993 to apply their standard rate of VAT (of at least 15 per cent) to motor fuels.4 The combined effect of the motor fuel excises plus VAT is that motor fuels are taxed substantially more heavily than other goods, and, in general, considerably more heavily than other uses of energy (see Table 1).

A large part of government tax revenues accrues from taxes on motor fuels in most European countries (for example, in 1990 motor fuel taxes accounted for 5 per cent of total tax revenues in the UK, and 4 per cent in France and Germany).

Diesel fuel is frequently taxed at a different rate from petrol. In Europe the excise tax per litre on diesel fuel is usually lower, often substantially lower, than the tax per litre on

3 Depending on the methodology used, they calculate that the tax relief costs some DM1.8 billion to DM4 billion in forgone tax revenue.

4 As observed in subsection 2.2 above, the level of VAT levied on motor fuels is, in the main, relevant only for household purchasers of fuel; VAT-registered businesses (all businesses, except for very small firms) can in effect claim back the VAT paid on motor fuel, by being able to deduct "input" VAT from the amount of VAT payable on outputs.
<table>
<thead>
<tr>
<th></th>
<th>ECU per Litre</th>
<th>Proportion of Average Retail Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>0.59</td>
<td>72%</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.47</td>
<td>64%</td>
</tr>
<tr>
<td>France</td>
<td>0.67</td>
<td>79%</td>
</tr>
<tr>
<td>Germany</td>
<td>0.59</td>
<td>74%</td>
</tr>
<tr>
<td>Greece</td>
<td>0.55</td>
<td>75%</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.49</td>
<td>65%</td>
</tr>
<tr>
<td>Italy</td>
<td>0.65</td>
<td>75%</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>0.44</td>
<td>67%</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>0.67</td>
<td>73%</td>
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<tr>
<td>Portugal</td>
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<td>73%</td>
</tr>
<tr>
<td>Spain</td>
<td>0.48</td>
<td>67%</td>
</tr>
<tr>
<td>UK</td>
<td>0.34</td>
<td>71%</td>
</tr>
<tr>
<td>Unweighted EU average</td>
<td>0.54</td>
<td>71%</td>
</tr>
</tbody>
</table>

Source: OECD (1994).

<table>
<thead>
<tr>
<th></th>
<th>Leaded</th>
<th>Unleaded</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>0.46</td>
<td>0.39</td>
<td>0.28</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.32</td>
<td>0.29</td>
<td>0.22</td>
</tr>
<tr>
<td>France</td>
<td>0.54</td>
<td>0.48</td>
<td>0.31</td>
</tr>
<tr>
<td>Germany</td>
<td>0.48</td>
<td>0.43</td>
<td>0.29</td>
</tr>
<tr>
<td>Greece</td>
<td>0.44</td>
<td>0.44</td>
<td>0.33</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.36</td>
<td>0.33</td>
<td>0.28</td>
</tr>
<tr>
<td>Italy</td>
<td>0.51</td>
<td>0.46</td>
<td>0.36</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>0.35</td>
<td>0.30</td>
<td>0.23</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>0.53</td>
<td>0.47</td>
<td>0.28</td>
</tr>
<tr>
<td>Portugal</td>
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<td>0.42</td>
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<td>Spain</td>
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<td>0.36</td>
<td>0.26</td>
</tr>
<tr>
<td>UK</td>
<td>0.27</td>
<td>0.23</td>
<td>0.22</td>
</tr>
<tr>
<td>Unweighted EU average</td>
<td>0.43</td>
<td>0.38</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Source: OECD (1994).
petrol. As Table 2 shows, the differential in favour of diesel fuel ranges from 18 per cent in the UK to 48 per cent in the Netherlands. Within the European Union, the average tax to price ratio is 0.71 for petrol and 0.56 for diesel. Most countries in western Europe (and all EU countries) have in the last few years also introduced a tax differential between leaded and unleaded petrol, to encourage car users to switch from leaded petrol to the less environmentally-damaging unleaded fuel. In most European countries this tax differential has been introduced through differences in excise duty levels rather than VAT rates. The size of the differential varies between countries (see Table 2). Countries also differ in the length of time that the differential has been operative, and in the extent to which the differential is supported by other measures discouraging use of leaded petrol.

The ratio of tax to retail price for motor fuels is on average appreciably higher in Europe than in the United States. Across an average of the 12 European Union countries taxes constituted 68 per cent of the retail price for leaded petrol and 57 per cent for diesel fuel in 1992, compared with equivalent figures for the US of 25 per cent and 36 per cent respectively.

(f) Special fuel taxes
In addition to VAT and excise taxes, motor fuels are also subject to a number of special taxes in different countries. These include environmental damage taxes (the carbon taxes introduced by the Nordic countries, and the SO₂ tax in Sweden); fuel storage taxes to fund emergency stocks (in some EU countries); taxes to fund public works on related infrastructure and research and development (for example, in France); and a variety of franchise fees, business taxes and sales taxes. Overall, however, excise taxes comprise some 95 per cent of the special (non-VAT) taxes levied on motor fuels.

(g) Road-use charges and tolls
In Europe tolls are mainly used to charge for primary roads and motorways; some 30 per cent of motorways in Europe are tolled, of which the majority (90 per cent) are in France, Italy and Spain. These three countries derive substantial revenues from tolls: in 1991, some $900 million in Spain, more than $1.75 billion in Italy and around $3.5 billion in France. In Switzerland any domestic or foreign vehicle under 3.5 tonnes wishing to use a Swiss motorway has to purchase and display a permit which allows the vehicle to use all Swiss motorways for a year. Heavy goods vehicles from other countries have to pay a proportion of the Swiss heavy goods vehicles ownership tax where the amount payable will depend upon how long the vehicle spends in the country. Norway, Finland and Sweden all levy an additional distance-related charge on diesel-using heavy goods vehicles where the vehicle is charged a standard rate per mile dependent on the class of vehicle.

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5 The comparison uses data from OECD (1994). Value Added Taxes are included in the comparison for leaded petrol, since this is predominantly purchased by individuals, but are excluded from the comparison for diesel fuel, since VAT-registered businesses can generally recover VAT paid on inputs.

6 Department of Transport (1993); prices converted to dollars using 1991 exchange rate.
Table 3

Emissions of Pollutants in the UK in 1991: the Percentage of the Total Attributable to Road Transport

<table>
<thead>
<tr>
<th></th>
<th>All Road Transport</th>
<th>Cars</th>
<th>Diesel-powered Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>90</td>
<td>81</td>
<td>2</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Black smoke</td>
<td>42</td>
<td>6</td>
<td>39</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>52</td>
<td>29</td>
<td>21</td>
</tr>
<tr>
<td>Fine particulate matter</td>
<td>27</td>
<td>10</td>
<td>n.a.</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>19</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Volatile organic compounds</td>
<td>37</td>
<td>22</td>
<td>6</td>
</tr>
</tbody>
</table>


Experience of explicit congestion charges is limited to the city centre access tolls introduced in Bergen in 1986 (Larsen, 1988) and in Oslo in 1990 (Solheim, 1990). Several cities in Europe are currently exploring the possibility of introducing electronic charging systems which potentially allow charges to be related to the location, distance and time of road use; there is some prospect that such a system will be implemented shortly in the UK in Cambridge (Ison and Hughes, 1993).

3.2 Linkage between road taxes and air pollution

Road transport is responsible for a substantial proportion of emissions of a number of important atmospheric pollutants, including local, regional and global pollutants. In the UK, road transport accounts for about 90 per cent of all emissions of carbon monoxide, half of all emissions of nitrogen oxides, and more than a third of all emissions of black smoke, and of volatile organic compounds (see Table 3). One-fifth of UK emissions of carbon dioxide, the principal greenhouse gas, originates from road transport sources.

In considering the possible contribution that can be made by taxation to the regulation of air pollution, a key issue is that of the linkage between the available tax instruments and the level of emissions from different sources. Only if the taxes closely proxy underlying environmental costs will the incentive provided by taxation lead to efficient changes in the use of polluting vehicles. If, on the other hand, the linkage between the tax base and environmental costs is weak, taxes may lead to inefficient patterns of polluter response to the fiscal incentive.

The contribution of road transport to air pollution varies between different types of vehicle. In particular, diesel engines emit considerably higher amounts of nitrogen oxides, black smoke and particulates than petrol engines, while having lower emissions of carbon dioxide and carbon monoxide. Emissions are also affected by the extent to which vehicles are fitted with pollution abatement equipment. Three-way catalytic converters, which have become a standard requirement on new cars sold in the European Union since 1993,
result in substantial reductions in emissions of carbon monoxide, nitrogen oxides and hydrocarbons from petrol engines, but lead to somewhat higher fuel use for equivalent power, and hence higher carbon dioxide emissions.

Heavier taxation of road transport would, if it reduced the level of road transport, be liable to reduce emissions of these various pollutants. This would be true if taxation reduced the total number of journeys taken; it would also generally hold if heavier taxes on private motoring were to induce individual substitution away from private motoring towards public transport, assuming that public transport is less environmentally-damaging. Figures presented by Hughes (1990) suggest that the energy used per passenger mile in a mid-sized petrol-driven car with an average 1.5 occupants is some four times the energy used per passenger-mile in a train with 60 per cent occupancy, and more than twice the energy required per passenger mile in a bus with a 25 per cent occupancy rate.

Nevertheless, despite the probability that higher taxes would reduce emissions, the various taxes on motor vehicles and motor fuels discussed in section 2.1 are not directly proportional to the amounts of atmospheric pollution damage caused by individual road transport decisions, and are, at best, only a partially-efficient signal for individual decision-making. For example, there is only weak correlation between the amount of motor fuel used and the costs of additional atmospheric pollution. The externality costs of vehicle use generally depend on where and when journeys are made, and this is not captured in the taxation of fuel consumption. Thus, for example, the level and composition of various pollutants in vehicle exhausts differ depending on traffic conditions; in congested situations, significantly greater amounts of certain pollutants such as carbon monoxide will be emitted per litre of fuel used than in uncongested driving conditions.

Unpublished data from the Transport Research Laboratory Environment Centre show that, compared to travel at 100 kilometres per hour, cars travelling at 60 km/h emit three times more carbon monoxide, 75 per cent more hydrocarbons, 25 per cent less nitrogen oxides and 10 per cent less particulates and carbon dioxide. Emissions of all pollutants are substantially higher at very low speeds than at 100 km/h, but the increase is particularly marked in carbon monoxide emissions (some 20 times higher at 5 km/h than at 100 km/h) and hydrocarbon emissions (about 15 times higher at 5 km/h).7

4. The Policy Option of Higher Petrol Taxes

4.1 Elasticity evidence

Higher petrol prices would have three main effects:

(i) Reductions in vehicle use. The cost of each journey made would increase, and “marginal” or inessential journeys would be discouraged.

(ii) Reductions in vehicle ownership. For some owners of motor vehicles, a higher petrol price would make ownership no longer worthwhile. The number of

7 The authors are grateful to John Hickman of TRL Environment Centre for supplying these data. The figures refer to average emissions across light vehicles under 3.5 tonnes gross weight (that is, cars and light vans), based on the UK estimated vehicle mix in 1995.
vehicles owned would fall, as a result of fewer purchases of new vehicles and/or earlier scrapping of existing vehicles.

(iii) Higher fuel efficiency of the vehicle stock. Higher petrol prices would tend to encourage manufacturers to design more fuel-efficient motor vehicles, and to encourage purchasers of new cars to choose more fuel-efficient vehicles. Also, high petrol prices might encourage the more rapid scrapping of “gas-guzzling” older vehicles.

Econometric evidence of three types can be found in the literature: time-series aggregate estimates of petrol demand; cross-country cross-section estimates; and estimates based on pooled household micro-data for a number of years.

The relevant elasticities for assessing the impact of changes in motor fuel taxation include the “own-price” relationship between the price of petrol and petrol consumption, and also the cross-price elasticities between public and private transport. However, prices alone are not the only relevant factors affecting demand. The cost of private vehicle transport, for example, depends not only on the price of petrol, but also on the efficiency of the vehicle being used, the value of time to the user, and so on.

According to the Commission of the European Communities’ (1980) survey of petrol consumption elasticities with respect to price from 1966 to 1975: “There is substantial evidence to support a short-run one-year elasticity of about -0.2”. They also found that the minimum long-term elasticity is “approximately -0.4 or twice that of the short term”. Their conclusion is strengthened by Goodwin’s later survey (1992) in so far as “there is a reasonably clear pattern for long term elasticities to be between 50 per cent and three times higher than the short term”. However, Goodwin (1992) and Oum et al. (1992) point to a general increase in elasticities in later studies. Nevertheless, there is a good deal of consensus across data-sets, model specifications and estimation periods.

Goodwin’s (1992) survey presents an unweighted average of 120 estimates of the elasticity of demand for petrol with respect to prices. The overall average is -0.48. The average short-run elasticity is reported as -0.27 for time-series models and -0.28 for cross-section data. The long-run time-series models give an average elasticity of -0.71 with -0.84 for cross-sectional models.

While elasticities of this nature are useful, the reduction in petrol consumption will not necessarily be directly proportional to reductions in traffic level. Multiple car-owning households may shift their mileage towards the most efficient car, and in the longer term may trade down to smaller and more efficient cars. While the long-run studies cited above generally allow for this, the nature of the efficiency trade-off is interesting (and relevant for policy) in itself and is seldom modelled explicitly. An exception is in Reza and Spiro (1979) who report an elasticity of petrol consumption with respect to efficiency of -0.80 in the short term and -0.76 in the longer term when the stock of cars is allowed to adjust. Crawford (1993) using UK National Travel Survey data shows that, for two-car households, an increase in petrol costs skews household usage towards the most efficient car. The elasticity of the mileage shares between cars with respect to relative costs per mile is -0.12.
The above evidence relates to the effects of motor fuel price changes on fuel consumption. The effect of petrol prices on traffic levels is likely to be less than that on petrol consumption, due to the scope for increases in fuel efficiency through changes in driving behaviour and, in the long run, the purchase of more fuel-efficient new vehicles.

Two distinct elements have an impact upon traffic level: car ownership and car usage. The elasticity of the size of the car stock with respect to petrol prices has been variously estimated at between -0.15 to -0.41 according to the level of car ownership (Hensher et al., 1992), and -0.1 to -0.2 (Berkovek and Rust, 1985).

According to Oum et al. (1992) the average short-run elasticity of vehicle use, with respect to petrol prices, is -0.23 on US data, and -0.09 to -0.24 on Australian data. The corresponding long-run elasticities are -0.28 and -0.22 to -0.31. These averages are based upon seven studies.

In summary, therefore, the evidence on demand responses suggests that the impact of motor fuel price changes through changes in taxation is likely to be quite low. There is clearly likely to be a greater impact on fuel use and vehicle emissions than on vehicle use and congestion, particularly in the long run.

4.2 Distributional effects
Policies to reduce transport-related air pollution through higher taxation of motor fuels would potentially have distributional effects of some significance, given the substantial increases in tax levels which might be involved. However, the pattern of distributional incidence varies between countries, depending on the pattern of vehicle ownership and use in different countries.

The distributional impact of changes in motor fuel taxes in the UK has been discussed by McKay, Pearson and Smith (1990), using simulation results from a consumer demand model estimated using UK household micro-data. The distributional effects of the petrol tax increase across the income distribution as a whole are relatively modest. Petrol spending tends to increase with income at lower income levels, because the density of car ownership is much lower amongst low-income households. The additional petrol duty therefore has a progressive distributional incidence across income groups, in the sense of taking a higher percentage of spending from better-off households. Unlike the case of tax increases on domestic energy, the changes in the distribution of tax payments across the income distribution as a whole as a result of higher petrol taxes raise no obvious distributional issues.

Nevertheless, as Pearson and Smith (1990) note, high taxes on petrol may - in the short term at least - be unacceptable for their impact on certain groups, such as rural dwellers, for whom no alternatives to petrol consumption may be available in the short term. Such households may have high consumption, and, unlike urban dwellers, may not easily be able to switch to public transport. In the long run, of course, it may be desirable for relocation to take place, so that poorer households do not choose to live in areas which cannot support a public transport service. However, in the shorter term, increases in petrol duty may lead to unavoidable increases in the tax burden on poorer rural households, without having any significant impact on their fuel consumption.
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The evidence on the distributional incidence of higher petrol taxes in the UK contrasts with the situation in the US, where some estimates have suggested that higher petrol taxes would be significantly regressive in their distributional incidence. Thus, Congressional Budget Office (1990) estimates show that higher motor fuel taxes would take a much greater share of post-tax income from lower-income households than from higher-income households (although a broadly constant share of total spending across these groups). Poterba (1991) has observed that there may be a case for preferring incidence measures based throughout on expenditures as the yardstick of household living standards, on the grounds that this may be more consistent with a life-cycle model of household welfare and behaviour. In this case, he notes, the regressivity encountered with studies which judge household living standards by incomes is reversed.

4.3 Fiscal treatment of complements and substitutes

Where, as will inevitably be the case, taxes on vehicles and fuels cannot reflect all of the various social costs associated with road transport, a combination of fiscal policy measures, including taxes on complementary activities and subsidy on substitutes, will be likely to be an improvement on taxation of motor vehicles and motor fuels alone. This approach might include, for example, additional taxes or charges on parking in urban areas, and subsidy to public transport.

A relevant issue is likely to be the impact of subsidy to public transport on demand. A certain amount of evidence is available on two relevant elasticities, the price (fare) elasticity of demand for public transport of various types, and the cross-price elasticity between public and private transport.

Studies of demand for bus transport generally show it to be relatively insensitive to price in the short run, with more responsiveness indicated in the longer term. The one exception to this conclusion is Gilbert and Jalilian (1991, cited in Goodwin, 1992) where the elasticity of London bus travel with respect to fares is estimated at over -1 in the long run and -0.8 in the short run. Most other studies suggest elasticities much lower than this (see Goodwin and Williams (1985) for buses, and Goodwin (1992) for rail demand).

There is relatively little quantitative evidence on the impact of motor fuel taxation on the use of public transport. Such substitutions are a potentially significant part of the behavioural response to higher fuel prices; also, policies to increase the availability of public transport may be an important component of a policy package to reduce private car use. Unfortunately the data required for explicit modelling of cross-price elasticities between public and private transport is enormous, and relevant evidence is sparse. Bates and Roberts (1979) and Crawford (1993) using the UK National Travel Survey for 1975-76 and 1985-86 respectively, both find that access to and the frequency of public transport services are important influences of car ownership and use, but cannot estimate cross-price effects. Mackett (1984), however, cited in Goodwin (1992) gives a cross-elasticity of car ownership with respect to bus fares of -0.04. Bland (1984), also using National Travel Survey data but in a calibration exercise, calculates the elasticity of bus usage with respect to petrol prices of between +0.2 and +0.5 (depending on assumptions regarding other behavioural parameters).
Table 4

Total Tax (VAT plus Excises) on Various Fuels
Expressed as a Percentage Mark-up on the Pre-tax Price
in European Union Countries in 1993

<table>
<thead>
<tr>
<th></th>
<th>Leaded</th>
<th>Unleaded</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>259</td>
<td>225</td>
<td>160</td>
</tr>
<tr>
<td>Denmark</td>
<td>178</td>
<td>153</td>
<td>217</td>
</tr>
<tr>
<td>France</td>
<td>387</td>
<td>332</td>
<td>211</td>
</tr>
<tr>
<td>Germany</td>
<td>284</td>
<td>261</td>
<td>177</td>
</tr>
<tr>
<td>Greece</td>
<td>298</td>
<td>338</td>
<td>247</td>
</tr>
<tr>
<td>Ireland</td>
<td>189</td>
<td>175</td>
<td>144</td>
</tr>
<tr>
<td>Italy</td>
<td>301</td>
<td>261</td>
<td>228</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>169</td>
<td>169</td>
<td>143</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>269</td>
<td>225</td>
<td>157</td>
</tr>
<tr>
<td>Portugal</td>
<td>267</td>
<td>241</td>
<td>185</td>
</tr>
<tr>
<td>Spain</td>
<td>219</td>
<td>191</td>
<td>157</td>
</tr>
<tr>
<td>UK</td>
<td>242</td>
<td>170</td>
<td>192</td>
</tr>
<tr>
<td>Unweighted EU average</td>
<td>258</td>
<td>229</td>
<td>185</td>
</tr>
</tbody>
</table>

Source: OECD (1994).
Note: Calculations include VAT throughout; the figures calculated this refer to the situation of final consumers. VAT-registered traders can deduct VAT payments from VAT liability.

5. The Policy Option of Tax Differentiation

Environmental considerations might be reflected in the structure of road taxes in a number of different ways. Certain specific environmental problems might be best tackled by specifically-targeted fiscal measures — such as incentives to use unleaded petrol or to fit catalytic converters.

5.1 Unleaded petrol

Encouraging the use of unleaded petrol by introducing a differential tax rate (see Table 4) seems to have been relatively successful; the proportion of unleaded petrol sold has risen rapidly in many European countries. For example, in the UK the proportion of unleaded petrol has risen from a negligible share of total sales in 1986 to about half of total petrol sales in 1993. In the Netherlands, the market share of unleaded petrol has risen from less than one per cent of all petrol sold in 1986, when the differential was introduced, to some 70 per cent in 1992.

Large effects on behaviour have been achieved with relatively small tax incentives, mainly because leaded and unleaded petrol are very close substitutes. If the two varieties were perfect substitutes, even a small differential would be expected to induce consumers to switch to the lower taxed variety. In the case of the leaded-unleaded differential, however, the rate of take-up has been complicated by the fact that only a proportion of the
vehicle stock could use the unleaded fuel without modification; for some other vehicles, modification was technically feasible, although not always costless. While this may have helped to reduce the rate of diffusion of unleaded petrol, diffusion rates may have been accelerated by the preference for some consumers for using the more environmentally benign fuel. It is probably now unlikely that a higher differential would increase the take-up of unleaded petrol. In most European countries, the marginal saving when buying unleaded petrol rather than leaded petrol is already large enough to outweigh the fixed costs of converting cars to run on unleaded petrol and any efficiency disadvantage of cars running on unleaded petrol, for all except those who do very few miles per year. The remaining users of leaded fuel will contain a disproportionate number of owners of older cars, used for relatively low mileages; others may simply be poorly informed, and unlikely to be responsive to marginal adjustments to the fiscal differential.

5.2 Diesel

While a tax differential between leaded and unleaded petrol has been introduced for environmental reasons in many European countries, the long-standing differential between excise levels on diesel fuel and petrol (see Table 4) might equally be considered in the light of the environmental attributes of the two fuels. In fact, the relative environmental damage caused by petrol- and diesel-engined vehicles is complex; emissions of some pollutants, especially those affecting urban air quality, tend to be higher from diesels than from catalyst-fitted petrol cars (and in some cases than petrol cars without catalysts), while emissions of greenhouse gases may be rather higher. Whether diesel should be preferred to petrol on environmental grounds, or vice versa, thus depends partly on the relative weighting given to various different environmental problems.

Emissions of carbon monoxide, nitrogen oxides and total hydrocarbons from diesel engines are substantially lower than from conventional petrol engines. Figures given in QUARG (1993, p.6) suggest that diesel-engined cars emit only some 3 per cent of the carbon monoxide emitted per kilometre by cars with conventional petrol engines, 50 per cent of the nitrogen oxides, and 10 per cent of the total hydrocarbons. Three-way catalytic converters sharply reduce emissions of each of these pollutants from petrol cars. Nitrogen oxide emissions are reduced to about half the level of equivalent diesel engines, and hydrocarbon emissions to two-thirds of the diesel level; on the other hand, even with a catalyst fitted, petrol cars have more than double the carbon monoxide emissions of diesels. Tax differentiation may encourage such altruistic, “pro-green” behaviour by signalling which goods have lowest environmental cost. These figures relate to warmed-up engines. Since catalysts need time to reach their operating temperature, initial emission levels from catalyst-fitted petrol engines can be substantially higher. The “cold-start emissions penalty”, in terms of the ratio of pollutant emissions from a cold engine compared to a warm engine could be around 10 for carbon monoxide and hydrocarbons from a catalyst-fitted petrol engine, compared with a cold-start penalty of 2 or less for standard petrol and diesel engines. When used for short journeys in urban areas, much of the advantage of catalyst-fitted engines over diesel engines in emissions of these pollutants may be lost (QUARG, 1993, p.9).
The potential advantages of diesel engines in respect of emissions of these regulated pollutants will thus be substantially eroded by the steady diffusion of three-way catalytic converters through the petrol-engined vehicle stock; given that new cars contribute a high proportion of total mileage, the mileage-adjusted diffusion rate is likely to be rapid. In addition, diesel engines, especially when poorly adjusted, are substantial sources of emissions of black smoke and fine particulates; these are implicated in respiratory ailments, and also include known carcinogens. QUARG (1993, p.6) observes that particulates emissions from petrol cars are so low that they are not routinely measured; particulate emissions from diesel cars "may be an order of magnitude higher" than from catalyst-fitted petrol cars.

Carbon dioxide emissions from motor vehicles are closely linked to the amount of fuel used and its carbon content. Diesel engines are substantially more fuel-efficient than equivalent petrol engines; on the other hand, diesel fuel has a higher carbon content per litre than petrol. Drawing a balance between these two effects, a diesel engine needs to have an efficiency advantage of at least 11 per cent over an equivalent petrol engine for the diesel to have lower carbon dioxide emissions. Estimates given in QUARG (1993, p.14) suggest that at a speed of about 40 miles per hour, carbon dioxide emissions from petrol cars (without catalytic converters) and diesel cars were broadly similar; carbon dioxide emissions from petrol cars fitted with three-way catalytic converters were higher, by about one third.

The implication of this would appear to be that the existing differential in favour of diesel fuel over petrol in most western European countries cannot be clearly justified by reference to the relative environmental damage caused by diesel- and petrol-engined vehicles. In practice, of course, the differential has arisen for wholly non-environmental reasons, largely reflecting governments' concern about the impact of high diesel duties on the costs of industry. While there are, as discussed in subsection 2.2 above, good reasons for motor fuels used in intermediate inputs to be taxed less heavily than motor fuels used in final consumption (since, in an efficient indirect tax system, the burden of revenue-raising taxes should fall on the latter only), the distinction between diesel- and petrol-engined vehicles no longer coincides exactly with the distinction between intermediate and final consumption uses of motor fuels. The substantial differential in favour of diesel fuel in European countries has contributed to the growth of a significant market for diesel-powered passenger cars. The market for diesel cars has recently expanded considerably, partly as a result of developments in the technology of small diesel engines; diesels now account for some 20 per cent of all new car sales in the UK, compared to only some 6 per cent of the existing car stock. Given the lack of any clear environmental justification for the differential in favour of diesel, and some clear disadvantages from the point of view of urban air quality, this development is, at best, environmentally-neutral, and, at worst, reflects environmentally undesirable incentives within the taxation of motor fuels.

5.3 Catalytic converters
Diffusion of catalytic converters in petrol-engined vehicles has been achieved largely as a result of mandated standards for new vehicles. However, during the period before these
standards became mandatory, some countries encouraged accelerated up-take of the new standard by a fiscal incentive for new vehicles fitted with catalytic converters. Similar issues could arise in future, as new vehicle technologies (such as alternative-fuel vehicles) or new pollution abatement technologies are developed. What contribution might be made to accelerated diffusion by fiscal incentives?

The issue largely turns on the impact of the new technology on the cost and desirability of the vehicle. Where, as in the case of a catalyst, the new technology requires an initial costly investment, and then provides only social benefits (in terms of reduced pollution), while leaving operating costs unchanged (or even slightly higher), individual decisions to fit the technology voluntarily require altruistic motives; the technology has a net private cost to the vehicle owner. For consumers with altruistic motives for installation, fiscal incentives may possibly have a beneficial "signalling" role in encouraging greater diffusion, as with the unleaded petrol differential. However, the size of the incentive may be relatively incidental to its value as a signalling device. For consumers without an altruistic motive for installation, the minimum level at which the incentive might be expected to be effective in inducing greater diffusion is when it is sufficient to offset all of the additional private costs (installation costs, and possibly higher operating costs) from fitting the device.

5.4 Tax incentives for alternative fuels

Over the medium term there is considerable scope for the development of vehicles powered by alternative fuels of various sorts, which may have lower emissions of certain air pollutants. Michaelis (1995, this issue) reviews the market potential for such vehicles. Many of the available alternative fuels require specially-adapted vehicles or different engine technologies, although some, including reformulated gasoline, can be used in existing vehicles. For the former group of fuels, Michaelis argues that the main market is likely to be in light-duty vehicle fleets; use of alternative fuels by car drivers is likely to be mainly in the form of fuels which can be used in existing vehicles.

The tax policy issues raised by the two groups of alternative fuels vary. For fuels which can be used in existing vehicles, the main issue will be the relative taxation of these fuels and existing motor fuels, so as to reflect their relative environmental attributes. As in considering the petrol/diesel differential, fuel taxation may be able to reflect the relative environmental impact only approximately, if the environmental impact of these fuels varies depending on factors such as pattern of use (urban versus long-distance driving, and so on) and maintenance standards.

Where alternative fuels require major adaptation or replacement of existing vehicles, their rate of diffusion will depend on both vehicle and fuel costs; policies to extend diffusion could act on either or both of these costs. As Michaelis shows, the capital costs of alternative-fuel vehicles are generally higher, although the fuel may be cheaper. In this

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10 For example, since July 1994, the state of Connecticut in the US provides a corporate profits tax break, of 50 percent of the cost, to any commercial fleet operator that converts vehicles from gasoline to cleaner fuels, such as natural gas, or to electricity; after conversion, the new fuel is exempt from the 31 cents/gallon state fuel tax (New York Times, 19 September 1994).
case, it may be profitable for high-mileage users to convert, without any fiscal inducement. The role of any fiscal treatment will then be to encourage greater use; here considerations of efficiency and "cost-effectiveness" of policy may conflict. In general, to the extent that environmental costs are directly proportional to fuel use, an efficient pattern of additional use of alternative-fuel vehicles will be achieved purely by subsidising the fuel. However, this may involve greater "deadweight", in the sense that a large part of the tax incentive may be paid to high-mileage users who would choose the alternative fuel in any case. Lower deadweight may be achievable by subsidising the vehicles rather than the fuels, or by targeting particular types of vehicle or user for subsidy, although this may encourage a pattern of take-up which is somewhat less efficient. Choosing between the two options will generally depend on the range of mileages, the responsiveness of users to financial incentives and the existence of any other factors besides lifetime costs which may affect the pattern of diffusion in the absence of subsidy.

6. Conclusions

Many of the environmental problems of urban areas can be attributed to road transport. Motor cars are major sources of local pollutants, such as lead, carbon monoxide and noise. Road congestion exacerbates these problems, and also imposes direct costs on road users, in the form of the time and money wasted in traffic jams and slow-moving urban traffic flows. Motor vehicles are responsible for many deaths, both of road users and pedestrians, each year. They also make a significant contribution to global environmental problems, through emissions of carbon dioxide and other greenhouse gases. Many of these problems are growing rapidly, as rising incomes lead to an increasing demand for road transport.

Unlike many of the other areas of tax policy where environmental tax measures might be considered, road transport is already the subject of heavy taxation, levied mainly for revenue reasons. There is considerable potential for changes to the tax system to reflect the various externalities caused by motoring. The structuring of road taxes appropriately, to reflect all of the various externalities associated with private motoring, will, however, be complex. Sections 4 and 5 of the paper have discussed evidence on the likely effects of various possible tax changes to vehicles and vehicle fuels.

The impact of changes to the general level of petrol taxes on fuel use, and consequently emissions, could be appreciable. Much of the impact would come about through changes in the size and fuel efficiency of motor vehicles, rather than in traffic levels.

There is a case, on second-best grounds, for taxing complements to environmentally-damaging road use, and subsidising substitutes, where the available tax bases are not completely proportional to the environmental damage. While it is clear that this is the case as far as congestion is concerned, the linkage between fuel use and air pollution may also be affected by various factors which cannot be reflected using motor fuel taxes alone. Congested road use is liable to generate higher emissions than uncongested use, due to higher emission levels at slow speeds and in intermittent driving conditions. A package of fiscal measures, including perhaps higher parking charges and public transport

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subsidies, to discourage vehicle use in congested situations, may thus be more effective at discouraging vehicle emissions than the taxation of fuels and vehicles alone.

Changes to the structure of taxes on road transport could also contribute to transport-related air pollution abatement. Tax differentials, such as the differential in favour of unleaded petrol, appear to have had a sizeable impact on behaviour, and consequently could be expected to have had a significant impact on the problem of vehicle emissions of lead in urban areas. This experience would suggest that the existing differential in favour of diesel fuel in European countries might also have a powerful impact on fuel choices; to the extent that diesel engines emit higher levels of certain significant urban pollutants than the current generation of (catalyst-fitted) petrol engines, there may be an environmental case for narrowing the existing differential, to prevent an increase in the share of diesel-powered private cars.

References


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