The Distributional Effects of Taxes on Private Motoring

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Executive summary

Individual decisions about vehicle ownership and use involve some purely private financial costs such as vehicle purchase price, insurance and fuel expenses. In addition, the use of road transport by each individual potentially imposes various costs on others, such as noise and air pollution and congestion. Individuals may or may not take account of these costs when making transport decisions. If they do not, these social costs will tend to be over-produced because they are rarely directly charged for.

There are a number of ways of controlling socially damaging activities. It can be done via a regulatory framework (setting emissions levels or allowable traffic volumes, for example (quantity controls), or specifying production technology, pollution abatement equipment etc.) or by using market mechanisms such as taxes and charges.

Taxes may have some advantages over regulation, such as achieving a certain level of pollution reduction at a lower cost when abatement costs differ across polluters and are costly for authorities to ascertain. On the other hand, a tax base that is well linked to the social cost is often hard to find. In these circumstances, regulatory policies such as fitting cars with catalytic converters may be a more effective and less administratively costly tool than taxes.

As well as correcting for the over-production of socially costly activities, environmental taxes raise revenues. In recent years, there has been interest in the idea that a revenue-neutral swap between an environmental tax and an existing distortionary tax (such as a labour tax) might yield a double dividend by improving both the environment and the efficiency of the tax system. In practice, we probably do not know enough about the effects that the tax system has on welfare to achieve such an efficient tax swap (if we did, we would have designed an efficient tax system already and the second dividend would not be on offer). This is a very strong notion of a double dividend. A weaker form, which is more plausible, says that we can gain more by using the revenue to lower an existing tax than by recycling it as a lump sum.

Presently, the only commitment that the government has made on the taxation of road transport is the 6 per cent annual real increase in road fuel excise duties. This may be a good policy instrument for tackling carbon dioxide emissions. The use of road fuel, however, is not closely linked with other social costs such as congestion and other air pollutants, and so road fuel duty would be a blunt instrument with which to tackle these problems.

As well as the efficiency aspects of environmental taxation, we might also be interested in its distributional effects. The effects of changes in road fuel duty on household welfare will depend on household spending patterns and the extent to which demand for car transport responds to price changes.

We present an empirical model of car use conditional on ownership which allows us to investigate the distributional effects of increases in road fuel duty. We find that the demand for car mileage is relatively unresponsive to changes in the cost per mile of driving. We find that a 1 per cent increase in the per-mile cost of driving reduces car mileage by less than half of one per cent. We also find weak evidence that two-car households respond less to price changes than households with a single car. The greatest behavioural responses are amongst poor households in urban areas. The overall distribution of the welfare effects of such a reform is such that poorer households are relatively less affected since they tend not to own cars. Amongst car owners, however, the welfare effects are greatest for poorer households, particularly in rural areas. For a 30 per cent increase in fuel prices, for example (which would result from six years of the government's pre-announced duty increases compounded into a single increase of roughly 40 per cent), the poorest tenth of the car-owning population would see the cost of maintaining their living standards increase by 2.25 per cent. The richest tenth of car-owning households would see this increase by less than 1 per cent.

1. Introduction

Department of Health assessments have suggested that, each year, several thousand premature deaths and many thousands of hospital admissions are linked to exposure to particulate emissions.[1] Road transport is a major source of particulates and other pollutants such as greenhouse gases which contribute to global warming. Concern over the levels of pollution and congestion arising from road traffic and the associated deleterious effects on health and the environment have led both the previous Conservative and the new Labour governments to consider various measures to combat these problems. In August of this year, John Prescott announced the Labour government's intention of formulating an integrated transport policy, to make public transport more appealing and encourage people out of their cars. The Conservative government commissioned studies into the feasibility of road pricing and congestion charging, but no widespread measures of these kinds were instituted or seem likely to be in the near future, although pricing and charging are among the options listed in Labour's consultation document on an integrated transport policy.[2] The one fiscal measure firmly adopted by the previous government specifically aimed at the environmental problems associated with road transport was a commitment to real year-by-year duty increases on road fuels. Its promise of real increases of at least 5 per cent per annum into the future was augmented to at least 6 per cent in the newly elected Labour government's first Budget this July.

Similarly, in its 1994 report on transport and the environment, the Royal Commission on Environmental Pollution reviewed a number of different types of instruments, including explicit road charging, but concluded that the technology did not then exist to make its widespread application feasible. It argued that the use of economic instruments would be an effective way in which to reduce levels of environmental damage associated with road transport. The report concluded that fuel excise duties represented the most powerful of the economic tools currently available and recommended that fuel duty should be increased year by year so as to double the price of fuel, relative to the prices of other goods, by 2005.

This would represent an enormous increase in the relative price of a good brought about through taxation. It would double the cost of motoring relative to that of other activities and, assuming offsetting indirect tax reductions are not made elsewhere, it would add 3.9 percentage points to the increase in the cost of living of the average household over the period.[3] By comparison, had VAT been applied to domestic energy at the full 17.5 per cent, then the rate of increase of the cost of living would have only risen by an additional 0.8 percentage points; the effects of the Commission's proposals on the cost of living of households in the UK would be more than four times greater, on average, than those of VAT on domestic energy at the full rate, and over 12 times greater than the effect of the present 5 per cent rate on domestic energy. Furthermore, as with domestic energy, there

[1]Department of the Environment, 1996.

[2]Department of the Environment, Transport and the Regions, 1997.

[3]This calculation uses the fixed weight from the retail price index and assumes no demand responses to price increases.

is no reason to suppose that this tax burden would be distributed evenly across the population. It would be likely to affect different sorts of families in various parts of the country very differently. In particular, the likely progressivity of the tax might vary between urban and rural areas, with families in rural areas, who are of necessity more car-dependent, bearing a greater proportion of the tax burden than those in towns.

The possible scale of duty increases, and the fact that their purpose is to change behaviour, mean that any assessment of their distributional impact that ignores behavioural change may be of little use. Further, the extent to which different households with different incomes and travel requirements adjust their behaviour in response to the tax change may be important in determining the distribution of the consequent welfare effects.

In this Commentary, we develop a statistical model of UK households' behavioural decisions regarding the use of private vehicles, and the interaction between private and public transport. Unlike a more conventional tax and benefit model, this model will allow for the behavioural responses which are the principal objectives of environmental taxes and which are crucial to the correct estimation of their distributional consequences. This will enable us to simulate the effects of duty increases aimed at reducing the environmental costs associated with road transport and to evaluate them in terms both of their success in altering behaviour and of their consequent distributional effects.

An outline of the rest of this Commentary is as follows. In Section 2, we review recent trends in the pattern of car ownership[4] and use, the characteristics of the vehicle stock and the costs of car ownership and use. Section 3 discusses the costs that the unchecked use of private transport might impose on society, and reviews the different policy instruments that may be available to the government, both in theory and in practice. It moves on to discuss past transport policy in the UK and some of the more commonly proposed future policy options. Section 4 describes the method that we use to measure the welfare effects of our simulated tax increases on households in terms of their impact on the cost of living. A detailed description of our empirical model is given in Section 5 and in the Appendix, along with the simulation results of various levels of duty increase in Section 6. Section 7 concludes.

[4]Throughout, we use the term 'car ownership' to mean both private ownership of and having continuous access to a car. This will include, for example, company cars that are not registered to the using household.

2. UK car ownership and usage

Between 1985 and 1995, total motor vehicle traffic grew by 39 per cent.[5] The largest growth was in cars and taxis (41 per cent). In this section, we present data on recent trends in road transport and, in particular, the ownership and usage of private cars. The cost per mile of car travel depends on fuel prices and the fuel efficiency of the car. There are two ways in which the efficiency of the car stock can change: through a change in the characteristics of the vehicle stock by the scrapping of old vehicles and the purchase of new ones, or through a change in the use of the existing stock. The fuel efficiency of a given car can depend on how it is driven on a particular journey (motorway speed, for example) and on the nature of the journeys undertaken (short or long (warm-up tends to be relatively fuel-inefficient), congested conditions requiring stop–start driving, and so on). The 'average' efficiency of journeys for a given car stock could also be affected by multiple-car-owning households altering the allocation of their journeys away from, or towards, their more fuel-efficient vehicles. Cost per mile affects car use, and efficiency determines fuel consumption, given mileage, and these are both of interest in assessing the social impact of road transport, particularly since policies such as increases in fuel taxes may affect vehicle efficiency as well as fuel use. In a preliminary examination of the data, therefore, fuel efficiency and hence changes in the characteristics of the vehicle stock and in the nature of car use are of interest to us as well as simply levels of car ownership and use. We begin with a description of changes in car ownership over time and by household characteristics. We then look at the characteristics of the cars owned, followed by a description of trends in car use and in the use of other forms of transport. Finally, we describe the evolution of various costs of motoring.

2.1 Car ownership

Between 1981 and 1992, the number of cars per 1,000 population grew by about a third from 277 to 367.[6] Much of this growth was to do with the increasing proportion of households with more than one car. Over the period in the UK, the proportion of households with one car remained constant at 45 per cent, but the proportion of multiple-car-owning households increased from 15 per cent to 24 per cent. The areas with the greatest concentration of multiple-car-owning households were the south-east of England (32 per cent) and the south-west (30 per cent).

Figure 2.1a compares the proportion of households with at least one car by income decile (decile 1 is the poorest 10 per cent of households, decile 10 the richest 10 per cent) in 1974 and 1995–96.[7] Within each year, the proportion of households with a car generally increases with their position in the income distribution. In 1995–96, for example, nearly all households in the top decile have at least one car, while only around

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[5]Measured in billions of passenger kilometres. Source: *Road Transport Statistics, Great Britain*, 1996 edition, Table 2.1a, p. 16.

[6]Source, *Regional Trends*, 1995 edition.

[7]Note that the period covered by the Family Expenditure Survey (FES) changed from calendar to financial year in the interim.

Figure 2.1a. Proportion of car-owning households by income decile

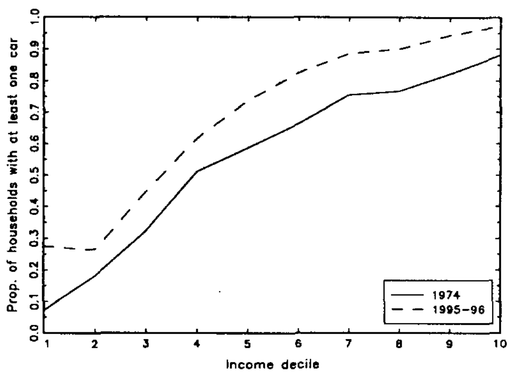
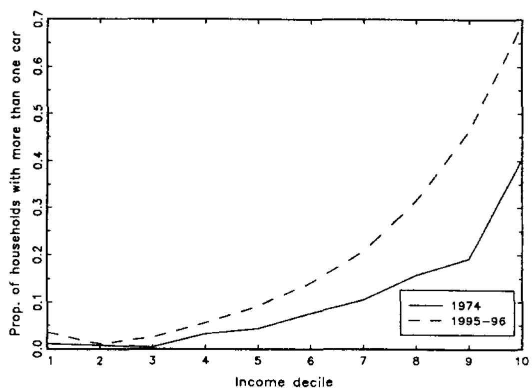


Figure 2.1b. Proportion of households with more than one car by income decile



Source: Family Expenditure Surveys, 1974 and 1995–96.

one-third of households in the bottom 10 per cent have a car. The greatest growth in ownership over the period appears to have been amongst these poorer households.[8] Only 7.3 per cent of households in the bottom decile had a car in 1974 compared with 27.5 per cent in 1995–96.

Figure 2.1b shows the proportion of households with more than one car by income decile for the same two years. Amongst the bottom 10 per cent in 1974, multiple car ownership was very rare. Ownership rates grew to around 3.5 per cent by 1995–96 for this group. The growth in multiple car ownership was much more marked amongst the highest income group, where the proportion of households with two or more cars rose from around two in five to about two-thirds over the period.

Figures 2.2a and 2.2b show rates of car ownership by population density measured by persons per hectare. The data are drawn from the National Travel Survey (NTS) for the

Figure 2.2a. Proportion of car-owning households, by population density

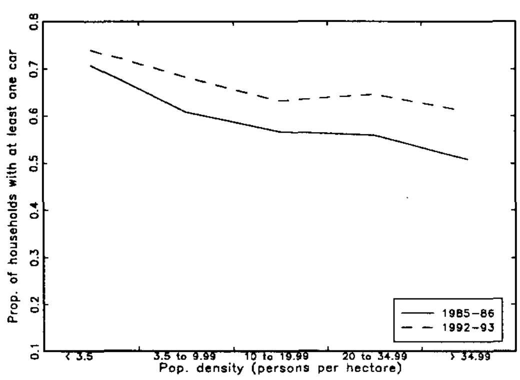
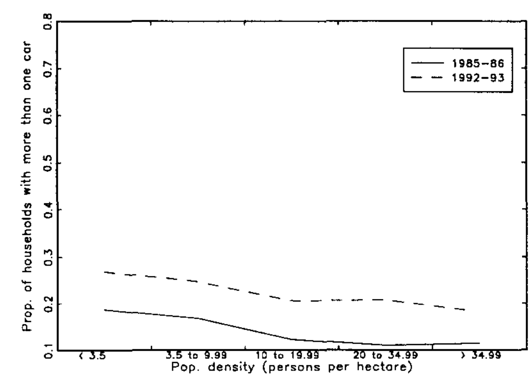


Figure 2.2b. Proportion of households with more than one car, by population density



Source: National Travel Surveys, 1985–86 and 1992–93.

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[8]This may be partly because of a change in the age composition of households in the bottom income decile from mainly older households to include more households consisting of younger people. In addition, part of the growth may be to do with increased numbers of self-employed households in 1995–96 compared with 1974, many of whom report low incomes in the FES.

Figure 2.3a. Proportion of car-owning households, by age of head of household

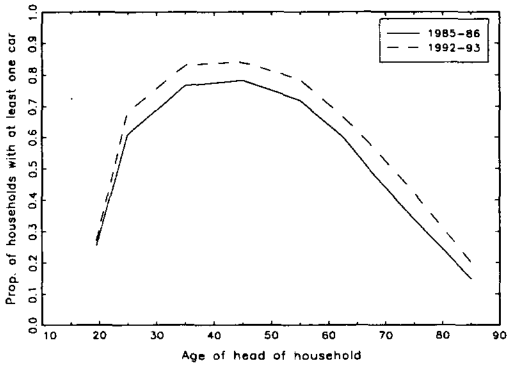
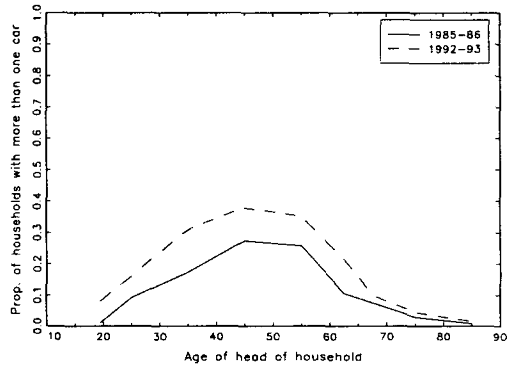


Figure 2.3b. Proportion of households with more than one car, by age of head of household



Source: National Travel Surveys, 1985–86 and 1992–93.

years 1985–86 and 1992–93 and show greater rates of both overall ownership and multiple car ownership in rural areas in both periods. Growth between the two periods in overall car ownership has been greatest in the more urban areas. In areas with more than 35 persons per hectare, the overall ownership rate grew by over 10 percentage points, while growth in the most rural areas (less than 3.5 persons per hectare) was around 3 percentage points. Growth in multiple ownership seems to have been fairly constant across areas with different densities.

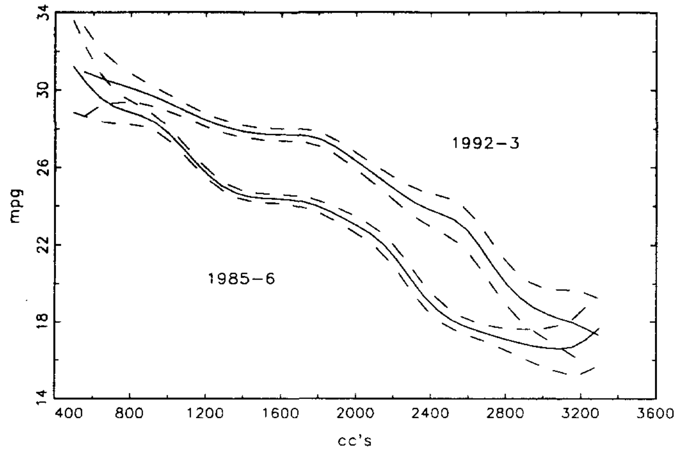
Figures 2.3a and 2.3b show the distributions of ownership (overall and multiple) by the age of the head of the household for the same years of NTS data. Overall ownership rates and the rate of multiple ownership are low amongst the youngest and oldest households and there appears to have been very little growth in overall ownership rates amongst the very youngest households between the periods shown. The growth in multiple car ownership was lowest for elderly households. Some care should, however, be exercised when looking at the data for the extremes of the age distribution because of the relatively small number of observations. The number of households with a head who is less than 21 years old was about 100 in the 1985–86 NTS, and about 200 households had a head who was over 80 years old.

2.2 Vehicle characteristics

Using data from the NTS, Figure 2.4 shows the variation between vehicle efficiency and engine size, for the two survey years 1985–86 and 1992–93. The solid line is a plot of a kernel regression line,[9] the dashed lines either side are the pointwise 95 per cent confidence interval of the regression. As is to be expected, larger engine size is associated with lower fuel efficiency at a given time, and there appears to be a trend towards greater fuel efficiency for all engine sizes between the two survey years. The widening of the confidence interval for 1992–93 compared with that for 1985–86 for larger engine sizes

[9]A kernel regression is a statistical technique that allows relationships between two variables to be described without the need for a functional form (see Hardle (1990)).

Figure 2.4. Efficiency and engine size

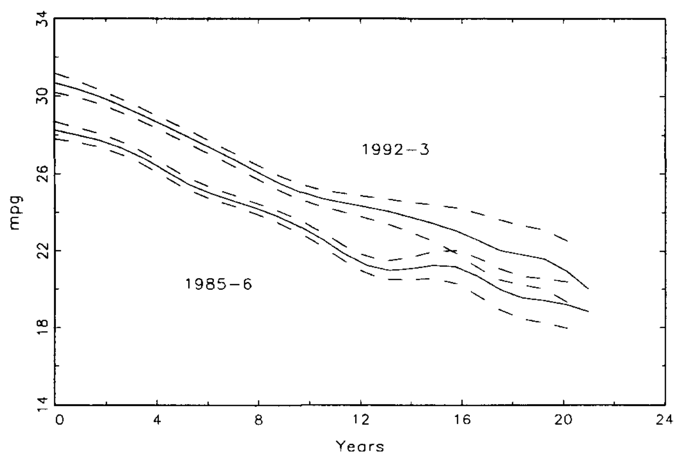


Source: National Travel Surveys, 1985–86 and 1992–93.

indicates that there are relatively fewer larger-engined cars in the later year or that there is a greater dispersion in their fuel efficiencies.

Figure 2.5 illustrates a similar kernel regression showing the relationship between age of vehicle and efficiency. It shows a deterioration of efficiency with age within each survey year, with a general improvement in efficiency at a given age over time. Note that a car that was new in 1985–86 is seven years old in 1992–93 and that its expected fuel efficiency should be read from the 1992–93 regression line. This shows a slower decline of efficiency for a given car over time than between cars of different ages at a particular point in time. The widening confidence band for older cars in 1992–93 compared with 1985–86 indicates relatively fewer old cars in the later sample or a greater dispersion in their fuel efficiencies.

Figure 2.5. Efficiency and vehicle age



Source: National Travel Surveys, 1985–86 and 1992–93.

2.3 Car use

Figure 2.6a shows that the average total number of journeys taken per person each year increased by around 17 per cent between 1975–76 and 1989–91, from 935 to 1,091, and then declined a small amount to 1,052 in the 1993–95 survey. The increasing importance of the car in making journeys is apparent in the data, with cars accounting for 59 per cent of all journeys in 1993–95 as compared with only 46 per cent in 1975–76. As can be seen from the figure, the number of non-car journeys has actually decreased over the period, the total journey growth being attributable solely to an increase in car journeys of about 44 per cent.

The share of car-miles out of total mileage has also increased since 1975–76, from around 72 per cent to 81 per cent in 1993–95, as illustrated in Figure 2.6b. Total yearly mileage per person has increased from 4,710 miles in 1975–76 to 6,511 miles in 1993–95. As with journey numbers, this increase is due to an increase in car-miles travelled of around 57 per cent from 3,375 miles in 1975–76 to 5,296 miles in 1993–95, with miles travelled by all other modes decreasing by about 9 per cent over the same period.[10]

As is evident from Figure 2.6, the mileage share of cars is consistently above the journey share, implying that the car becomes increasingly prevalent as the mode of travel as journey length increases. This can be seen in Table 2.1 — for example, cars accounted for 71 per cent of short journeys (defined as between one and five miles), increasing to 86 per cent in the case of long journeys (over 10 miles), in 1993–95. However, the figures indicate that the gap is closing. Although the car is becoming more important in journeys of all lengths, its use for making short journeys is growing more rapidly than its use for longer journeys — from 62 per cent in 1985–86 to 71 per cent in 1993–95 for short journeys as compared with 83 per cent to 86 per cent over the same period for long journeys, for example. The increasing reliance on the car as a means of travel implies a reduction in the use of other forms of transport. Table 2.1 shows declines in the use of buses for making short and medium-length (between five and 10 miles) journeys and in the use of rail transport (which, anyway, accounts for a small proportion of journeys) for medium-length and long journeys.

Figure 2.6a. Journeys per person per year and proportions by car

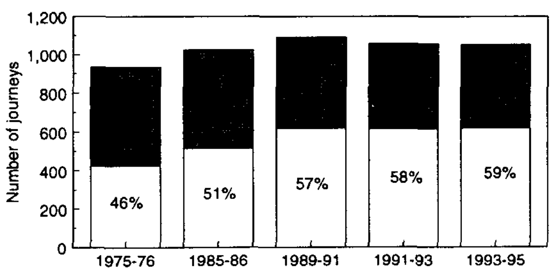
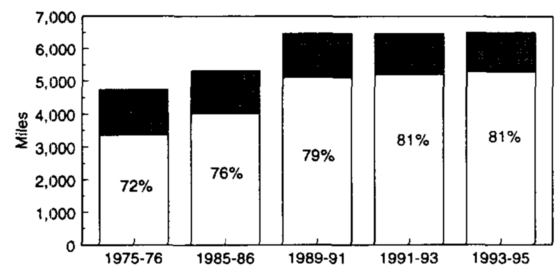


Figure 2.6b. Miles travelled per person per year and proportions by car



Key: The shaded segments represent non-car journeys and the non-shaded segments represent car journeys.
Source: National Travel Surveys, 1975–95.

[10]Note that the NTS data record domestic air travel but not international air travel, which is likely to have increased over the period 1975–76 to 1993–95.

Table 2.1. Proportions of journeys, by travel mode and journey length

	Car		Local Bus		British Rail	
	1985–86	1993–95	1985–86	1993–95	1985–86	1993–95
Short (1–5 miles)	62	71	14	10	<1	<1
Medium (5–10 miles)	79	85	12	9	2	1
Long (over 10 miles)	83	86	3	3	7	5

Source: National Travel Surveys, 1985–86 and 1993–95.

Table 2.2. Proportions of short and very short journeys by travel mode

	Car		Walk		Bicycle	
	1985–86	1993–95	1985–86	1993–95	1985–86	1993–95
Very short (under 1 mile)	13	15	83	82	2	2
Short (1–5 miles)	62	71	16	12	3	2

Source: National Travel Surveys, 1985–86 and 1992–93.

Table 2.3. Average distance, time and speed of car journeys by year

	1975–76	1985–86	1989–91	1991–93	1993–95
Distance (miles)	7.9	7.8	8.2	8.5	8.5
Time (mins)	20	20	20	20	20
Speed (mph)	22	23	25	26	26

Source: National Travel Surveys, 1975–95.

Table 2.4. Average distance, time and speed of some alternative journey modes

	Local bus			LT underground			British Rail		
	Time (mins)	**Distance** (miles)	**Speed** (mph)	**Time** (mins)	**Distance** (miles)	**Speed** (mph)	**Time** (mins)	**Distance** (miles)	**Speed** (mph)
1975–76	27	4.1	11	44	8.2	15	61	27.3	33
1993–95	30	4.1	10	49	8.2	14	78	31.9	39

Source: National Travel Surveys, 1975–76 and 1993–95.

Table 2.2 shows that there has also been a slight increase in the use of cars in making very short (under one mile) journeys, with a marginal decrease in walking, which, however, remains the predominant method of taking journeys of this length. The table also shows that the increasing use of cars in making short journeys is reflected in a reduction in the proportion of such journeys made by bicycle or by walking.

Table 2.3 shows average time, distance and speed of car journeys across survey years. Average time and distance are derived from journeys for which the car was the main mode of transport, whereas speeds are calculated only from journey stages where the car was actually used (hence the discrepancy between speed and distance divided by time). As can be seen, the average time of a car journey has remained constant between 1975–76 and 1993–95 at 20 minutes, and distance covered and average speed have increased slightly.

Table 2.4 shows similar figures for some other transport modes. The figures are calculated in the same way as above, and hence average speeds exclude waiting times and

Figure 2.7a. Car journeys as a percentage of all journeys, by purpose

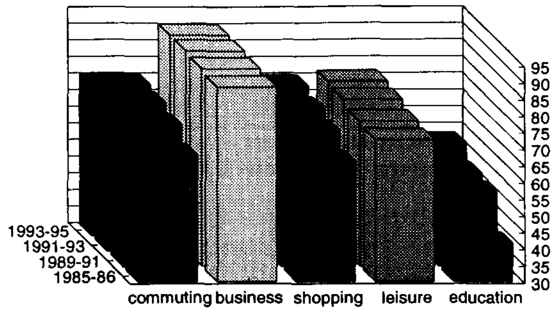
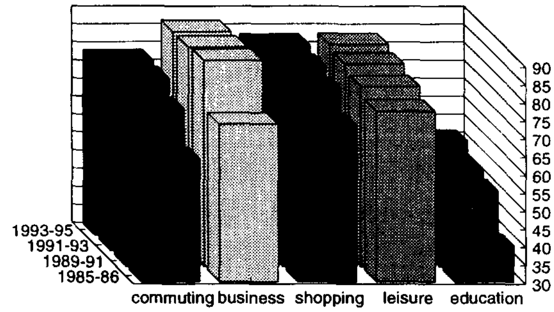


Figure 2.7b. Car-miles as a percentage of all miles, by purpose



Source: National Travel Surveys, 1985–95.

so on. They show a slight deterioration in bus and underground speeds between 1975–76 and 1993–95, and a more significant increase in average rail speeds.

Figures 2.6a and 2.6b showed the increase over time in the percentage of all journeys and all miles travelled by car. Figures 2.7a and 2.7b break this down for five of the most common journey purposes. For all five purposes, there has been an increase in the percentage of journeys made by car, particularly for shopping, commuting and education (which includes journeys made escorting others, for example 'the school run'). The increase is only very slight for business journeys, for which the car, anyway, accounts for around 90 per cent of all journeys. In contrast, the share of car-miles out of all miles for business purposes showed quite a big increase from 1985–86 to 1989–91, implying the car is increasingly important for making longer business journeys. The distance share of the car has also increased for commuting, shopping, leisure and education.

Figures 2.8a and 2.8b show that the share of all car journeys and distances accounted for by each purpose has remained fairly constant over survey years. Leisure accounts for the highest percentage of journeys taken and distance travelled. Whilst shopping and commuting now account for roughly equal percentages of journeys, commuting accounts for more distance than shopping. Business trips account for only a small percentage of all car journeys and of all car-miles, although the latter is higher than the former, implying that business journeys tend to be relatively long in distance. Education also accounts for

Figure 2.8a. Car journeys as a percentage of all car journeys, by purpose

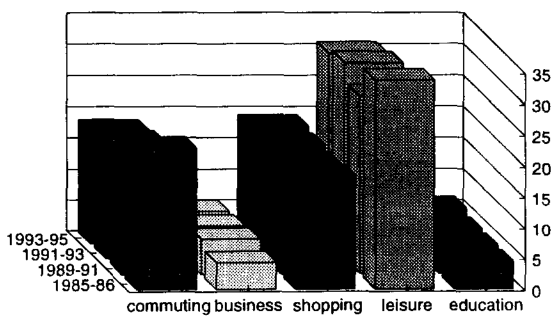
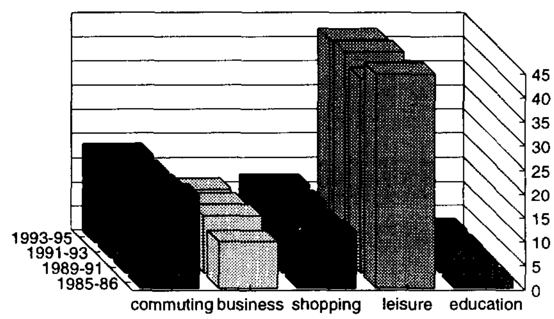


Figure 2.8b. Car-miles as a percentage of all car-miles, by purpose



Source: National Travel Surveys, 1985–95.

a small percentage of car journeys and for the smallest mileage percentage of the five purposes.

2.4 The costs of car ownership and use

The solid lines in Figures 2.9a–d show the change in various vehicle costs over time, with the dashed line showing the evolution of the general rate of inflation measure by the retail price index (RPI). Both series are indexed at January 1974 = 1 and run to April 1997. The difference between the two paths in each case illustrates how the real costs of vehicle ownership and use have changed, with the slopes indicating the rate of price inflation.

Figure 2.9a shows that, throughout the period, fuel prices increased at roughly the same rate as general inflation, except in 1979, which saw a sharp increase in its relative price, and 1986, which saw a sharp drop. Since 1992, real fuel duty increases have raised the price of petrol faster than average prices. Figure 2.9b shows that car purchase prices increased at the same rate as general prices between 1974 and 1978, and saw a slight increase in real price from then until 1981. Since then, the index has increased more

Figure 2.9a. Fuel prices and the RPI, January 1974 to April 1997

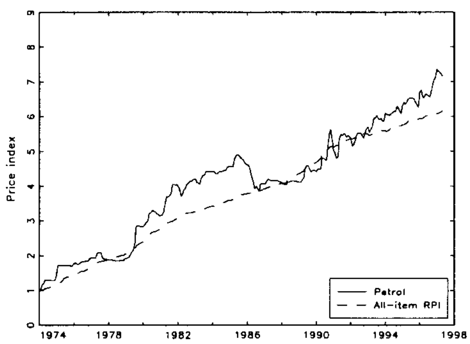


Figure 2.9b. Car purchase prices and the RPI, January 1974 to April 1997

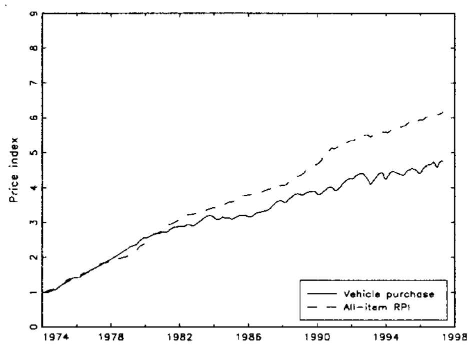


Figure 2.9c. The cost of vehicle maintenance and the RPI, January 1974 to April 1997

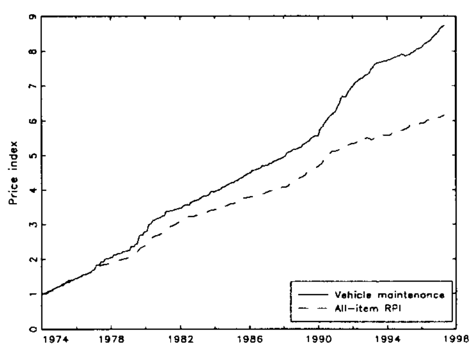
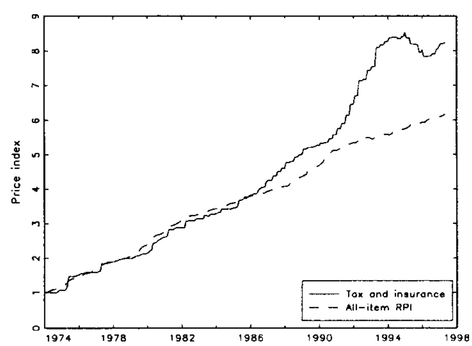


Figure 2.9d. The cost of tax and insurance and the RPI, January 1974 to April 1997



Source: Retail Prices Index, Office for National Statistics, London.

slowly than has the general price level. Figure 2.9c shows that, from around 1977 onwards, the cost of vehicle maintenance has increased at a higher rate than general prices, thus steadily increasing the real cost of vehicle maintenance. The same is true for vehicle tax and insurance from 1986 onwards, as shown in Figure 2.9d. Before 1986, the real cost of vehicle tax and insurance remained roughly constant. Over the whole period (January 1974 to April 1997), the general index for the cost of motoring has increased by 629 per cent. The all-item RPI increased by 617 per cent.

3. Transport policy

Earlier this year, the Deputy Prime Minister, John Prescott, announced the newly elected Labour government's intention of formulating an integrated transport policy, to curb people's reliance on their cars and get them onto public transport. In this section, we discuss the problems associated with the use of private transport that might give rise to the need for such government intervention. We explore the policy instruments that could be used both in theory and in practice. We then review briefly past government policy towards road transport in the UK, and, finally, we survey some options for new or reformed policies.

3.1 The argument for intervention

Individual decisions about vehicle ownership and use involve some purely private financial costs, such as vehicle purchase price, insurance and fuel expenses. In addition, the use of road transport by each individual potentially imposes various costs on others, such as noise and air pollution and congestion, which are rarely directly charged for. Simple economic analysis tends to regard people as being motivated only by financial self-interest. If this were the case, the second set of uncharged costs, or 'negative externalities', would not be reflected in their decisions regarding vehicle ownership and use. In reality, it could be the decisions of that some people (for example, people who are concerned about the state of the environment) are affected by more than personal financial costs alone, and so their decisions will be affected by these broader costs even when they are not charged for. Thus, for example, the impact on global warming of exhaust emissions may or may not enter the decision of whether to drive to the supermarket, depending on what issues concern the individual driver. In this Commentary, we will call any costs associated with vehicle ownership and use that individuals impose on others, *but that they do not take into account*, the 'social costs' of road transport. When such social costs exist, there may be a role for government policies that attempt to face people with more of the external costs associated with their journeys.[11]

The social costs arising from road transport may be numerous. They could include environmental costs such as air pollution from exhaust emissions, noise pollution, visual impact and so on; congestion costs and accident risk imposed on other road users; and the cost of road damage from the passage of vehicles.[12]

Road fuel combustion leads to the emission of a wide variety of air pollutants. Some contribute to global environmental problems — carbon dioxide and other gases that cause potential global warming, and nitrogen oxides and sulphur dioxide leading to acid rain, for example. Emissions from road transport can also be a factor in localised

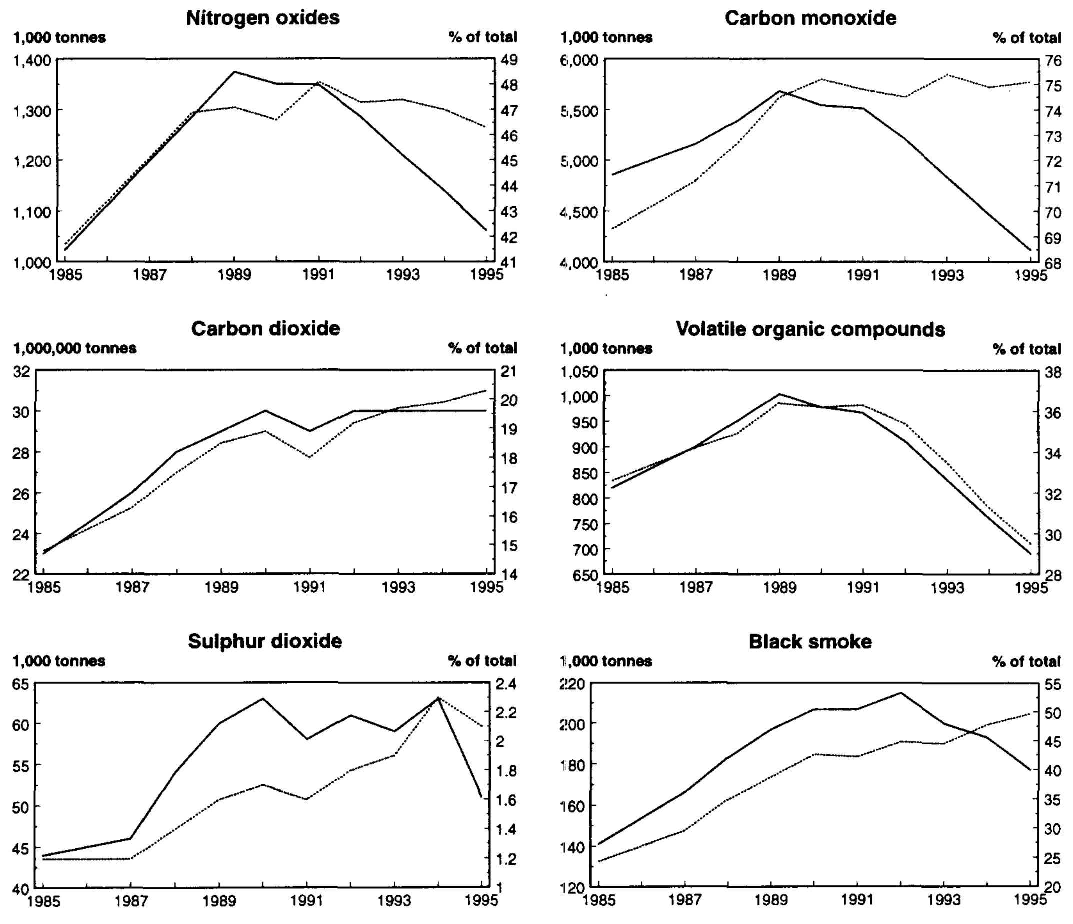
[11]Note that if people take some of the broader costs into account of their own accord, then intervention for these costs would be unnecessary and possibly even welfare-reducing. If people take costs into account to varying degrees, then policies would have to be individually tailored — something that is usually extremely problematic and that we do not discuss further here.

[12]The annual vehicle excise duty is sometimes perceived as a proxy for road user fees. It is, however, a lump-sum fee and so in no way charges the driver for the road use cost of a marginal journey.

episodes of poor air quality — for example, emissions of black smoke and particulates which appear to contribute significantly to respiratory disorders, and nitrogen oxides and volatile organic compounds which can react to create photochemical smogs.[13] The social costs of many pollutants can therefore depend on when and where they are emitted, since their effect can depend on whether the area is highly populated, on the existing concentration of the pollutant (and hence on traffic levels) and so on.

The content of exhaust emissions varies by type of fuel, and emissions of some pollutants per litre of fuel used can also be affected by driving speeds. In addition, fitting the vehicle with 'clean' technology can help reduce the emissions of certain substances. For example, diesel is associated with higher emissions of nitrogen oxides and particulates than petrol, and the emissions of carbon monoxide, nitrogen oxides and volatile organic compounds from petrol cars can be reduced greatly by the fitting of a

Figure 3.1. Emissions of major pollutants from road transport between 1985 and 1995: volumes and percentages of emissions from all sources



Key: The solid line shows absolute emissions levels whilst the dotted line gives emissions from road transport as a percentage of emissions from all sources.

Source: Digest of Environmental Statistics, 1997 edition, Department of the Environment, Transport and the Regions.

[13]See QUARG (1993) or the Department of the Environment (1996) for a review of the effects associated with emissions from road fuels.

three-way catalytic converter. Figure 3.1 shows the contribution from road transport to six major air pollutants. The figure shows growth in the levels of all pollutants from road transport until around 1990. Since then, emissions of carbon dioxide have been roughly constant and emissions of sulphur dioxide have shown no real trend except possibly starting to decline in the final year. Absolute emissions of the other four pollutants have declined in recent years. The decline in emissions of nitrogen oxides, carbon monoxide and volatile organic compounds is possibly due to the spread of catalytic converters through the petrol car stock. Percentage contributions of road transport for nitrogen oxides and volatile organic compounds have also decreased. Percentage contributions to black smoke, however, have increased and those to carbon monoxide have stayed fairly constant.

Another likely social cost of road transport is traffic congestion. The externality arises because each driver reduces the speed of other vehicles, and the resulting cost is that of increased journey times or the decision not to take a road journey. Whilst pollution damage is inflicted by road users on society in general, congestion costs are imposed, immediately, on other road users or potential road users. Newbery (1988 and 1990) has estimated that the time wasted in Britain through traffic congestion is extremely high, and the resulting social costs significant. In addition, congestion levels can exacerbate environmental externalities. For example, stop–start driving on congested roads tends to be considerably less fuel-efficient than travelling in uncongested conditions. Thus more fuel is used and more pollutants emitted for a given journey.

Accident externalities arise because one individual's driving behaviour may increase the risk of injury or death to other road users and because, in the event of an accident, costs are incurred by the emergency services, the NHS and so on, which are not taken into account by the individual, even if they are fully aware of the personal costs of becoming involved in an accident (trauma, permanent physical disability, loss of earnings etc.).

A final cost that drivers do not take into account, since they are not charged directly for road use, is the wear and tear caused to the road network by the passage of their vehicles. This will vary according to the type of vehicle (broadly by axle load) and by the standards to which the road itself is built (for example, its thickness): heavy vehicles with few axles travelling on thin roads, say, are the most damaging.[14]

Naturally, attempts to assess the total external costs associated with road transport are problematic since they involve difficult estimates such as the potential effect of greenhouse gases,[15] the value of a life saved or the annoyance cost of noise. Nevertheless, attempting to quantify the social costs arising from road transport is a valuable exercise, and various studies indicate that they could be substantial. Pearce et al. (1993) estimated the annual aggregate external costs associated with road transport in 1991 to be between £22.9 billion and £25.7 billion depending on the valuation of a saved life: £13.5 billion lost by congestion, road damage of £1.3 billion, £2.8 billion of

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[14]See Newbery (1990).

[15]Note that, even though the effects of greenhouse gas emissions may be highly uncertain, this is not an argument for doing nothing to reduce them or postponing the decision, since acting now is a form of insurance against possible future harmful outcomes. See Broome and Ulph (1991).

pollution costs plus £0.6 billion for noise, and accident costs of £4.7 billion to £7.5 billion. Newbery (1995) (drawing in part on updated work by Pearce and Crowards (1995)) estimates external costs for 1993 of between £29.3 billion and £36.9 billion per annum, depending on the valuation of a life and on the assumed mortality and morbidity effects of particulates (in the time between the two studies, new evidence suggested that these may have been underestimated in the past). Congestion costs are estimated to be £19.1 billion, the increase over the Pearce et al. estimate being due partly to the increase in time costs over the period as measured by wage costs and partly to increased passenger–car–kilometres travelled.

3.2 Theoretical background

When negative externalities such as pollution exist, they will tend to be produced in too large an amount compared with the social optimum, since polluters are not charged for the damage they inflict. Policies could be formed that try to curb the level of the externality. This would obviously result in benefits from reduction of the socially damaging activity, such as health improvements from better air quality. There would also be economic costs to the policy in the form of the cost of investing in 'clean' technology, for example. In common with the assessment of all government policy, intervention should go ahead only if the costs do not exceed the benefits. This rule gives a simple theoretical prescription for the optimal level of reduction to the externality — namely, to the point where the social benefit of another unit reduction equals the social cost. There are a number of ways of controlling socially damaging activities. It can be done via a regulatory framework (setting emissions levels or allowable traffic volumes, for example (quantity controls), or specifying production technology, pollution abatement equipment etc.) or by using market mechanisms such as taxes and charges. The optimal, or Pigovian,[16] tax would face individuals with the full costs of their actions. The previously 'free' infliction of social damage would now be charged for, thus 'internalising' the externality. Economists have long recognised that there may be certain factors recommending price instruments as a choice of policy tool with which to address externalities, in that they may achieve a given reduction of socially detrimental activity in a more efficient way than alternative policies. For simplicity, the remainder of this section will mainly use environmental taxes on pollution as an illustration, although the arguments apply equally to taxes to address any other external cost such as congestion.

Taxes versus other instruments

Theoretically, it is desirable to correct an externality as directly as possible. Thus either a tax or a quantity control on emissions will, in general, be superior to alternative direct controls such as limiting traffic levels or specifying technology (for example, requiring all cars to be fitted with a given piece of emissions-reducing equipment). Simply limiting traffic does not encourage the use of less-polluting technology and hence is not likely to achieve pollution reduction in the most efficient way. Specifying equipment means the same abatement measure, hence cost, must be taken by all polluters, whereas the

[16]So called after Arthur Pigou, who, as far back as 1920, was one of the first people to advocate the use of taxes to correct externalities.

resulting benefit may vary — for those who drive very little, for instance, the reduction in pollution may not be large enough to justify the cost of the equipment. Of course, in order to charge Pigovian taxes or enforce quantity controls, it is necessary to be able to measure individuals' emissions levels, something that may not always be possible and that we return to below.

Price mechanisms can have advantages over quantity controls because they economise on informational requirements, although the circumstances under which this is true are sometimes misunderstood. The cost and benefit information the government would need to set an *ideal* pollution tax or congestion charge would also tell it the optimal pollution level or traffic volume — the information needed to set the optimal price or quantity is identical. For example, when the costs of abatement differ across people, optimal individual abatement levels may not be uniform, since efficiency requires pollution reduction where it is cheapest. The information required to calculate the optimal tax level includes knowledge of these varying abatement costs, and so would also allow calculation of the optimal (individually tailored) pollution levels. The advantages of taxation stem from the fact that such information is often costly for the government to acquire (for instance, investigating the expense to car drivers of altering their behaviour). In this case, whilst some perfectly optimal outcome is not being aimed for, a tax at least ensures that any pollution reduction occurs where the costs are lowest without the need for knowledge of abatement costs which designing the equivalent quota system would require. Similarly, congestion charging, for example, ensures that those who value their journey most will travel, whereas traffic limits apply equally to people with low and high valuations.

Lack of information over the costs of altering behaviour can, though, lead to drawbacks in the use of environmental taxes since this implies that the reaction to the tax, and hence the level of pollution reduction, can be hard to predict. Of course, uncertainty over responses will be resolved to a certain degree by implementing the tax, which could then be adjusted.[17] The extent of these drawbacks depends on the cost of making 'mistakes' in the level of pollution abatement. In certain circumstances, quantity controls may be preferable; in cases where the costs of pollution are very high — for example, it is imperative to reduce levels below a certain fatal threshold — so that the costs of making 'mistakes' in abatement are high, setting an emission level can be preferable to setting a tax (Weitzman, 1974).[18]

Finally, taxes can have long-run advantages over regulation. Because each unit of pollution is charged for, this gives a continuing incentive to reduce levels, by, say,

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[17]Although responses — for example, investment in new technology — could be affected if people expect tax changes in the future or if they think that, by revealing information, current responses might affect the calculation of future taxes.

[18]Weitzman actually considers the case of taxes versus tradable permits. These are permits issued or auctioned by the government allowing a certain total amount of emissions which polluters can then trade amongst themselves. Tradable permits are attractive in that they combine characteristics of quantity controls and price mechanisms — the level of pollution reduction will be certain, and tradability ensures an efficient pattern of abatement. Whilst the use of tradable permits has great appeal in some cases, we do not consider them further here as they are not a practical solution in the case of pollution from road transport — permits allowing a certain level of exhaust emissions, to then be traded amongst drivers, would be an inoperable system.

inventing cheaper methods of abatement, rather than simply complying to the minimum standard set by regulation. Although, with a quota, there is the incentive to carry out the necessary reduction in pollution as cheaply as possible, there is no incentive to go beyond the minimum standard, whereas taxes give the extra incentive that each unit reduction in pollution results in a tax saving to the polluter.

Tax levels

Pigovian analysis of optimal environmental taxes tends to consider one externality in isolation in an otherwise perfect economy where the costs and benefits of pollution abatement are known. The point where the marginal cost of pollution abatement equals the marginal benefit is easily calculated, and so, therefore, is the optimal tax. We have already mentioned that there may be uncertainty over costs and benefits, and this is one obvious way in which the optimal level of pollution reduction and hence appropriate tax levels become, themselves, uncertain. The situation is further complicated when we consider the existence of many externalities and the presence of other distortions in the economy such as pre-existing distortionary taxes used to meet the government's revenue requirement. Taxes aimed at addressing one externality may interact with others. For example, reducing fuel consumption may dictate a tax on fuel, but this could stimulate the development of more fuel-efficient vehicles which may lead to a different effect on mileage and congestion than if fuel efficiency had remained static. Environmental taxes can also interact with existing revenue-raising taxes, eroding their base by reducing the consumption of the good or the level of the activity on which they are set. This means that the costs and benefits of instituting the tax reach far beyond the direct costs and benefits of pollution reduction, even if these could be easily quantified. The same rule applies that the optimal policy would just match the benefit of further pollution reduction with the costs, but the costs and benefits are much wider and consequently harder to calculate than simple analysis might suggest. It is worth noting that these same considerations may affect the determination of alternative policies such as quantity controls.

Tax revenues

Another feature of taxes compared with some other environmental policy tools is that they raise revenue. Governments have revenue requirements, but the revenue-raising appeal of taxes over other forms of environmental policy is a feature often overlooked by elementary analysis, which tends to assume that the receipts are returned to the economy in lump-sum form, and so have no consequences for economic efficiency. More lately, however, there has been some debate over whether the revenue raised from environmental taxation can be used to achieve some extra benefits beyond those contained in traditional Pigovian analysis. Taxes used to raise revenue — for example, income or corporate taxes — tend to distort consumption, labour supply or production decisions. Economic literature on optimal tax rates looks at how to set taxes to collect the required amount of revenue in the least distortionary way. Policymakers may also care about the effect a tax has on the distribution of income, and optimal tax analysis can be extended to include equity considerations by allowing different income groups to have different weights in aggregate welfare. The best way to collect a given amount of revenue is then a balance between efficiency and equity. In recent years, there has been interest in the idea that a revenue-neutral swap between an environmental tax and an existing tax could yield an extra gain over and above correcting the environmental externality. The idea is that ordinary taxes create distortions whereas environmental taxes correct them, and so a swap between the two will reduce the overall level of distortion in the tax system, hence yielding a 'double dividend'. This 'strong' form of the double dividend says that such a tax swap will improve welfare *even if* the effect on the environment is ignored. This idea is particularly appealing from a policy perspective since, as discussed above, the benefits of pollution reduction can be extremely difficult to quantify. If the strong double dividend proposition held, then it would not be necessary to establish the size of the environmental benefit from the new tax, but only that it is positive, in order to guarantee an overall gain.

There is little consensus over whether such a double dividend exists. Environmental taxes 'work' because the environmental benefit and the revenue raised outweigh the cost to consumers or producers of the price increase resulting from the tax. 'Ordinary' taxes have only the last two attributes — that they raise revenue and distort prices. It is this aspect on which the double dividend argument focuses, proposing that a swap between the two taxes will raise revenue in a less distortionary way. But, in fact, there is no a priori reason for thinking that an environmental tax will be a more efficient revenue-raiser than the tax it replaces (indeed, quite the opposite if the original tax system was well designed). This may be even more the case if the analysis incorporates distributional concerns, since many environmental taxes are likely to be fairly regressive — for example, energy taxes. In the end, whether a double dividend will arise from a particular tax swap is a matter for empirical investigation. In addition, if an environmental tax is also used as a revenue-raiser, any uncertainty over the response to the tax becomes particularly problematic since revenue-raising taxes should be able to provide a stable, easily predictable stream of funds. Of course, revenues will probably become easier to predict once the tax has been in place for some time.

It is important to remember that the absence of a double dividend does not mean environmental taxes should not be used, since they may yield a single dividend of an overall welfare improvement when environmental gains are included. In addition, there is little controversy among economists over the possibility of a 'weak' double dividend — that a tax swap can reduce the economic costs of introducing an environmental tax compared with other methods of recycling the revenue. For example, using the environmental tax revenue to reduce an existing distortionary tax reduces the distortionary cost of the tax system compared with lump-sum redistribution of the revenue which would be efficiency-neutral (although, again, this may depend on distributional considerations since uniform lump-sum transfers are progressive).

3.3 Taxes in practice

Pigovian taxes charge directly for the social cost of pollution which, in turn, necessitates the ability to measure the offending activity. In practice, direct measurement of emissions may not be possible or would involve enormous administrative costs or prohibitively expensive metering technology. Theoretical comparisons of different policy options tend to ignore administration and measurement costs, which are a very real consideration in practice. For example, measuring individuals' levels of car exhaust emissions by time and place is probably not a feasible option. In such circumstances, it may be possible to approximate the direct charge by taxing activities or goods that are related to the externality and for which taxation is relatively administratively simple, perhaps even restructuring existing taxes. Carbon dioxide emissions from vehicles are broadly linearly related to fuel consumption, and the global warming effects of carbon dioxide depend linearly on emissions, so a fuel tax would be a good proxy for a direct tax on this externality. However, it is unlikely that it will always be possible to find a practical tax base that is so well linked with the externality; as described above, the cost of other exhaust emissions can vary by location, weather conditions and so on, and their levels can be affected by whether, for example, the car is fitted with a catalytic converter, and so fuel taxes are not a particularly accurate way to charge for these environmental costs. It may be necessary to use a range of taxes and subsidies to approximate the direct charge on the externality, but theoretical analysis suggests that the correct combination is not always obvious and can be counter-intuitive.[19] Moreover, again taking administrative costs into account, the range of workable tax bases available to the government may be limited, and the cost of applying a myriad of minor taxes in an attempt to mirror exactly the social costs of an externality may outweigh the benefits of so doing. It is clear that, far from the Pigovian ideal, governments have a limited set of taxes and charges to address the combined effect of the various social costs associated with road transport. In some cases, taxes may be quite effective in achieving emissions reductions — since the introduction of a tax differential in favour of unleaded over leaded petrol, the share of unleaded petrol in total petrol sales has increased substantially and lead emissions from road transport have decreased (although other factors, such as the use of catalytic converters which can only function with unleaded petrol, may also explain its increased share). In this example, a tax differential may have been quite a successful policy since leaded and unleaded petrol are very close substitutes for most people and so only a small price differential should be necessary to induce a switch. In other cases, where a tax base well-linked to the externality is hard to find, perhaps regulation is more effective — emissions standards requiring new cars to be fitted with catalytic converters may explain the decline in emissions of nitrogen oxides, carbon monoxide and volatile organic compounds illustrated in Figure 3.1.

In summary, there are some reasons to suggest that taxation can be a useful environmental policy tool in that it may deliver a certain goal — for example, a given reduction in pollution — more efficiently than the alternatives. However, while simple economic theory gives some easy rules for setting environmental taxes, reality can be rather different. Quantifying the costs and benefits of an environmental policy can be extremely difficult. Whilst this is problematic for assessing any policy measure, the particular issue for taxes is that responses to price increases may be difficult to predict. In addition, rather than ideal direct taxation of the externality, the feasible taxes available to

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[19]We would expect it to be appropriate to tax goods or activities that are complementary with the externality and to subsidise those that are substitutes — for example, tax parking spaces and subsidise buses to alleviate urban congestion. However, taxing an imperfectly linked complement good to the externality distorts the consumption of the good. If a substitute for this good exists, then taxing this second good as well may improve the situation, even if the second good is also a substitute for the externality-generating activity so that taxing it seems intuitively the wrong policy. See Wijkander (1985).

the government may only loosely be related to the social cost it is attempting to address. Even if these problems did not exist, the interaction of environmental taxes with existing distortions in the economy would greatly complicate the calculation of their ideal level. This means that, rather than attempting to determine some optimal outcome, analysis tends to focus on estimating how a certain tax (say an increase in motor fuel taxation) would affect behaviour (how people use their cars, in this case) and what the welfare implications would be. In Section 5, we present a model of the determinants of private transport decisions which will allow us to estimate the (short-run) effects of certain price increases on car use. We address the issue of calculating the (non-environmental) welfare effects of a tax reform in Section 4.[20] In particular, whilst our discussion so far has focused mainly on the question of efficiency in tax-setting, we may also, as mentioned, be concerned a great deal about the distributional consequences of environmental taxation when assessing its welfare implications. Before moving on to these sections, we discuss some aspects of transport policy in the UK.

3.4 Transport policy in the UK

The use of tax instruments to correct externalities is not a new idea in economics, and, in recent years, many papers have been written advocating their attractions as a practical policy tool.[21] Despite this, taxes and charges to deal explicitly with the social costs of transport are only used to a limited extent in the UK. Indeed, the main fiscal instruments currently employed number but two — road fuel taxes and the annual vehicle excise duty (VED). These have existed for many years and were introduced primarily as revenue-raisers rather than to address any external costs associated with road transport. This section aims to give a short review of the development of policies towards road transport in the UK.

Fuel duties

As well as being liable to the standard rate of VAT, road fuels are subject to specific excise duties. In recent years, the design of road fuel duties has been partly environmentally motivated. In the Budget of March 1993, the then Chancellor announced an annual real increase in duties of at least 3 per cent a year in order to tackle the problem of carbon emissions and global warming. Later the same year, in the November Budget, this commitment was raised to an increase of at least 5 per cent in real terms each year. This year, in the post-election Budget, the new Chancellor, Gordon Brown, announced a further one percentage point increase to this figure, taking promised annual real increases in fuel duties up to at least 6 per cent. Figure 3.2 shows the real value of excise duties applied to leaded petrol between January 1974 and April 1997. The revalorisation of duties in annual Budgets shows up clearly. Over the entire period, excise duties have shown a real increase of around 35 per cent. Most of this increase has come about since 1992. The graph shows the erosion of real duties in the

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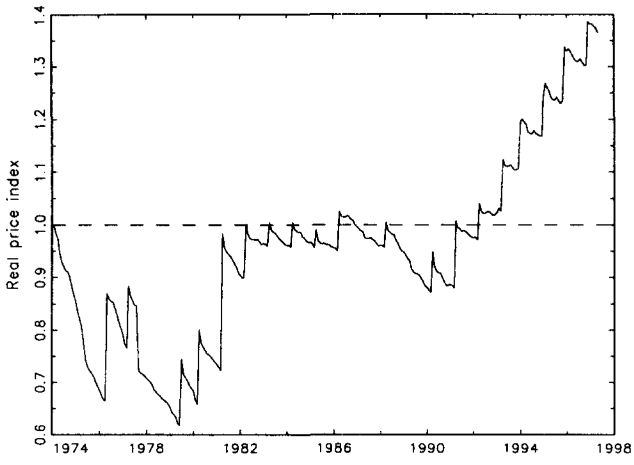
[20]A complete cost–benefit analysis would obviously require inclusion of the environmental benefits of the policy — for example, health improvements from pollution reduction — but this is beyond the scope of this Commentary.

[21]See, for example, Pearce, Markandya and Barbier (1989).

Figure 3.2. The real value of leaded petrol excise duties, January 1974 to April 1997



1970s and early 1980s, with a sharp increase in 1981, followed by annual revalorisations which more or less track general inflation until 1988. It also indicates that increases in real fuel duties may have been tacit policy, prior to the Chancellor's formal announcement, from as early as 1991.

In addition to general increases, differential road fuel duties have been used with the aim of encouraging the use of those fuels thought to be less environmentally damaging. An obvious example of this is the duty differential in favour of unleaded over leaded petrol, introduced in April 1987 and widened in subsequent years. In the 1995 Budget, an increase in the relative duty on super-unleaded fuel was announced due to concern over the high level of aromatic hydrocarbons in this fuel, thought to be carcinogens.

Standard diesel engines used to produce significantly lower emissions of certain pollutants, such as carbon monoxide, nitrogen oxides and hydrocarbons, than petrol engines. However, the advent of catalytic converters has removed this advantage — fitting a three-way catalytic converter to a petrol engine can result in a reduction of nitrogen oxide and hydrocarbon emissions below that of diesel engines. In addition, diesel is associated with high emissions of particulates compared with petrol.[22] Which is to be preferred on environmental grounds is ambiguous. As a result, the duty on diesel, which used to be taxed more favourably than petrol, was brought into line with that on standard unleaded petrol in the 1994 Budget largely for environmental reasons.

In the 1994 Budget, the level of duty on road fuel gases was frozen, and, in 1995, it was reduced by 15 per cent to bring their price into line with those of petrol and diesel and make them a viable alternative fuel. Diesel engines can be converted to run on road fuel gases, which emit much lower quantities of nitrogen oxides and particulates (up to 70 per cent less) than diesel. In 1996, the level of duty was further reduced by 25 per cent in recognition of the fact that the environmental impact of road fuel gases may be below

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[22]A detailed comparison of emissions from diesel and petrol engines can be found in QUARG (1993).

that of diesel. As with leaded versus unleaded petrol, a cost saving from switching to the alternative fuel is thought necessary in order to cover vehicle conversion costs.

Usually, we can think of demand as being not for a car itself, but for travelling, some of which can be done in the form of car-miles. The cost per mile of car transport is affected by fuel prices and by the fuel efficiency of the vehicle. An increase in fuel taxes thus has a direct effect on the cost per mile of car travel, but may also have an indirect effect through inducing changes in fuel efficiency. In the shorter term (i.e. for a given vehicle stock), the fuel efficiency of a given car can be affected to a certain extent by the way it is driven, deteriorating, for example, at very high speeds, so an increase in fuel taxes may encourage more fuel-efficient driving behaviour. Multiple-vehicle households may also switch away from their less fuel-efficient vehicles and towards those with higher fuel efficiency, thus increasing the 'average' efficiency of their travel. In the longer run, an increase in fuel taxes may increase the efficiency of the vehicle stock by encouraging the manufacture and purchase of more fuel-efficient new cars and accelerating the scrapping of older, fuel-inefficient vehicles. The direct effect of fuel taxes is to increase the cost of vehicle usage and so tend to reduce individuals' mileages. The indirect effect tends to act in the opposite direction by increasing fuel efficiency. Because of this, the effect on mileage of fuel taxes may be different from their effect on fuel consumption.

The longer-term effects of an increase in fuel taxes may also be to reduce the level of the vehicle stock. In as far as an increase in fuel prices increases the costs of motor travel, it may make vehicle ownership no longer worth while for some people.

Cars are just one mode of travelling, and the response to an increase in the price of this form of transport will also depend on individuals' willingness and ability to substitute towards other modes of travel such as public transport. We would therefore expect responses to vary according to individuals' circumstances. For example, rural dwellers may have little access to reliable public transport, and therefore little short-term alternative to their car for travel purposes. In the longer term, people can change their circumstances, and we could even see relocation in response to increases in motor travel costs, to reduce the distance from home to work and amenities or to increase access to public transport.

Fuel taxes affect the cost of all journeys and so do not effectively address congestion costs since these will vary with time and place, thus requiring the deterrence of some journeys but not others. In addition, they are an unequal tax on mileage across drivers, adding more to the cost of a mile in a fuel-inefficient car (i.e. one that travels few miles per gallon) than to the cost of a mile in a fuel-efficient one. Finally, as noted in Section 3.3, fuel taxes cannot perfectly address the social costs of pollution associated with vehicle use.

Vehicle excise duty

VED is an annual, fixed charge on vehicle ownership. From 1985 to 1991, the rate on private vehicles was £100, and it has since been increased in successive Budgets to its current level of £150 (equivalent to a nominal increase of about 7 per cent each year over the six years). Unlike VED on private vehicles, which is uniform regardless of characteristics (except for vintage cars, for which there is zero VED), HGVs pay VED that is differentiated according to the weight of the vehicle. This is designed to reflect the fact that road damage tends to increase with vehicle weight. Most HGV duty rates were frozen for the seven Budgets prior to this year's, in which they were only increased in line with inflation. They now range from £160 for HGVs up to 7,500 kg to £5,170 for two-axle semi-trailers between 33,001 kg and 44,000 kg. In this year's Budget, the new Chancellor also announced the introduction, in 1998, of a reduction in VED of up to £500 for lorries and buses producing low particulate emissions.

As well as the recurrent charge of VED, a one-off sales tax used to be levied on the purchase of new cars in addition to the standard rate of VAT. This was charged at 10 per cent on five-sixths of the list price of a new car, halved to 5 per cent in March 1992 and abolished in November 1992.

Unlike fuel taxes, which affect the cost of car use, VED is a fixed tax on car ownership. Once paid, VED has no effect on the cost of making an additional journey, and is the same for a person who uses their car a lot as for a person who uses it a little. It is also (currently) independent of fuel efficiency and other vehicle characteristics. Such a tax is therefore not an ideal proxy for externalities related to car use and/or vehicle type, such as pollution and congestion. VED increases the cost of car ownership and may indirectly affect pollution and congestion levels by deterring ownership, thus reducing the aggregate vehicle stock. It could also influence the age composition of the vehicle stock — the annual charge may represent a significant proportion of the value of very old vehicles to their owners and make their ownership no longer worth while. This, in turn, can affect aggregate emissions, since old cars tend to be built to less strict emissions standards and performance also tends to deteriorate with age. As with fuel taxes, responses to increases in VED may vary according to ability and willingness to substitute towards other forms of transport.

The tax treatment of company cars and fuel

Company cars and free fuel for private motoring are two benefits in kind that companies often provide for their employees. Some method is therefore needed to assess this benefit for the payment of income tax and other taxes such as employer's social security payments that would otherwise be due on wage income. Cause for concern will arise where this assessment process means that cars and fuel tend to be an undertaxed benefit in kind so that there is an incentive for employers to provide these perks instead of normal income payments, or where the price perceived by employees is less than if these purchases were privately made.

Owners of company cars pay income tax on 35 per cent of the manufacturer's retail list price of a car less than four years old, with a one-third reduction for cars more than four years old. In addition, the liability is reduced on cars with high business mileages: a one-third discount applies on annual mileages between 2,500 and 17,999, and mileages of 18,000 and above attract a two-thirds discount. There is thus an incentive to increase business mileage in order to reduce tax liability.

Around half of employees with company cars (some 800,000 people)[23] receive free fuel for private motoring as a benefit in kind. Its cash equivalent for personal taxation purposes is taken to be a fixed amount depending on engine size. The same banded amounts are used to charge employers VAT on the free fuel they give for private motoring (only VAT on fuel used for business purposes can be reclaimed by companies). This flat tax liability irrespective of amount means that free fuel is certainly undertaxed above a certain level of consumption. Recipients of unrestricted free fuel perceive a zero marginal price for the good, as opposed to private purchases where each unit is charged at the market price.

Another benefit in kind provided by employers linked to motoring which has attracted some attention is free car-parking spaces. These represent a substantial tax-free perk and may encourage the use of cars to commute to work. About 80 per cent of company cars used for commuting into London get free parking, and taxation of this benefit could help ease congestion.

Regulation

Certain regulatory measures are also in force in the UK, mainly via the adoption of EC directives setting emissions standards for vehicles. Directives introduced in 1989 and 1991 set emissions standards to be met by all new models of car from July 1992 and by all new cars from January 1993 which, with technology in its current state, can only be met by most vehicles via the fitting of a catalytic converter.

3.5 Policy options

Fuel duties

In its 1994 report on transport and the environment, the Royal Commission on Environmental Pollution recommended increasing fuel duties so as to double the relative price of fuel by the year 2005. In a response to this report, Newbery (1995) estimated that the total external costs of road transport far outweighed the revenue raised from road taxes (of which fuel tax is the main contributor), and that, from this point of view, a large increase in fuel duties could be justified. However, as he points out, fuel taxes are a very blunt tool for addressing many of these social costs — for example, congestion (which his estimates show to account for over half of total external costs). One cost for which fuel taxes are a good proxy is the global warming effect of carbon dioxide emissions, which the Commission particularly aimed its proposals at tackling. Although the effects of global warming are difficult to cost, the revenue from fuel taxes is far in excess of Newbery's and others' (for example, Pearce et al. (1993)) estimates, and the implied carbon tax from the Royal Commission's proposal is several times greater than, for example, the European Commission's suggested rate for a carbon tax. When a good is taxed for revenue-raising and environmental reasons, theory indicates that the total tax can be broken down into its revenue-raising and its externality-correcting components. It could be argued, then, that we should not be comparing total revenue with global

[23]Inland Revenue 1996 Budget news release no. 4, 'Income tax: company car fuel scale charges for the year 1997–98'.

warming costs because road fuels are taxed in part to raise revenue. However, it is difficult to justify the introduction of a large carbon tax on road users when such a policy is not applied to other fuel-using sectors of the economy. As regards current policy, the government is committed to real fuel duty increases of at least 6 per cent each year, which would, for example (assuming no change in real production costs) increase relative petrol prices by about 30 per cent over six years.

Vehicle excise duty

Given that the design of new tax systems may be administratively costly, there may be some appeal to restructuring existing taxes on road transport to reflect more accurately the social costs involved.

In contrast to the UK, many other countries differentiate VED on private vehicles for environmental reasons. Examples include differentiation by engine size and deductions for cars meeting certain emissions standards or for those fitted with catalytic converters. For several years, the previous government kept under review the option of introducing a similar scheme in the UK, and this possibility has also been mentioned by the new government, but no definite change is at present imminent.

It would be possible, as in other countries, to differentiate VED on the basis of vehicle characteristics. The Royal Commission on Environmental Pollution (1994) argued for VED becoming graduated on the basis of fuel efficiency when new. The reasoning is that fuel-efficient cars use less fuel per mile, and hence produce less pollution per mile, than fuel-inefficient cars. However, fuel efficiency of a car when new does not directly link to emissions levels, since these can also depend on whether the car is fitted with a catalytic converter, on the type of fuel used and so on, and also possibly on the age of the car. In any event, fuel taxation is the most direct way to address issues associated with fuel efficiency and would render additional taxes related to fuel efficiency unnecessary. Since emissions tests now form part of the annual MOT test, a level of VED based on these test results might be better targeted. Whatever the basis for differentiating VED may be, though, it still remains the case that VED is independent of individual car usage.

Road pricing

Two of the external costs associated with motor transport are directly related to road use — namely, congestion costs and road damage. It is important to draw the distinction between road pricing aimed at the external costs associated with road use and charging tolls as a means of paying for the provision of the road infrastructure. Newbery (1988 and 1990) argues that charging for road damage is relatively simple, as it is closely related to ton-miles travelled by vehicle type. Charging for congestion, however, is much more problematic since it depends on the volume of traffic in a given area at a given time. In addition, the response to congestion charging might be rather complex since, unlike other external effects such as pollution, congestion itself affects the demand for road transport, leading to feedback effects. A charge may have the direct effect of reducing vehicle transport demand, thus reducing congestion, but this alleviation of congestion makes road transport more desirable, tending to offset the initial effect somewhat.

Other countries charge for road use in various ways. A number — for example, France, Italy and Spain — have charged for the use of motorways by levying tolls since the 1950s or 1960s, with motorways being planned and built with tolling in mind. In a Green Paper, *Paying for Better Motorways*, published in 1993,[24] the UK government considered three methods of motorway charging — conventional tolls, permits and electronic direct charging. Electronic charging can operate by fitting the vehicle with an electronic tag that signals the presence of the vehicle to a receiver. A central computer can then record the distance travelled and charge the driver's account accordingly. The introduction of conventional tolls in the UK was dismissed as impractical. Being relatively densely populated, the land required for toll booths is at more of a premium in the UK than in some other European countries. UK motorways were not built with tolling in mind and have a high frequency of junctions, particularly in densely populated areas. In addition, toll booths could lead to significant delays at certain times and places. A further concern was that, with the UK's well-developed network of trunk roads, motorway tolls would lead to large-scale diversion of motorway traffic onto A roads. Electronic charging was seen as a better way to charge directly for use, since it avoids tolling plazas and queuing, but it was felt that technology was not sufficiently advanced to contemplate its introduction for several years. Permits were seen as the best medium-term solution to motorway charging although it was recognised that they are a somewhat inflexible tool and do not relate directly to motorway mileages.

Where congestion charging has been used in other countries, it has usually been in the form of a charge for access to a particular area, commonly to cross a boundary that defines the start of the city centre. Singapore introduced an area licence scheme in 1975, charging vehicles to enter the city centre between certain times by requiring the purchase of daily or monthly permits to be displayed on the windscreen. Three Norwegian cities also charge vehicles to enter the centre, with payments either being made electronically, via the fitting of an electronic tag to the vehicle, or at a booth. Objections to these simple cordon charging systems are that they are too inflexible and do not differentiate charges according to how severe congestion actually is at a particular time. The UK government commissioned a three-year study into congestion charging in London, considering more flexible methods of congestion charging, with a final report published in 1995.[25] Among the charges considered were one based on the time spent in a particular area and one based on the distance travelled. It concluded that technology was not yet advanced sufficiently to make congestion charging a viable proposition in the capital in the near future, but that it may be possible in smaller cities. Research into congestion charging has also been conducted in a number of other areas such as Cambridge and Bristol.[26] The system proposed for Cambridge involved a charge based on the time taken to travel half a kilometre being above a certain threshold value, a proxy for measuring congestion levels.[27] In August this year, a project investigating responses to urban road pricing was

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[24]Department of Transport, 1993a.

[25]MVA Consultancy, 1995.

[26]Smith et al., 1994; Department of Transport, 1993b.

[27]See May and Nash (1996) for a review of the design of policies to tackle urban congestion.

also launched in Leicester. Participants have the choice of paying a fee to enter the city, deducted electronically from a 'smart card' as they pass through roadside beacons, or switching to a park-and-ride service that uses a bus priority route and can also be paid for via the smart card.

Public transport

It is sometimes suggested that public transport could be subsidised (or further subsidised) to encourage people away from their cars and onto buses and trains. If using public transport is associated with lower social costs than private transport, then people may face the wrong relative prices between modes, and lowering the costs of public transport is an alternative to raising the costs of private motoring, if this is, for some reason, easier to achieve. Although it may be preferable to charge each mode at full social cost, undercharging for private transport could mean it is optimal to undercharge for other modes. Hughes (1990) estimates that a petrol car with a 1.4-litre engine carrying 1.5 people uses three times the energy per passenger-kilometre of a bus with 60 per cent occupancy, with the figure rising to six times as much energy in the case of a 2-litre car. That replacing, say, 30 cars by one bus on the road could go some way to easing congestion also seems fairly plain. Again, as the social costs of transport vary with time, location, existing traffic conditions and so on, we could expect the differential costs between public and private transport to vary similarly. For example, a bus on an empty rural lane has no benefit in reducing congestion. Ideal subsidies would be complicated to design. In addition, subsidising public transport could attract wholly new users as well as people who have substituted away from other forms of transport, a somewhat undesirable side-effect of a policy aimed at reducing the impact of transport decisions on society, particularly if subsidies mean that public transport prices under-reflect its social costs. In addition, since, for example, rail and most bus services are now privatised, it may be problematic for the government to subsidise directly many fares under the present system, depending on how prices are regulated and also on the public's acceptance of large subsidies to privatised industries.

Empirical evidence tends to suggest that cross-price elasticities of demand between transport modes are low (although, of course, this is likely to be less so for some areas than for others), so that subsidies to public transport would do little to attract people away from their cars. Newbery (1990) suggests that quality improvements in public transport (possibly at the expense of private transport — for example, giving more road space to buses and less to cars) may be a better way of encouraging users of private transport to switch modes. The use of these kinds of policies was hinted at by John Prescott when he announced plans for an integrated transport strategy, leading to the publication of a White Paper in Spring 1998, aimed at getting car users to substitute to public transport. Possible measures could include extra bus lanes and tougher enforcement against cars travelling or parking in bus lanes. A final aspect of the policy of subsidising public transport is, of course, that subsidies require public funds that are raised using taxes that may cause distortions elsewhere in the economy.

4. The distributional effects of environmental taxes

In this section, we describe the way in which it is possible to measure the effects that indirect tax changes have on households' economic well-being. We also discuss the importance of allowing for any consequent changes in households' behaviour when making this calculation. Why both the behavioural and the welfare effects might be expected to differ between households with different incomes and different demographic compositions is then analysed.

4.1 Indirect tax changes, cost-of-living indices and economic welfare

Since indirect taxes influence households' economic welfare and behaviour by altering the prices that they must pay for different goods and services, the concept of a cost-of-living index is the most useful way in which to think about how we might measure the welfare effects of an indirect tax reform such as increases in road fuel duties. We begin by considering a single household. We discuss distributional effects below.

A cost-of-living index measures the relative cost of reaching a given level of economic welfare under different sets of prices.[28] In the present case, the changes in prices that we might be interested in are those induced by an indirect tax change. In this context, a cost-of-living index will measure how much it costs to enjoy the level of economic welfare that existed before the tax reform, compared with how much it costs after the reform. For example, if the price of a good goes up, households are poorer in real terms — their current incomes can buy less. The cost-of-living index calculates how much extra income they now need to get back to their original welfare level. In order to isolate the effect of the tax reform under consideration, everything else that also determines economic welfare must be kept constant in the comparison. This is what a cost-of-living index does. The question of how, exactly, we should measure the cost of living remains.

If we denote the reference level of welfare (say pre-reform welfare) as U_0, then the cost-of-living index that measures the effects of a tax change is written as

$$\frac{c(p_T, U_0)}{c(p_0, U_0)}$$

where p_0 is the set of pre-reform prices, p_T is the set of post-reform prices and $c(p, U)$ is the cost function. The cost function tells us the minimum expenditure necessary to reach a certain level of welfare, U, given a set of prices, p.

If we know the cost function, then we simply compute it for the pre-reform set of prices, then recompute it holding welfare constant but with the new tax level for the good or

[28]Typically in economics, we view welfare as deriving from the consumption of goods and services. We might also think that it derives from environmental quality (we could view the environment as a public good) and so, while an environmental tax increases the cost of buying goods, it increases the welfare derived from clean air, say. The net effect on the cost of living may be ambiguous. An optimal environmental tax should reduce the cost of living. We are unable to value environmental improvements and therefore confine our attention to the measurable, distributional effects of tax-induced price increases of goods.

goods of interest. We then calculate the ratio. The problem, in practice, is that we typically do not know the cost function and estimating it is often difficult. In this Commentary, we adopt a simpler approach in which we use an approximation to the cost function. While this does not require the true cost function to be known, it does take into account behavioural responses to tax changes and thus provides a better approximation to the true welfare effects than simple, zero-behavioural-response approximations.[29]

All we need to know in addition to the pre-reform demand and the pre- and post-reform prices (which are both either easily observed or calculated) is the welfare-constant demand response. This can be estimated much more readily than can the entire cost function and (unless the behavioural response is insignificant) the results prove a more reliable estimate of the true effect than the first-order (non-response) approximation (which is simply the Laspeyres price index, $p_T q_0 / p_0 q_0$). We describe the derivation of the demand response in Section 5.

4.2 Distributional effects

So far, we have implicitly concentrated on the effects of an indirect tax change on the welfare of a single or a representative household. True measures of these welfare effects will, in general, depend upon the pre-reform level of welfare. Even if all households derive economic welfare from goods in the same way, and even if they all face the same prices, an indirect tax reform will affect their welfare differentially if spending on the good of interest varies with total income or total expenditure. If consumption patterns vary by household characteristics, then price changes will affect the welfare of different household types differently, even if spending patterns were constant with respect to income within each group.

Constant spending on a good as a proportion of total spending (a property of demand known as homotheticity) is a necessary and sufficient condition for the existence of a single index of welfare.[30] In other words, it has to be the case that all households spend exactly, say, half their income on housing, a quarter on food, an eighth on clothing, etc.,

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[29]See Banks, Blundell and Lewbel (1996). The minimum cost of reaching the same welfare level that existed prior to the reform, $c(p_T, U_0)$, is approximately equal to the pre-reform demand for road fuels evaluated at post-reform prices, $p_T q_0$, plus a second term that depends upon the magnitude of the welfare-constant demand response to the relative price change, $\partial q / \partial p|_{U=U_0}$, which is always negative. This is set out in the equation below.

$$c(p_T, U_0) \approx p_T q_0 + \frac{1}{2} \frac{\partial q}{\partial p}\bigg|_{U=U_0} (p_T - p_0)^2.$$

This expression is straightforward to calculate if the demand response term can be estimated. By the usual assumption that households are cost-minimisers, we know that the minimum cost of reaching pre-reform welfare at pre-reform prices is just the actual pre-reform spending, $c(p_0, U_0) \equiv p_0 q_0$, so dividing through by pre-reform expenditure gives the approximation to the true index that we are after:

$$\frac{c(p_T, U_0)}{c(p_0, U_0)} \approx \frac{p_T q_0}{p_0 q_0} + \frac{(p_T - p_0)^2}{2 p_0 q_0} \frac{\partial q}{\partial p}\bigg|_{U=U_0}.$$

This has the interpretation that the true cost-of-living index is approximately the cost of satisfying original demand under the post- compared with the pre-reform prices (i.e. a Laspeyres price index, $p_T q_0 / p_0 q_0$) plus a term that accounts for some degree of behavioural change in response to the tax reform.

[30]This result was proved by Malmquist (1953), cited in Diewert (1981).

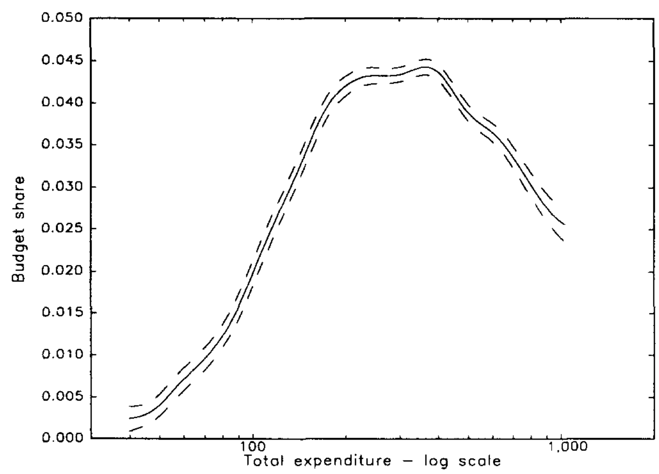
regardless of their incomes. If this is the case empirically, then there will not be a distributional effect — the impact of a tax change on the economic welfare of all households will be identical.

If homotheticity does not hold, then a single index cannot be appropriate for every household; in other words, there will be a distributional effect associated with a given tax reform. Further, the greater the relative price change brought about by the tax reform, and the greater the disparity in spending and behavioural responses, the greater will be the variation around the average measure. The prima-facie evidence for this in the case of road fuels is presented below.

Figure 4.1 shows the relationship[31] between the proportion of household total (non-housing) expenditure that is spent on road fuels against (log) total expenditure. This graphical relationship is known as an Engel curve, after Engel's (1895) investigation into family spending patterns in which he showed that the proportion of total spending allocated to necessities tends to fall as income (and consequently total expenditure) of the household rises. Thus a downward-sloping Engel curve usually defines a necessity, an upward-sloping curve a luxury. On this definition, it appears that road fuels have the characteristic of a luxury for poorer, lower-spending households and that of a necessity for richer households. The solid line of the curve shows the (local) average of the budget share for a given total expenditure level. The dashed lines report the 95 per cent confidence interval around that average.

Given the data on the distribution of car ownership described in Section 2, the shape of the budget share / total budget relationship is not surprising. Low average shares amongst poorer households correspond to lower rates of car ownership among these households, and consequently many households will have a zero share.

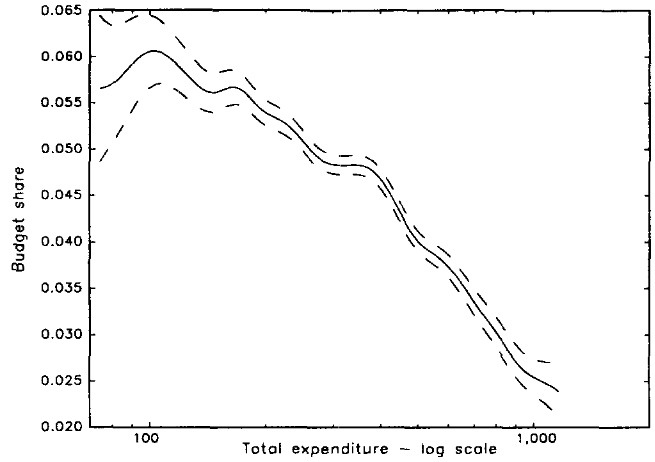
Figure 4.1. The Engel curve for road fuels: all households



Source: Family Expenditure Survey, 1995–96.

[31]The relationship is described by kernel regression techniques; see Hardle (1990).

Figure 4.2. The Engel curve for road fuels: households with cars



Source: Family Expenditure Survey, 1995–96.

Figure 4.2 splits the FES sample according to whether or not the households interviewed have access to a car. The Engel curve for car-using households has then been estimated. The shape of the Engel curve is different from that for all households as a result of many non-car-owning households being dropped from the bottom of the spending distribution, and the plot indicates that, conditional on having a car, road fuels are a necessity. The widened 95 per cent confidence interval at the low total budget / high budget share end of the curve indicates the relative sparsity of the data once non-car-using households, and their associated zero budget shares, are dropped.

These Engel curves give initial evidence that the welfare effects of taxes on road fuels and car usage which change the set of relative prices faced by consumers will differ across types of households and across the income distribution.

5. Modelling behavioural responses

As we have argued above, both the effectiveness of the incentives provided by environmentally motivated taxation and the consequent distributional effects depend upon households' differing demands for road fuels and the differing way in which they adjust their demands in response to price changes. In this section, we briefly describe a simple model of car usage and present a description of the distribution of behavioural responses to changes in the cost per mile of driving and to changes in the availability and cost of alternative forms of road transport. This model will be used to calculate the welfare-constant demand responses needed for the estimation of the distributional effects of alternative tax reforms. This is discussed in Section 6. We begin with a description of the dataset used.

5.1 Data

The data used for estimation are from the annual National Travel Survey, 1988 to 1993. This is the latest in a series of surveys designed to provide a national data source on personal travel. Previous surveys have been carried out in 1972–73, 1975–76, 1978–79 and 1985–86. The NTS contains detailed information on households' and individuals' travel as well as their characteristics (age, income etc.). Each member of a participating household recorded a travel diary for the week in which they were surveyed and was interviewed twice — the first time to obtain household and personal details, the second to collect diaries and to record mileages and fuel consumption. The characteristics of the households' stock of vehicles were also recorded. In our applied work, we have 18,458 households, of which 12,209 have at least one car and 2,973 have two.[32]

5.2 An empirical model

The relationship of interest to us is between household car mileage and the real per-mile cost of driving, conditional upon the availability and real cost of other forms of transport, household income, composition and other characteristics, and regional characteristics. We estimate a log–linear model of car use in which we regress log mileage on the above variables. This tells us, for example, the relationship between proportional changes in mileage and absolute changes in cost. We choose this specification because it seems to fit the data well and because it also allows demand responses to price (and income) changes to vary according to the level of demand. Regressing log miles on log cost per mile, for example, would have imposed the restriction that the elasticity of demand had to be identical for every household. Since it is partly this variation that we are interested in, we do not consider the log–log model. The added benefit of estimating the model in the log–linear form over the other main alternative that is popular in studies of demand — a share-equation-type model (which would estimate the relationship between the share of total travel by car and the total amount of miles travelled by every mode) — is that share models require an additional regression equation, predicting

[32]We discard households with three or more cars due to lack of observations.

household total travel, to be estimated before the car-miles response can be recovered. The present model estimates the response of interest directly.

There are two main statistical problems to be overcome in estimating the model we have in mind. The first concerns *selectivity* bias caused by the fact that we only observe mileages for the subsample of our data whose demand for car-miles (conditional on their other characteristics) is sufficient for them to have a car.[33] The second concerns the *endogeneity* of the cost per mile which arises because a household's unobserved taste for miles may be correlated with its cost per mile, which is the price of road fuels divided by the efficiency of the car, and with the number of miles that the household drives.[34]

We deal with selectivity by using a sequential form of the Heckman two-step selectivity model.[35] The model is a sequential one in which households first decide whether or not to have a car, and then decide how many cars they will have. Here, because of the relatively few cases of households being observed with more than two cars in our data, we restrict the choice to either one or two cars. The decisions over whether or not to have a car and how many cars to have will depend upon the number of miles a household will expect to drive, and it is this that causes the problem of selectivity. We therefore need to control for the correlation between observed mileage and the conditional probability of being observed in the sample of car owners.[36]

The problem with the endogeneity of the cost per mile of driving is dealt with through instrumental variables. For example, households that like to drive may search harder for cheaper road fuels, may have their cars converted to unleaded petrol which is cheaper than leaded or may drive their cars more economically. This leads to a spurious relationship between the quantity and the price which is driven through the correlation between two choice variables, whereas we seek to identify the effects of a price change that is beyond the household's control, i.e. a tax-induced change. We use the average cost per mile of all *other* households in the same region in the same time period as the

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[33]In other words, we observe the mileage choices of households that have a stronger preference for car-miles than households that do not own a car. This may bias the results if the two groups are dissimilar, as they probably are. We also control for the effect of the correlation between the number of cars and mileage by estimating the ownership model in two stages: zero cars versus a car, and one car versus two.

[34]In other words, the correlation between the cost of petrol and miles driven which arises through choices made by the driver will bias our estimate of the relationship between miles driven and changes in the cost per mile over which the driver has no control (such as tax changes), which is what we are interested in.

[35]Heckman, 1979.

[36]The benefit of the sequential model (for other studies that use this approach, see Cragg and Uhler (1970), McFadden (1981) and Koujianou (1995)) is that it is easy to estimate and that it is less restrictive than a multinomial model. A multinomial approach would model the choice between zero, one and two cars in one step, but allows no correlation in the random errors associated with each choice. This is known as the independence of irrelevant alternatives property and means that the choice between zero and two cars, say, is independent of the characteristics of the choice between one and two cars, and is even independent of the existence of the alternative (one-car) choice (see McFadden (1976) and Hausman and McFadden (1984)). The second restrictive quality of the multinomial model is that all choice probabilities share an identical set of elasticities (a marginal change in a variable has an identical effect on the probabilities of a household making each alternative choice). Following Koujianou (1995) and others, we include an inclusive value term in the first stage of the choice model. This identifies the first- from the second-stage model and (roughly) has the intuition that it represents the utility available in the second stage of the sequence.

household to instrument its cost per mile. We argue that this is a reasonable predictor of its own cost per mile, but that it is not a choice variable for it.[37]

We also split our sample according to whether households have one or two cars and estimate the model separately for each group (controlling for the selectivity bias as discussed above). This allows as much flexibility as possible in estimated responses. Detailed descriptions of each element of the ownership and usage models are given in the Appendix.

5.3 Results

The regression results from each stage of the estimation are provided in the Appendix. The main results are summarised in Table 5.1.

In general, the model fits and explains the behaviour of households with a single car much better than it does the behaviour of households with more than one car. The marginal effects of changes in variables are often similar, at least in sign, in the two groups, but they are usually statistically better determined amongst households with a single car. In part, at least, this is due to the greater number of observations that we have for single-car households (around eight-and-a-half thousand, which is over twice as many as we have for two-car households). The number of households with more than two cars was considered too small for reliable modelling and these households have been excluded.

The relationship that is of prime interest in this model is that between miles driven and the cost of those miles, since it is by altering the cost per mile that taxes on road fuels will exercise their influence on behaviour. The other highly important variables, from a distributional point of view, concern the effect of income on mileage and the relationship between the availability and cost of other forms of transport and car mileage. These also matter for the environmental consequences of a tax on road fuels. While all of these relationships are well determined in the statistical sense for single-car households, this is not the case for two-car households. In fact, these effects are not statistically significantly different from zero for two-car households. Nevertheless, these are the best estimates we have and we use them in the distributional analysis that follows. It should be remembered, however, that the simulated effects that tax changes have on the welfare of two-car households will be statistically insignificantly different from the first-order (zero-behavioural-response) approximation. There is relatively little benefit, statistically, in using demand responses to improve our estimates for these households. There is some benefit for one-car households.

One variable in particular requires some further discussion: the fuel subsidy dummy variable. Some individuals, mostly during the course of journeys related to their work, receive a fuel subsidy, either partial or full, on either their entire mileage or a part of their

[37]At least in the short run. In the longer term, households can change their location.

Table 5.1. Main regression results

Variable	Single-car households	Two-car households
Real cost per mile	The effect is negative and statistically significant: an increase in the real cost per mile causes a drop in mileage.	The effect is statistically insignificantly different from zero. The magnitude of the relationship is roughly half that for single-car households.
Real gross household income	Increases in real income raise mileage, but the rate of increase declines with income.	Increases in real income seem to have no statistically significant effect on car use by two-car households.
Fuel subsidy	Having some form of fuel subsidy increases household mileage.	Having some form of fuel subsidy increases household mileage.
Age of head of household	The relationship between age and mileage is an increasing one. The rate of increase, however, declines with age.	The relationship between age and mileage is similar to that found in single-car households, although it is not statistically significant.
No. of children	The number of children present in the household has a statistically insignificant effect on mileage.	The number of children in the household is negatively related to the miles driven by the household.
No. of persons aged 17–75	An increase in the number of household members aged 17 to 75 increases mileage.	The number of household members aged 17 to 75 has an insignificant effect on mileage.
Employment status of head of household	Employment status has a statistically insignificant effect on mileage.	Employment status has a statistically insignificant effect on mileage.
Occupation class	Professional, clerical and skilled manual workers all have significantly increased mileages compared with the unskilled.	Occupation class has a statistically insignificant effect on mileage.
Population density	Households in the least densely populated areas have significantly increased mileages compared with those in the most populous areas.	The effects on mileage of the population density of the area in which two-car households live are insignificant.
Region	Although the effects are not all statistically significant, all standard regions have increased mileages compared with London; the greatest increases are in Scotland and Wales, the smallest in East Anglia and the south-west.	All standard regions have increased mileages compared with London; however, only those in the East Midlands are statistically significant.
Public transport — availability	The availability of a frequent bus and rail service has the effect of reducing mileages driven.	The availability of a frequent bus and rail service has a statistically insignificant effect on mileage.
Public transport — real cost	The effect of reductions in the real cost of bus travel is to reduce car mileages. The effects of rail costs are insignificant.	Real costs of bus and rail transport, conditional on availability and frequency, are statistically insignificant.
Company car	Households with company cars have significantly greater mileages than those without.	Company cars have no significant effect on overall household mileages.

mileage.[38] Since miles that are fully subsidised are free, we would not expect any reaction to increases in road fuel prices for drivers with full subsidies. But we would expect a reaction if their 'marginal mile' were not subsidised. That is, if they receive free fuel for all business mileage but not for their private mileage, we would expect a reaction in their private car use. Similarly, if their business mileage were only partially subsidised, say up to a certain number of miles per year or for certain journeys with particular purposes, we would expect a reaction in their business miles too. More generally, we might expect some of the sorts of factors that affect business use to be different from those that affect private use. The nature of the response to a change in the price of road fuels may not be the simple continuous smooth marginal response that our model is designed to estimate. Rather, because of the 'non-linear' nature of the price that they face for road fuels — say a zero price up to a certain number of miles and the normal price thereafter, in the case of a partial subsidy — changes in price may provoke a discrete response. That is, mileage may jump in response to a small proportional change in the price of road fuels.

While there are econometric methods that can allow for this, the NTS data that we use in this study do not supply enough information to allow us to use these methods. The NTS records whether a car attracts a subsidy (rather than the driver) but does not give us enough information to tell whether the car is used below or above any mileage allowance (i.e. we do not know which part of the budget constraint the driver is on). We therefore do not know whether the driver faces the full cost per mile even for, say, business use, and we are therefore unable to model a differential response. Nevertheless, we might still expect those households that receive some sort of subsidy to respond differently from those that do not.

The simplest effect that we can allow for in our model is to introduce a dummy variable[39] (1 if the household receives some subsidy and 0 otherwise) to account for the possibility that households receiving fuel subsidies may drive further if their average cost per mile is lower, and an interaction between this dummy and their cost per mile to allow their marginal response to a price change to be different from that of others. We find that only the dummy variable is significant — the positive effect on miles that a subsidy has translates into a slightly lower price-responsiveness for households receiving subsidies.

The behavioural (rather than statistical) strengths of these relationships are usually presented as *elasticities*, which measure the ratio between the proportional change in x associated with a small proportional change in y (the proportional change in car use resulting from a proportional change in cost per mile, for example). These are presented next.

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[38]For example, in the 1992–93 NTS, 2.9 per cent of vehicles received a commuting subsidy, 23.5 per cent a business use subsidy (50 per cent of company cars) and 1.1 per cent a private mileage subsidy (6.7 per cent of company cars). From the data in the NTS, we cannot tell if any cars attract entirely subsidised fuel, i.e. have a zero price for all mileage and hence a zero response to fuel price changes.

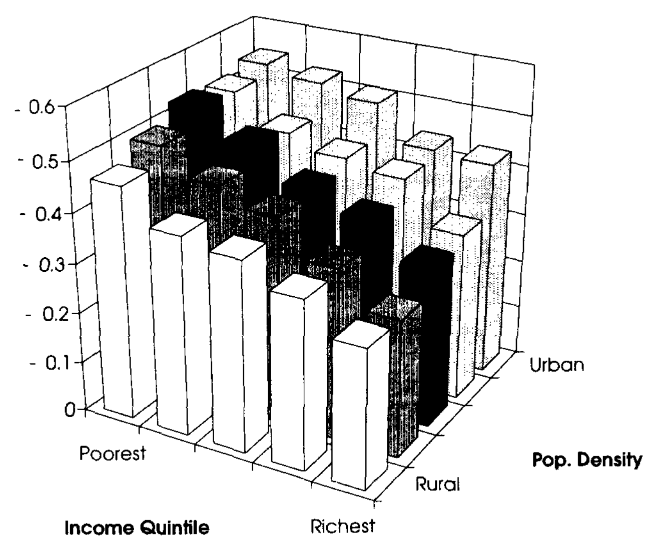
[39]We could split the sample according to whether or not a household received a fuel subsidy. This would be the most general method of allowing different responses between groups. However, the low number of observations in the fuel-subsidy-receiving group is likely to make the estimates unreliable.

The own-price elasticity of demand for car-miles

The own-price elasticity of demand measures the proportional change in demand for a good associated with a small proportional change in the price of that good. We estimate that the average price elasticity of demand for car mileage is around –0.48 for single-car households and around –0.20 for two-car households. The overall average is –0.41 (with a mean weighted standard error of 0.11). This means that a 1 per cent increase in the real cost per mile of driving will reduce mileages by 0.48 per cent and 0.20 per cent for one- and two-car households respectively, and by about 0.41 per cent overall; that is, two-car households (which are less than half as numerous in our data as single-car households) are about half as sensitive to variations in the per-mile cost of driving as single-car households. Two-car households tend to be richer than single-car households, which may mean that, since mileage increases with income, they respond proportionally less to price increases. In addition, whereas single-car households can only alter mileage and driving behaviour, two-car households also have the option of increasing the share of car travel done in their more-efficient vehicle, thereby helping to reduce their average cost per mile.

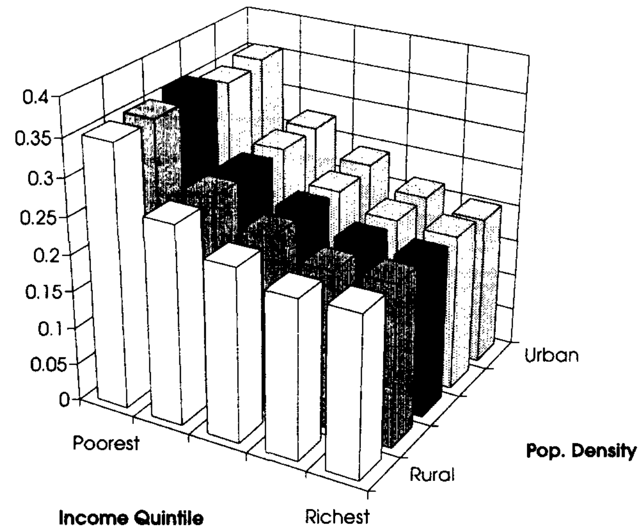
Figure 5.1 shows the distribution of price elasticities of mileage by income quintile and population density for all households with cars.[40] The greatest price sensitivity (an elasticity of around –0.54) is shown by the poorest car owners in households situated in the most urban areas. The smallest price response is amongst the richest households in rural areas.

Figure 5.1. The distribution of the price elasticity of miles, by income group and population density: all car owners



[40]The population density is not in quintiles but refers to the bands used in estimation. See the Appendix for a definition of the population density variables used.

Figure 5.2. The distribution of the income elasticity of miles, by income group and population density: all car owners



The income elasticity of demand for car-miles

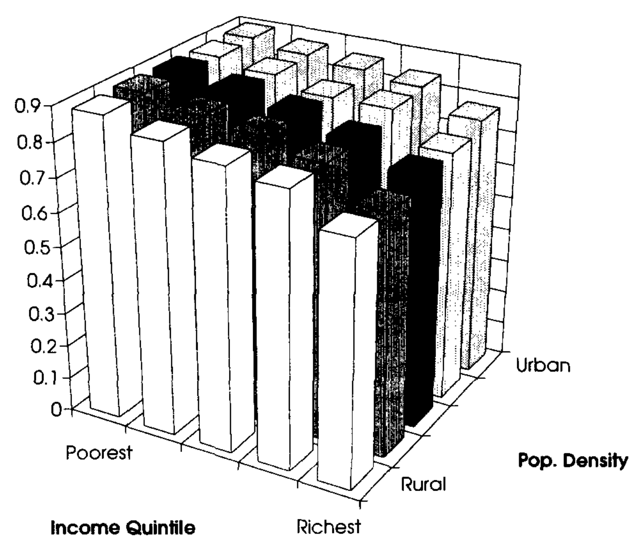
The estimate of the income elasticity measures the expected proportional change in car mileage associated with a small proportional change in income. The average income elasticity is 0.26 overall (with a mean weighted standard error of 0.07), i.e. a 1 per cent increase in income is associated with an increase in car usage of about 0.26 per cent on average. Car usage is therefore an example of a 'normal good' — that is, it is a good for which consumption increases with income. The average income elasticity for one-car households is 0.27 and that for two-car households is 0.21.

Figure 5.2 illustrates the distribution of income elasticities amongst households with cars by income group and population density. The greater variation in elasticity is with respect to income. The average income elasticity amongst the poorest income quintile is 0.35 compared with 0.21 for the richest fifth — i.e. poorer households' mileage responds about half as much again as that of richer households to a small change in their income. There is relatively little variation with respect to population density; indeed, given the standard error on the mean elasticity, it is highly unlikely that any variation with respect to population density is statistically significant.

Cross-price elasticity of car-miles with respect to bus travel

The estimate of the cross-price elasticity of demand measures the expected proportional change in car-miles associated with a small proportional change in the price of another good. In this case, the other good is bus travel, since variations in the cost of rail travel were not found to have a statistically significant effect on miles driven. The average cross-price elasticity is 0.83 (with a mean weighted standard error of 0.39), which means that a 1 per cent increase in the cost of bus travel will increase car usage by 0.83 per cent on average. To put it another way, if the cost of bus travel were to fall by 1 per cent, car

Figure 5.3. The distribution of the cross-price elasticity of miles with respect to the cost of bus travel, by income group and population density: all car owners



usage should drop by 0.83 per cent as households substitute towards the now relatively cheaper good. The average response is much higher among single-car households (0.91) than among two-car households (0.61).

Figure 5.3 illustrates the distribution of these behavioural responses by income group and population density for all households with cars. Most of the variation is with respect to income. On average, the rate of substitution between bus and cars is greater for poorer households (0.89) than it is for richer households (0.7). There is no statistically significant variation with respect to population density (our model allows for differences in the availability and quality measured by frequency of the service, which is also likely to vary with population density).

6. Analysing policy reforms

Having estimated a model of the demand for car-miles, we use the results to simulate the effects of tax reforms that change the cost per mile of driving. We simulate the effect such reforms have on the number of car-miles driven, and we use our estimates of compensated (welfare-constant) demand responses[41] to calculate the welfare effects on households.[42] We simulate the effects of three hypothetical duty increases of differing magnitude on road fuels. These tax increases result in price increases of roughly 4.5 per cent, 20 per cent and 30 per cent respectively. The first corresponds to a 6 per cent increase in real duties (following the Chancellor's minimum promised yearly real increase), while the third results from a duty increase of a little over 40 per cent (this is equivalent to six years of 6 per cent real increases compounded into a single increase). We first uprate the income, price and mileage data to 1997 values. We then predict each household's mileage under each of the tax increases and calculate the effect on their cost of living as described in Section 4.[43]

We are interested in analysing the effects of the change in road fuel duties on household welfare, and so, in order to isolate and identify those effects, we need to hold everything else constant. If we do not, then we risk confounding the part that is due to the tax change with the part that is due to, for example, increased incomes, or population growth in rural areas, or changes in household composition, employment patterns and so on. We do not, for example, attempt to model household income growth over time and predict future car use conditional on predicted values for all of the other explanatory variables in the model. Not only would this be difficult, but it would also be beside the point. Thus we are simulating the effects of the duty changes as if they all happened *today*. One further point to note is that our model is limited to the short run only, in the sense that the simulations do not allow for changes in car-ownership decisions, only for changes in mileage *given* the current stock of cars. In reality, of course, road fuel price increases of 30 per cent may induce important changes in ownership decisions.

Figure 6.1a shows the pre-tax-reform distribution of weekly mileages by income quintile and population density across all households. Mileages tend to increase with income and decrease with increasing population density. The very low average mileages in the lower

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[41]The important behavioural parameter that is required in order to calculate the welfare effects of a tax reform or price change is the welfare-constant (also known as the compensated) demand response. What is required is not an (uncompensated) elasticity, which is a proportional measure; rather, it is the small change in demand necessary to keep welfare constant, associated with (and divided by) a small change in price. This can be calculated from the estimated own-price elasticity (denoted e_p) and the income elasticity (denoted e_y) using the following relationship:

$$\left.\frac{\partial q}{\partial p}\right|_{U=U_0} = e_y\left(\frac{q}{y}\right)q + e_p\left(\frac{q}{p}\right)$$

where q is the quantity demanded (miles), p is the cost per mile and y is income. The compensated demand response, thus derived, can then be used in the calculation of the cost-of-living index as described above.

[42]We assume that households that receive a fuel subsidy face the increased cost per mile themselves.

[43]Note that we are probably overstating the effects of the duty increases somewhat, since we are simulating non-marginal changes, whereas the second-order approximation to the cost-of-living index described in Section 4 will only be close for marginal price changes.

Figure 6.1a. Simulated 1997 weekly mileage, by income quintile and population density: all households

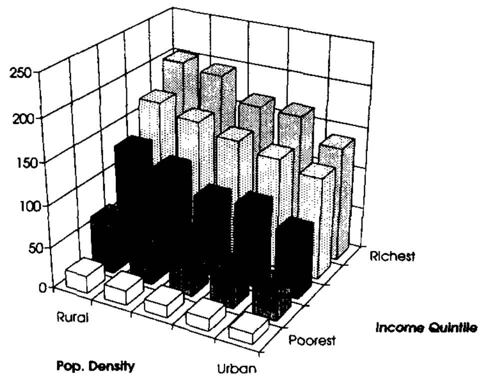
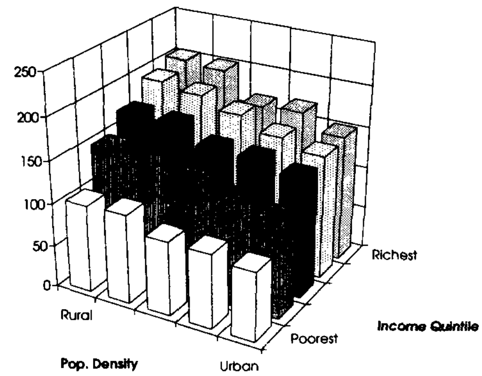


Figure 6.1b. Simulated 1997 weekly mileage, by income quintile and population density: car-owning households



income groups reflect their low ownership rates. Figure 6.1b shows the same information for car-owning households only. The general pattern is the same but is less exaggerated.

Table 6.1 summarises the effect on miles driven of the three duty increases (denoted 1, 2 and 3), both absolute and as a percentage of pre-tax-increase mileages. The last two rows show the mileage reductions for households with at least one company car and for households that only have private cars, respectively.

One-car households reduce their mileages by more than do two-car households, and their reduction also represents a higher percentage of their original mileage, which is to be expected, given our regression results of a less-elastic own-price demand for car-miles for two-car households than for one-car households. Households with company cars reduce their mileages by more than households with only private cars, but this represents a lower proportional reduction since company cars tend to be driven further than privately owned cars.

Figure 6.2a shows the average reduction in miles driven (for car-owning households only) across income decile for the three tax reforms. As is to be expected, reductions increase with the severity of the tax increase. The fall in miles increases quite steadily across the lower income deciles, then levels off, possibly even dropping slightly again

Table 6.1. Average weekly mileage reduction from simulated duty increases: absolute and as a percentage of original mileage

	Absolute weekly mileage reduction			Proportional weekly mileage reduction		
Duty increase:	1 (lowest)	2	3 (highest)	1 (lowest)	2	3 (highest)
All car owners	2.6	11.2	16.4	2.0%	8.3%	12.1%
One-car households	3.1	13.2	19.2	2.3%	9.8%	14.3%
Two-car households	1.4	6.0	8.8	1.0%	4.4%	6.5%
Company cars	2.9	12.6	18.5	1.5%	6.3%	9.2%
Private cars only	2.6	11.0	16.0	2.0%	8.6%	12.5%

Figure 6.2a. Absolute weekly mileage reductions from duty increases, by income decile: car-owning households

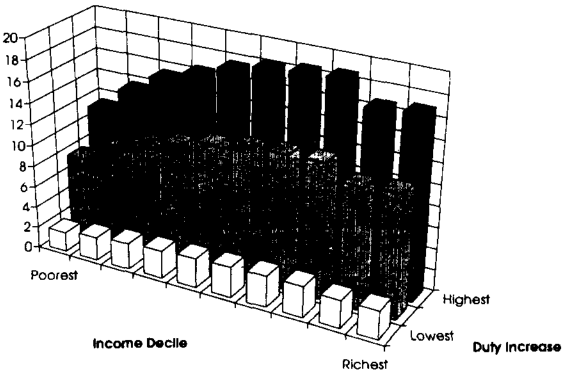
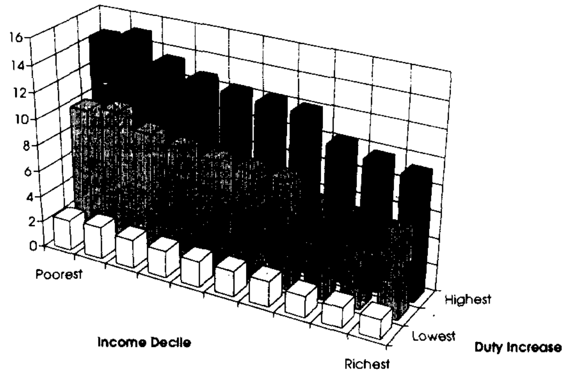


Figure 6.2b: Percentage weekly mileage reductions from duty increases, by income decile: car-owning households



across the very highest deciles. Figure 6.2b shows the reduction in miles as a percentage of pre-tax-change mileages, by income decile. This declines with increasing income decile, showing that whilst richer households might reduce their mileage by a higher absolute amount than poorer ones, the decrease forms a smaller proportion of their original mileage than it does in lower income brackets.

Figure 6.3 shows the reduction in miles driven by population density. The average response is slightly greater in rural areas, but does not show much variation across areas. Proportional reductions in mileages are not shown, as they follow no particular pattern across population density.

Table 6.2 summarises the effect that each tax reform has on households' cost-of-living indices for all households, for all car-owning households, for one- and two-car households separately, and for car-owning households with and without company cars. As explained in Section 4.1, this measure represents the financial compensation that would be required to restore the household to its original level of welfare after each tax increase. In Table 6.2, this is presented as a proportional increase in the cost-of-living

Figure 6.3: Absolute weekly mileage reductions from duty increases, by population density

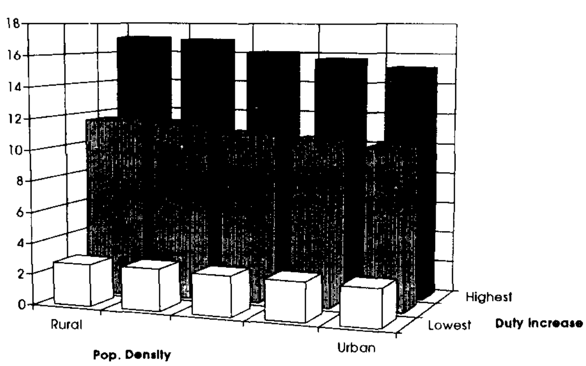


Table 6.2. Average effect of simulated duty increases on households' cost of living

	Increase in cost-of-living index (%)		
Duty increase:	**1 (lowest)**	**2**	**3 (highest)**
All households	0.17	0.7	1.1
All car owners	0.25	1.1	1.6
One-car households	0.28	1.2	1.7
Two-car households	0.19	0.8	1.2
Company cars	0.26	1.1	1.6
Private cars only	0.25	1.1	1.6

index.[44] For example, an increase in a household's cost-of-living index of 1.2 per cent would mean that the cost of achieving its original level of welfare has increased by 1.2 per cent for the household as a result of the increase in petrol prices. Naturally, the cost of living will not increase for non-car-owning households.[45]

The average effect on all households' cost of living ranges from an increase of 0.17 of a per cent for the smallest duty increase to 1.1 per cent for the largest duty increase. The effect on car owners alone is larger than the effect across all households. In addition, one-car households are, on average, more adversely affected by petrol price increases than are two-car households. This is because two-car households tend to be richer than one-car households and, though they may drive further, the expenditure on petrol of richer households with cars represents a lower proportion of their total spending, as illustrated in Figure 4.2. Households with only private cars suffer a marginally lower increase in cost of living than households with company cars, but the difference is almost negligible.

Figures 6.4a and 6.4b show the cost-of-living information averaged across income decile for all households and for car-owning households respectively. The figures are drawn to the same scale, as will be all the figures comparing all households and car-owning households in this section, to highlight the differences between the two groups. In the case of all households, the effect of each tax reform increases quite markedly across the first five income deciles, increases slightly to reach a peak at the sixth decile, then starts falling back down as income increases. Again, the impact on the lowest income groups is small because many of these households do not own a car. Figure 6.4b shows that the petrol tax increases affect the poorest car-owning households' cost of living the most adversely, with the impact decreasing as income rises.

Figures 6.5a and 6.5b show cost-of-living indices averaged across population density for all households and for car-owners only. For both groups, the cost of living increases slightly more in rural areas than it does in more urban areas.

[44]That is, $\frac{c(p_T, U_0)}{c(p_0, U_0)} - 1$.

[45]In fact, we might easily think that their cost of living may have fallen, since the reduction in traffic should have reduced the costs imposed upon them by motorists. There is no easy way to quantify this, however, and we do not consider environmental quality as a determinant of the cost of living for any household.

Figure 6.4a. Effect of duty increases on cost of living, by income decile: all households (%)

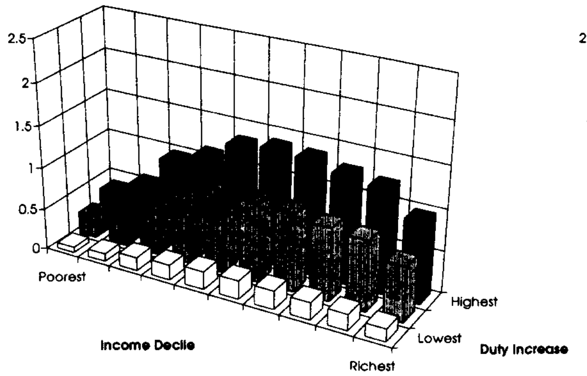


Figure 6.4b. Effect of duty increases on cost of living, by income decile: car-owning households (%)

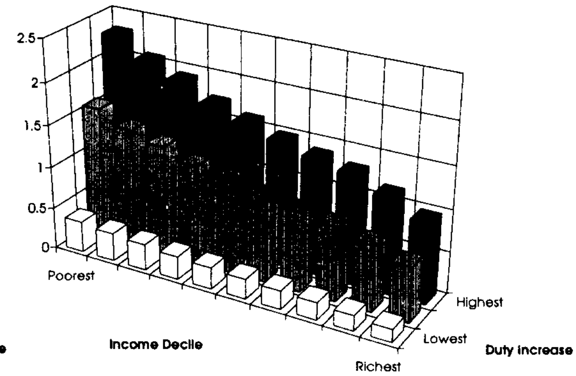


Figure 6.5a. Effect of duty increases on cost of living, by population density: all households

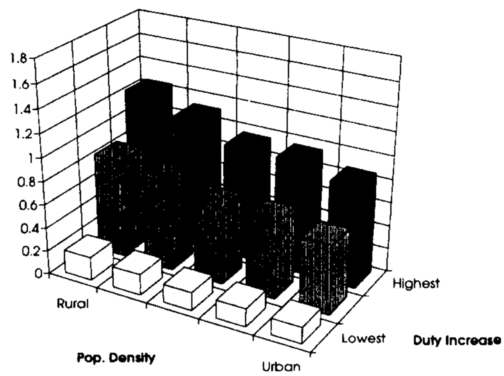
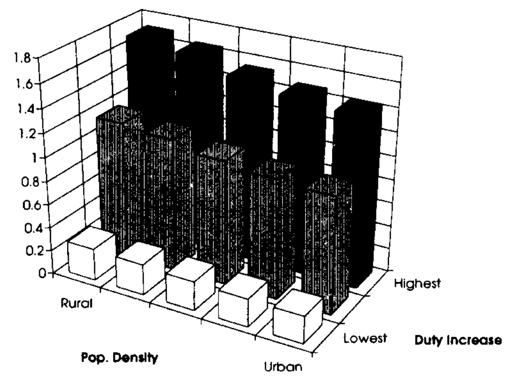


Figure 6.5b. Effect of duty increases on cost of living, by population density: car-owning households



For each of the three petrol duty increases, we used our simulated mileage responses to determine what the change in tax revenue collected would be. Revenue increases in all cases, which is to be expected, given the low own-price elasticities of demand estimated in our model. We then used this information to calculate the increase in VED necessary to raise the same amount of revenue and how this would affect households' cost of living, again keeping car ownership fixed. As we hold car ownership constant, the change in cost of living for each household is simply the increase in VED it pays. It transpires that the average effect on cost of living is always lower than for the petrol duty changes. This is a result of the fact that we keep car ownership fixed in our model. Because of this, VED acts like a lump-sum tax and so is a non-distortionary way of collecting tax, unlike duty on petrol, which alters consumer choices, since the demand for petrol is elastic to a certain extent. Hence, in this model, raising revenue through petrol duty involves extra dead-weight costs to households which do not arise using VED. Although, in reality, this would probably not be the case, since changes in VED may affect longer-run ownership decisions, we can at least use the results to compare the pattern of the effect of VED increases, given ownership, on cost of living compared with that of duty increases, even if we know in advance that the levels will be lower.

Figure 6.6a shows the effect on the cost of living for the third (highest) duty increase and the equivalent VED increase by income decile for all households. The first bar in each pair represents the effect of the duty increase and the second the VED change. While the effect of the VED increase on the cost of living has the same general pattern as that of the duty increase — that is, first rising with income decile, then falling — the relative changes are less extreme than for the duty reform. The fifth decile, for example, is affected more than the first, but not to the same proportionate degree as for the duty change. Figure 6.6b shows the same information for car-owning households only. Here, it can be seen that the effect on poorer households is greater than that on richer households, but this time relatively more so for the VED increase than for the duty increase. For example, with the duty increase, the cost of living increases somewhat over twice as much for the first income decile as it does for the tenth, whereas this figure is a little over three in the case of the VED increase. This is because these households can own either one or two cars, so the variation in VED paid is limited, and hence its share in total spending and effect on cost of living will vary considerably across income decile. Mileage, and therefore fuel duty payments, can vary to a much greater extent, and the tendency for mileage to increase with income leads to a less uneven effect on cost of living across income decile than for VED.

A similar point can be illustrated in Figures 6.7a and 6.7b, which show the change in tax paid as a percentage of income for the duty increase and for the VED increase, by income decile. Again, the duty increase is shown in the first bar of each pair and the VED increase in the second. Figure 6.7a covers all households. The VED increase affects poorer households more adversely and richer households more favourably than the duty increase. The duty increase is more or less progressive across the first six income deciles, whilst all that can really be said of the VED increase is that it affects the third decile more than the first two. Figure 6.7b shows the effect for car-owners only; both tax increases are regressive, but the VED increase is much more so than the duty increase.

Figure 6.6a. Effect of duty versus VED on cost of living, by income decile: all households

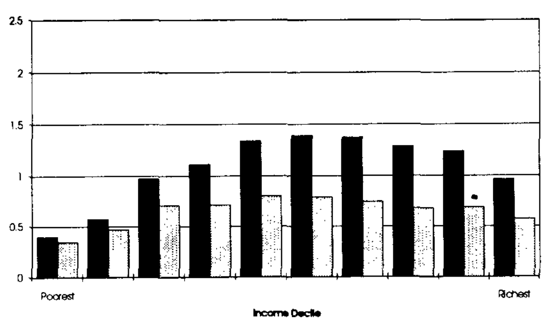
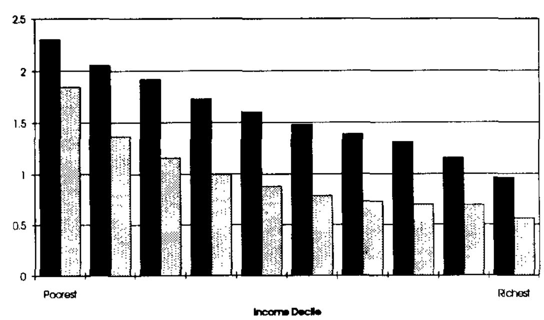


Figure 6.6b. Effect of duty versus VED on cost of living, by income decile: car-owning households



Key: Darker bars represent the highest fuel duty increase; lighter bars represent the equivalent VED increase.

Figure 6.7a. Increase in duty and VED as a percentage of income, by income decile: all households

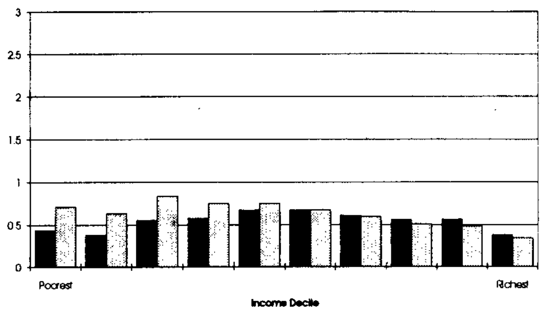
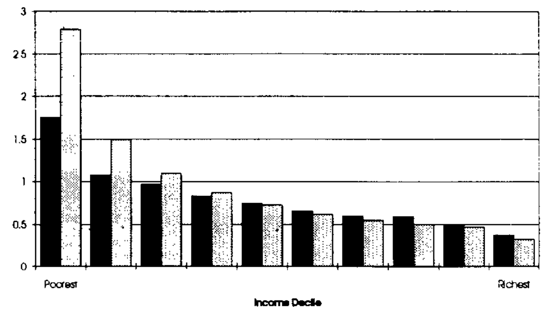


Figure 6.7b. Increase in duty and VED as a percentage of income, by income decile: car-owning households



Key: Darker bars represent the highest fuel duty increase; lighter bars represent the equivalent VED increase.

Figure 6.8a compares the cost-of-living impact of the duty and VED increases by population density. The VED increase affects rural households marginally more than urban households, but, again, the variation is not as pronounced as for the duty increase. Figure 6.8b shows the effect on car-owners only, and reveals that, across this group, the effect of the VED increase is more or less constant.

In contrast to the duty increases, increases in VED affect two-car households' cost of living more than one-car households', as would seem intuitive. As for households with company cars, whilst they, on average, own more cars than car-owning households without company cars, their cost of living is increased less by VED increases than households with only private cars.

We now present some of our simulation results by region, to show how different parts of the country may be differently affected. We break the sample down into Scotland, Wales and the eight standard regions of England (splitting the south-east into London and the rest of the south-east). For simplicity, we present results associated with the highest duty increase, as the regional patterns are the same for all three reforms.

Figure 6.8a. Effect of duty versus VED on cost of living, by population density: all households

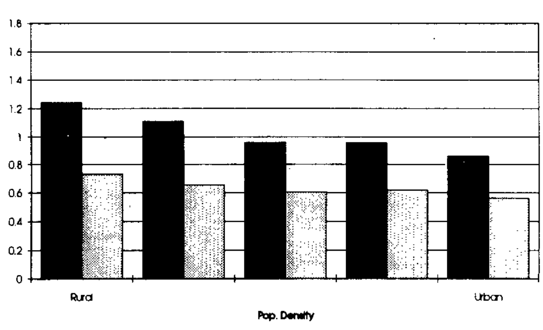
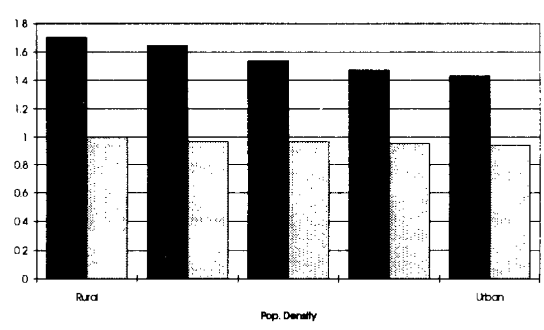


Figure 6.8b. Effect of duty versus VED on cost of living, by population density: car-owning households



Key: Darker bars represent the highest fuel duty increase; lighter bars represent the equivalent VED increase.

Figure 6.9a. Percentage of car-owning households, by region

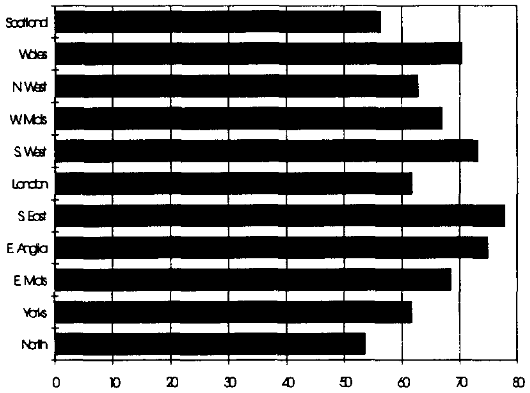
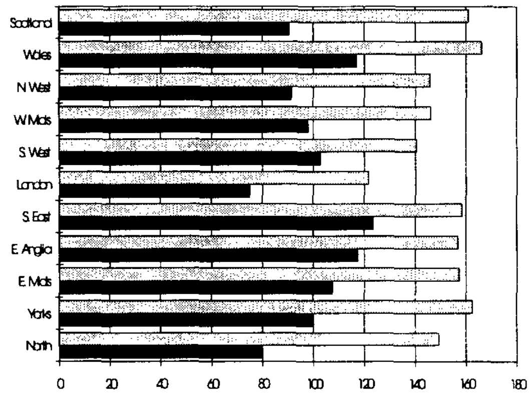


Figure 6.9b. Simulated 1997 weekly mileage, by region



Key: Dark — all households; light — car owners.

Figure 6.9a shows car-ownership rates across the regions in our sample. In all regions, over half of all households own at least one car, with Scotland, the north and London having relatively low ownership rates, and East Anglia, the south-west and the south-east relatively high ownership. Figure 6.9b shows pre-tax-reform weekly mileages across the regions for all households and for car-owning households only. The pattern of mileages across all households broadly follows that of car-ownership rates, although not exactly, as mileages across car owners are not identical across regions. Wales, then Yorkshire and Humberside, have the highest mileages across car owners, closely followed by Scotland and the south-east. London car owners have a relatively low weekly mileage.

Figure 6.10a shows the reduction in weekly mileage as a result of the duty increase, and Figure 6.10b shows this reduction as a percentage of original mileage. The highest mileage reductions occur in Scotland and Wales, but these do not translate into the highest relative mileage reductions, since original mileage is higher than average in Scotland and Wales. The East Midlands has the third highest mileage reduction and the second highest percentage reduction, topped only by London. Yorkshire and Humberside and the south-east have the lowest percentage mileage reductions.

Figure 6.10a. Absolute weekly mileage reduction from duty increase, by region

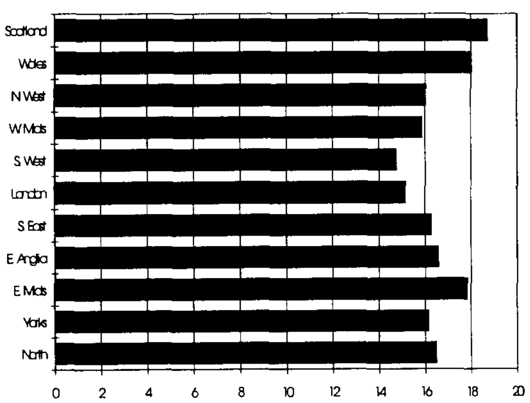


Figure 6.10b. Percentage weekly mileage reduction from duty increase, by region

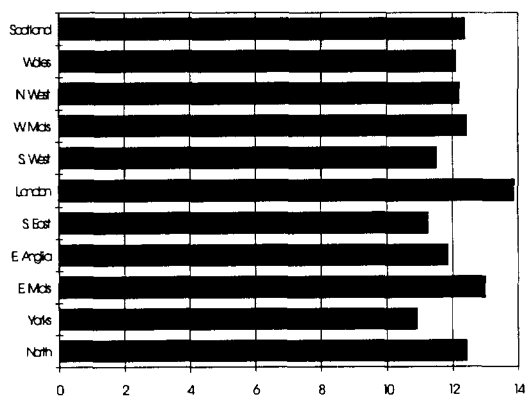


Figure 6.11a. Effect of duty versus VED on cost of living, by region: all households

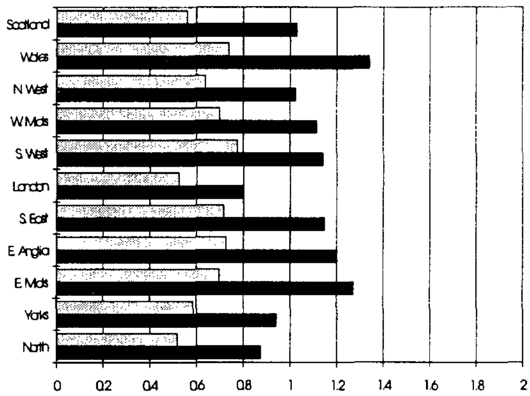
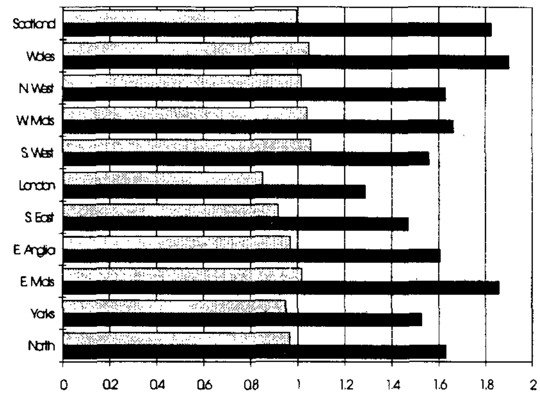


Figure 6.11b. Effect of duty versus VED on cost of living, by region: car-owning households



Key: Darker bars indicate the highest fuel duty increase; lighter bars represent the equivalent VED increase.

Figure 6.11a shows the effect on cost of living of the duty increase (the darker bar) and the equivalent revenue-raising VED increase (the lighter bar) for all households. Figure 6.11b shows the cost-of-living increase for car owners only. Again, for the reasons discussed above, the average effect of the VED increase on cost of living in each region is always lower in level than that of the duty increase. Across all households, Wales is the most affected by the duty increase and London the least, which is not surprising, given their respectively high and low mileages as shown in Figure 6.9b. However, other factors also have an effect on the cost-of-living impact. The south-east has a higher average mileage than Wales across all households, but is much less adversely affected by the duty increases, probably because households in the south-east tend to have higher incomes than those in Wales, so fuel expenditure takes a lower share of their budget. Across car owners, Wales, again, is the worst affected by the duty increase, followed by Scotland and the East Midlands. Once more, London sees the smallest cost-of-living increase. The VED increase has a more uniform regional effect on the cost of living than the duty increase. Across all households, Wales, the south-west and East Anglia are among the most affected, which makes sense as they are regions with relatively high levels of car ownership. The south-east has the highest levels of car ownership, but again the effect on the cost of living in this region is ameliorated by the high income levels of its residents. London and the north are the least affected; the north has the lowest levels of car ownership, and London has fairly low ownership rates and is also relatively wealthy. Across car owners, Wales and the south-west are again the most affected by the VED increase, but regional differences in cost-of-living increases are not that great, with perhaps only London noticeably less affected than the rest.

7. Conclusions

The data show that car ownership has grown over the last 20 years, with most of the increase coming from a growth in multiple-car ownership, and that car ownership is greatest amongst richer households and households in rural areas. In addition, the average efficiency of the car stock has improved over the period. However, a greater proportion of short journeys than ever are now being made by car which tends to reduce the average fuel efficiency of each journey. Overall car use has also increased, with large share increases in shopping and commuting mileages.

Since 1990–91, the absolute contribution to major types of air pollution made by road transport has stabilised for carbon dioxide and fallen for some other major pollutants. The falls in emissions in nitrogen oxides, carbon monoxide and volatile organic compounds may be largely to do with legislation requiring new cars to be fitted with catalytic converters. However, in many circumstances, the use of economic instruments in preference to regulation may have much to recommend it, particularly in the case of carbon dioxide.

In principle, policy should be aimed at charging for the social costs of pollution as directly as possible. Unfortunately, an appropriate tax base may be hard to find, since direct measurement of emissions is impractical. Carbon dioxide is an exception, and congestion also might be more amenable to charging, particularly with the emergence of increasingly sophisticated electronic charging systems. However, a widespread system of congestion charging has yet to be introduced.

The main economic tool presently used by the government to tackle the problems associated with traffic is road fuel duty. While this is simple to implement, road fuel duties are poorly related to many of the social costs imposed by car ownership and use. However, the government is committed to real yearly increases in fuel duties for the foreseeable future.

In a short-run behavioural model of car use estimated from UK household-level data, we find that the demand for car mileage is inelastic with respect to the cost per mile of driving. We find that a 1 per cent increase in the per-mile cost of driving reduces car use by less than half of one per cent. We also find weak evidence that two-car households respond less to price changes than households with a single car. The greatest behavioural responses are amongst poor households in urban areas. We find that a 30 per cent increase in fuel prices (which would result from six years of the government's pre-announced duty changes compounded into a single increase of roughly 40 per cent) will reduce mileages by around 12 per cent (holding everything else constant).

We find that the overall distribution of the welfare effects of such a reform is such that poorer households are relatively less affected since they tend not to own cars. Amongst car owners, however, the welfare effects are greatest for poorer households, particularly in rural areas. For example, the poorest tenth of the car-owning population will see their cost of living increase by 2.25 per cent, while the cost of living of the richest tenth of car-owning households will increase by less than 1 per cent.

Appendix: regression results

Heckman selection model, 1st stage — 0 versus 1 or more cars

Variable	Coefficient	Standard error	t statistic
ln(real income)	4.011673	.7627480	5.260
{ln(real income)}^{2}	–.1578697	.0418659	–3.771
Age of head of household	.0261775	.0099954	2.619
{Age of head of household}^{2}	–.0003232	.0001033	–3.128
Owner-occupier	.4096783	.1871309	2.189
Public rented	–.5594583	.1906936	–2.934
Private rented — furnished	–.7376948	.2345954	–3.145
Private rented — unfurnished	–.4545131	.2007303	–2.264
Part-time employee	–.0076280	.1088394	–0.070
Unemployed	.0521002	.1080969	0.482
Retired	–.0443052	.0880241	–0.503
Domestic work	–.9860325	.1137910	–8.665
Self-employed	.4700141	.0863354	5.444
Professional	.9304989	.0816375	11.398
Clerical	.2992252	.0646394	4.629
Skilled manual	.7209714	.0649310	11.104
Varying workplace	.3592957	.1414522	2.540
Urban workplace	–.1978642	.0947658	–2.088
Distributional trade	.1069934	.0532902	2.008
Difficulty with other modes	–.3270217	.0617401	–5.297
No. in household aged 17–75	1.002030	.1085933	9.227
No. of children	.0810053	.0303171	2.672
Bus — available and frequent	–.6740461	.0683389	–9.863
Rail — available and frequent	–.2454576	.0510724	–4.806
Pop. density of LA < 3.5 p.p.ha	.3407637	.0837004	4.071
Pop. density of LA 3.5–9.9 p.p.ha	.2131631	.0856885	2.488
Pop. density of LA 10–19.9 p.p.ha	.3246820	.0880481	3.688
Pop. density of LA 20–34.9 p.p.ha	.1417535	.0820690	1.727
High Street > 27 minutes walk	.1178612	.0532530	2.213
Standard region			
North	–.3371891	.1260021	–2.676
Yorkshire & Humberside	–.3347359	.1170863	–2.859
East Midlands	–.1107210	.1231686	–0.899
East Anglia	.1637128	.1541876	1.062
South-east	.2251939	.1036531	2.173
South-west	.2810974	.1202247	2.338
West Midlands	.0298680	.1085676	0.275
North-west	–.1690006	.1038409	–1.627
Wales	.0785108	.1391281	0.564
Scotland	–.3759008	.1105189	–3.401
Detached	.4851920	.0858543	5.651
Terrace	–.3970048	.0560529	–7.083
Flat (purpose-built)	–.4588680	.0739905	–6.202
Flat (converted)	–.6814057	.1318326	–5.169
No. of rooms	–.9131540	.3144655	–2.904
Inclusive value term	8.036922	1.067910	7.526
Constant	–24.18398	3.470134	–6.969

No. of observations = 18458 $\chi^2(45) = 11376.26$ Pseudo $R^2 = 0.4815$

Heckman selection model, 2nd stage — 1 versus 2 cars

Variable	Coefficient	Standard error	t statistic
ln(real income)	–6.256434	1.364509	–4.585
{ln(real income)}^{2}	.3566812	.0699651	5.098
Age of head of household	–.0966827	.0196433	–4.922
{Age of head of household}^{2}	.0013942	.0002189	6.369
Owner-occupier	1.178935	.3214501	3.668
Public rented	.5492322	.3467374	1.584
Private rented — furnished	.8127597	.4159286	1.954
Private rented — unfurnished	.3136481	.3667578	0.855
Part-time employee	–.4090821	.2183019	–1.874
Unemployed	–.7137014	.2213469	–3.224
Retired	–1.370165	.1630036	–8.406
Domestic work	–2.216084	.3536328	–6.267
Self-employed	.3058595	.1079512	2.833
Professional	1.001195	.1285582	7.788
Clerical	.4494134	.1294610	3.471
Skilled manual	.5482819	.1250223	4.385
Varying workplace	.2734774	.1018901	2.684
Urban workplace	–.1356865	.0803084	–1.690
Distributional trade	.0411560	.0558248	0.737
Difficulty with other modes	–.2218780	.1161881	–1.910
No. in household aged 17–75	5.693475	.1400745	40.646
No. of children	–.0499760	.0401383	–1.245
Bus — available and frequent	–.2575639	.0906286	–2.842
Rail — available and frequent	–.2368933	.0831977	–2.847
Pop. density of LA < 3.5 p.p.ha	.4314638	.1398737	3.085
Pop. density of LA 3.5–9.9 p.p.ha	.4939072	.1448473	3.410
Pop. density of LA 10–19.9 p.p.ha	.3678963	.1489832	2.469
Pop. density of LA 20–34.9 p.p.ha	.1732338	.1351222	1.282
High Street > 27 minutes walk	–.0334429	.0801589	–0.417
Standard region			
North	–.1386047	.2298607	–0.603
Yorkshire & Humberside	–.3963273	.2000636	–1.981
East Midlands	–.0624198	.2066469	–0.302
East Anglia	–.0223068	.2433199	–0.092
South-east	.2784388	.1679189	1.658
South-west	.0563612	.1943858	0.290
West Midlands	.2605594	.1796371	1.450
North-west	–.0190283	.1757265	–0.108
Wales	–.3530206	.2254685	–1.566
Scotland	–.3217867	.1989350	–1.618
Detached	.3510074	.0968745	3.623
Terrace	–.3191145	.0902266	–3.537
Flat (purpose-built)	–.4053191	.1713662	–2.365
Flat (converted)	–.2777593	.2816822	–0.986
No. of rooms	1.803599	1.083885	1.664
Constant	16.01651	6.670518	2.401

No. of observations = 12209 $\chi^2(44) = 8982.34$ Pseudo $R^2 = 0.6384$

Mileage equation: single-car households

Dependent variable: ln(miles).
IV estimation, exclusion restrictions — region/period average fuel price, region/period average fuel efficiency, time trend and trend squared.

Variable	Coefficient	Standard error	t statistic
Real cost per mile	–4.323402	1.807420	–2.392
ln(real income)	1.269268	.3233306	3.926
{ln(real income)}^{2}	–.0518674	.0168128	–3.085
Fuel subsidy	.2267703	.0314361	7.214
Age of head of household	.0230523	.0042977	5.364
{Age of head of household}^{2}	–.0003136	.0000461	–6.803
Owner-occupier	.2073628	.0807022	2.569
Public rented	.1345278	.0851955	1.579
Private rented — furnished	.1503096	.1088890	1.380
Private rented — unfurnished	.1856942	.0898742	2.066
Part-time employee	.0680903	.0491337	1.386
Unemployed	.1014773	.0557761	1.819
Retired	–.0148155	.0410699	–0.361
Domestic work	–.0507096	.0737190	–0.688
Self-employed	–.0068901	.0304325	–0.226
Professional	.2012451	.0376721	5.342
Clerical	.1250519	.0343296	3.643
Skilled manual	.0878716	.0334125	2.630
Varying workplace	.1253545	.0390127	3.213
Urban workplace	–.0107832	.0324230	–0.333
Distributional trade	–.0405190	.0207916	–1.949
Difficulty with other modes	–.0837771	.0323383	–2.591
No. in household aged 17–75	.1438636	.0597855	2.406
No. of children	–.0002571	.0122017	–0.021
Bus — available and frequent	–.1141843	.0259001	–4.409
Rail — available and frequent	–.0819374	.0221177	–3.705
Pop. density of LA < 3.5 p.p.ha	.1429967	.0433564	3.298
Pop. density of LA 3.5–9.9 p.p.ha	.1113651	.0395533	2.816
Pop. density of LA 10–19.9 p.p.ha	.0620290	.0395851	1.567
Pop. density of LA 20–34.9 p.p.ha	.0127249	.0364265	0.349
High Street > 27 minutes walk	.1044345	.0240655	4.340
Standard region			
North	.1137413	.0704050	1.616
Yorkshire & Humberside	.1600013	.0705937	2.267
East Midlands	.1425360	.0625267	2.280
East Anglia	.0959418	.0813619	1.179
South-east	.1356501	.0640357	2.118
South-west	.1109254	.0626739	1.770
West Midlands	.1577091	.0618490	2.550
North-west	.1209277	.0618075	1.957
Wales	.2193156	.0691342	3.172
Scotland	.2051001	.0710695	2.886
Real price of rail travel	–.6446073	.4063620	–1.586
Real price of bus travel	.9526288	.4537884	2.099
Prop. of company cars in household	.3701228	.0395819	9.351
Mills ratio[a]	–.0932088	.0480544	–1.940
Constant	–3.557919	1.737263	–2.048

[a]This term corrects for selection bias.

$N = 8477$	$F(45, 8431) = 50.85$	$R^2 = 0.2978$
Adj. $R^2 = 0.2941$	P-Smith $GR^2 = 0.1905$	Sargan $\chi^2(3) = 3.6532$

Mileage equation: two-car households

Dependent variable: ln(miles).
IV estimation, exclusion restrictions — region/period average fuel price, region/period average fuel efficiency, time trend and trend squared.

Variable	Coefficient	Standard error	t statistic
Real cost per mile	−1.961142	4.172922	−0.470
ln(real income)	−.6078050	.7770043	−0.782
{ln(real income)}^{2}	.0400048	.0400967	0.998
Fuel subsidy	.2407501	.0632768	3.805
Age of head of household	.0111215	.0116261	0.957
{Age of head of household}^{2}	−.0002060	.0001363	−1.511
Owner-occupier	−.3192487	.2150546	−1.485
Public rented	−.2406746	.2415094	−0.997
Private rented — furnished	−.3729537	.2745462	−1.358
Private rented — unfurnished	−.0921955	.2570750	−0.359
Part-time employee	.0490193	.1131430	0.433
Unemployed	.1899064	.1534527	1.238
Retired	.1946110	.1023677	1.901
Domestic work	.1675416	.2481124	0.675
Self-employed	.0311595	.0590867	0.527
Professional	−.1109023	.0922522	−1.202
Clerical	−.0351452	.0857290	−0.410
Skilled manual	−.0233641	.0825086	−0.283
Varying workplace	.0451383	.0484312	0.932
Urban workplace	.0606221	.0400078	1.515
Distributional trade	.0925110	.0275342	3.360
Difficulty with other modes	.0151888	.0683585	0.222
No. in household aged 17–75	−.2015585	.2237857	−0.901
No. of children	−.0589327	.0228236	−2.582
Bus — available and frequent	−.0315719	.0497245	−0.635
Rail — available and frequent	−.0533007	.0442728	−1.204
Pop. density of LA < 3.5 p.p.ha	.1145248	.0901524	1.270
Pop. density of LA 3.5–9.9 p.p.ha	.0141970	.0863373	0.164
Pop. density of LA 10–19.9 p.p.ha	−.0891422	.084407	−1.056
Pop. density of LA 20–34.9 p.p.ha	−.0291170	.0766422	−0.380
High Street > 27 minutes walk	.0303617	.0487412	0.623
Standard region			
North	.1792455	.1625756	1.103
Yorkshire & Humberside	.0912065	.1519287	0.600
East Midlands	.2591245	.1211520	2.139
East Anglia	.1829385	.1711603	1.069
South-east	.1555278	.1505209	1.033
South-west	.0863872	.1398652	0.618
West Midlands	.2323901	.1469879	1.581
North-west	.2417504	.1407342	1.718
Wales	.2450235	.1616782	1.516
Scotland	.0302141	.1568583	0.193
Real price of rail travel	−.8470843	.8481540	−0.999
Real price of bus travel	.6375004	.8317353	0.766
Prop. of company cars in household	−.0050647	.0757949	−0.067
Mills ratio[a]	.1081317	.0826288	1.309
Constant	7.228589	3.631559	1.990

[a]This term corrects for selection bias.

$N = 2973$ F(454, 2927) = 4.12 $R^2 = 0.0735$

Adj. $R^2 = 0.0586$ P-Smith $GR^2 = 0.0581$ Sargan $\chi^2(3) = 6.3031$

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