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THE IMPACT OF ECONOMIC POLICY INSTRUMENTS ON GREENHOUSE GAS EMISSIONS FROM THE TRANSPORT SECTOR

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Abstract

This paper uses modelling to analyse the impact of alternative economic policy instruments on carbon dioxide and other greenhouse gas emissions from the UK transport sector. The forecasting models incorporate cross-elasticities between modes. The paper considers the impact on emissions of carbon dioxide and other greenhouse gases of economic policies such as an increase in fuel taxation, and reductions in public transport fares.

INTRODUCTION

Global warming is the name given to the expected increase in average surface temperatures of the Earth as a result of increased concentrations in the atmosphere of anthropogenic (ie man-made) greenhouse gases. These gases consist of carbon dioxide, nitrous oxide, methane, ozone and chlorofluorocarbons (CFCs). Concentrations of greenhouse gases have been rising since the Industrial Revolution. Increased concentrations reduce outward infrared longwave radiation and therefore, via complex lagged effects on climate and sea temperature changes, increase surface temperatures. Complex physical climate modelling using general circulation models has concentrated on predicting the effect on average temperatures of a doubling of carbon-dioxide equivalent trace gases over pre-industrial revolution levels. Estimates of this lie in a range from +1.5 degrees centigrade to +4.5 degrees centigrade, with a best-guess central estimate of +2.5 degrees centigrade.

The problem of global warming is naturally of considerable international concern. In June 1992 the British Government, along with around 150 other countries, signed the Framework Convention on Climate Change in Rio. In January 1994 the Government published its proposals for meeting its Rio commitments in *Climate Change: the UK Programme* document. This set out the Government's plans to meet its target of returning UK emissions of carbon dioxide and the other greenhouse gases to their 1990 levels by the year 2000.

The Government document proposed to save 10 million tonnes of carbon against the projected forecast for 2000, and to reduce nitrogen oxides by 25 per cent from their 1990 level, volatile organic compounds (VOCs) by 35 per cent, and carbon monoxide by 50 per cent. The transport sector was to contribute 2.5 million tonnes to the carbon target, primarily through the effects of projected increases in real fuel duties on the demand for fuel in the roads sector. Transport would also make major contributions to the other greenhouse gas targets.

The present paper is concerned with assessing the effects of different policies in the transport sector in controlling the four greenhouse gases described above. In particular, the paper presents a set of price-sensitive models of the demand for travel and the demand for fuel in order to assess the effectiveness of alternative fiscal measures. The study is concerned not just with the short-to medium-term up to the year 2000, but also with the longer-term impacts.

The project on which this paper is based involved the development of a number of inter-linked models for measuring and forecasting greenhouse gas emissions from the transport sector. The most complicated of these is the car model, which provides a disaggregated model of the UK car stock, broken down by nine categories of engine size and 16 categories of vehicle age. The other project components are: the public transport demand model, which consists of a set of six forecasting equations for public transport demand; greenhouse gas emission coefficients for rail travel, based on emissions per train-km and passenger loadings for different types of traffic; greenhouse gas emissions for bus travel, based on emission factors for different sizes of buses and projections of the future bus fleet and passenger loadings; and a freight model which predicts road freight emissions on the basis of fuel use and projections of the demand for road freight and the contribution of different types of goods vehicle in the transport of total tonne-kms.

THE CAR MODEL

The aim of the car model is to have a model that enables us to predict the effect of a range of different types of policy. Such policies include: fuel price changes which will change total fuel consumption of the car fleet and hence total carbon dioxide emissions; regulations such as the mandatory fitting of catalytic converters which affect emissions of other greenhouse gases from new cars in the fleet; differential taxation systems on different sizes of cars; and changes in public transport fares which will have cross-modal impacts on the demands for car travel and car fuel.

Fuel consumption depends on the technical characteristics of the vehicles, on the distance they are driven and the type of road on which they are driven, and on driver technique. Our car model disaggregates the fleet by engine size (to allow for the impact of engine size on fuel consumption) and by vehicle age (to allow for the impact of technological progress in reducing fuel consumption). The model also allows for the fact that newer and larger vehicles are on average driven more kms per year than smaller and older vehicles.

Fuel consumption of the base year vehicle fleet depends on average kms driven and average fuel consumption per km. The former figures are derived from the National Travel Survey (Department of Transport 1993). This is a survey of travel behaviour carried out every few years. The 1989/91 National Travel Survey used in the present study involved a sample of 10,752 households completing travel diaries for seven consecutive days. From this survey we obtained figures of average kms driven each year by cars in each of our engine size and age ranges. We then estimated an equation relating average kms driven to engine size and vehicle age. This equation showed annual kms rising with engine size (ie larger cars run longer distances than smaller ones), and falling with age (ie newer cars run longer distances than older ones). This equation was then used to predict average kms for the car fleet based on the age/size characteristics of the fleet in any year. These give base annual kms for each type of vehicle which then (see below) vary with changes in GDP, fuel prices, and public transport fares.

Fuel consumption figures are derived from new car fuel consumption figures for different makes and models of car published each year by the Department of Transport. These figures cover three types of driving condition: an urban cycle; 90 kph; and 120 kph. Although these consumption figures are derived under test conditions, we have compared the resulting aggregate fuel consumption estimates from our model with independently-derived figures of aggregate fuel use in Britain to check that the results are consistent.

Fuel consumption forecasts in the model are based on a forecasting equation for new car fuel consumption which we estimated from data from earlier years. New car fuel consumption depends on the lagged price of petrol (lagged to years one, four and seven), plus a time trend to allow for underlying technological progress. This equation provides a forecast of how fuel consumption will change for vehicles of a specific engine size, and the model is designed to allow for the impact of changes in the distribution of new vehicles over different engine sizes.

The forecast of total new vehicles in each future year depends on projections of total car ownership which are at present based on the British Government's National Road Traffic Forecasts (Department of Transport 1989). These stock forecasts are combined with survival rates for cars of each age and engine size band, based on statistics of past survival rates (see Acutt and Dodgson 1994a, p.3), in order to predict new car sales in each year. In this way the model can allow for the absorption of new vehicles with new emission characteristics into the vehicle fleet.

Forecasts of annual kilometres for each type of vehicle are based on an equation in which the independent variables are GDP (with an elasticity of +0.20), the real price of fuel (with an elasticity of -0.15), and the prices of six public transport modes. The cross-elasticities on which the latter parameters are based are discussed below in Section 3 on the public transport models. The car kilometre forecasts are disaggregated into three types of road (roads in built-up areas; roads in non-built-up areas; and motorways) intended to reflect the different types of fuel consumption characteristics. We have forecast the proportions of total travel on these three types of road up to the year 2025 on the basis of past trends. One limitation of the model is that it does not take account of any effects on travel demand of the effects of rising traffic congestion.

The program then multiplies annual kilometres for each type of car on each type of road by the fuel consumption characteristics of that vehicle on that type of road to derive total fuel consumption. Since there is a one-to-one relationship between fuel burned and carbon dioxide emitted, carbon emissions can then be found by multiplying the fuel consumed by the appropriate emission coefficient. This, and all other emission coefficients in the models, are derived from an inventory of greenhouse gas emission coefficients in Britain compiled at the Warren Spring Laboratory (see Eggleston 1992).

Other greenhouse gas emissions (for nitrogen oxides, volatile organic compounds, and carbon monoxide) are based on emission coefficients per car kilometre. Emission coefficients for new vehicles fall considerably because of the mandatory introduction of three-way catalytic converters (CATS) on most new petrol cars from 1993. Consequently, overall emissions of these other greenhouse gases drop as these new vehicles make up an increasing proportion of the total fleet and of total vehicle-kilometres. We allow for the "cold-start" problem (that CATS do not light-up until the engine is warm) by presuming that CATS are not effective for the first two miles of all journeys: the appropriate proportion of all car journeys which are under two miles was derived from the 1989/91 National Travel Survey.

An increasing proportion of new cars in Britain are powered by diesel engines rather than petrol engines. In 1991 only 3.7 per cent of the car stock was powered by diesel, but 8 per cent of new cars were diesel. By 1993 5.9 per cent of the car stock was diesel, but in 1994 22 per cent of new cars were diesel. Our model allows for diesel cars by using different emission coefficients for that part of total vehicle-kms in any year estimated to be diesel-powered. We have projected the future proportion of new cars which are diesel as 20 per cent as a base case. Increasingly questions are being asked about the environmental advantages of diesel fuel, and we do not believe that the UK Government will encourage further diesel/petrol substitution. Indeed the slight duty differential in favour of diesel fuel compared with unleaded petrol was eliminated in the December 1994 Budget. In his Budget speech the Chancellor noted: "This differential is difficult to justify in economic, health or environmental terms. I therefore propose to tax diesel at the same rate as unleaded petrol".

The model requires forecasts of GDP, total car ownership, the real price of petrol, and price indices for the six public transport modes. The default values are presently the "low" and "high" NRTF forecasts of GDP, car ownership and the price of petrol, and constant real prices for public transport. However, the NRTF fuel price forecasts have now been superseded by new forecasts discussed in the present paper.

THE PUBLIC TRANSPORT DEMAND MODELS

Public transport demand is disaggregated into six sectors, largely on the basis of the availability of long series of annual data in this form. The six sectors are: British Rail (BR) InterCity; BR Network South East; BR Regional Railways; the London Underground; London buses; and other local buses. Data on passenger-kms were regressed on GDP, real fare indices and the real price of petrol. Results of this exercise were then combined with elasticity estimates from previous studies of British public transport demand to derive forecasting equations for the six public transport modes. These forecasting equations also incorporate cross-elasticities of demand between real petrol prices and the demand for each of the public transport modes.

These cross-elasticities, and the related set of cross-elasticities between public transport fares and the demand for car travel which are incorporated in the car model (see above), form the cross-modal link between the public transport model and the car model. It is difficult to derive estimates of cross-elasticities by normal means of statistical estimation, so the cross-elasticities are simulated via the relationship between cross-elasticities, and the product of own-price elasticity, modal traffic shares and the diversion factors which show the proportion of any extra traffic on one mode which is diverted from the other. This yields the following equation (see Acutt and Dodgson 1994: Dodgson 1985):

$$e_{oj} = (e_{jj})(q_j/q_o)(\delta q_o/\delta q_j) \qquad (1)$$

where

e_{oj} = cross-price elasticity between car travel and the fare on public transport mode j

e_{jj} = own-price elasticity on public transport mode j

q_j / q_o = modal share (traffic by public transport mode j divided by traffic by car)

$\delta q_o/\delta q_j$ = "diversion factor" (proportion of any increase in travel on public transport mode j resulting from a fare reduction which is diverted from car)

We derived the diversion factors from a survey of transport experts. Together with own-price elasticity estimates, and mode shares from the 1989/91 National Travel Survey, we could then derive our two sets of six cross-modal elasticities (for details and results see Acutt and Dodgson 1995).

The public transport models can then be used to predict public transport demand on each of the six modes as a function of GDP, the real fare level on the mode, and the real price of petrol. The London modes also allow for cross-effects between demand and the fares on other London modes. Our public transport demand forecasts are then combined with estimates of public transport emissions derived in our study. These emission rates are discussed in the next two sections of this paper.

GREENHOUSE GAS EMISSION COEFFICIENTS FOR PUBLIC TRANSPORT

Greenhouse gas emission coefficients for rail transport

Rail services in Britain use two fuels, gas oil for diesel trains, and electricity. Electricity in the UK is mainly generated from nuclear power, coal and (increasingly in the "dash for gas") by natural gas. Emission coefficients for coal and gas were published in Eggleston (1992), and are used in the present study.

As with the public transport demand forecasts, we disaggregated rail services by the three BR business sectors and the London Underground. British Rail supplied fuel consumption figures for their different business sectors, while London Underground provided business targets for traction current consumption per train-km. The BR figures were combined with unpublished data from the Department of Transport which breaks down the published figures on train-kms by sector into diesel and electric traction. Average passenger loadings were based on the very similar ten and five year averages for the four rail businesses. Thus we could calculate fuel consumption per passenger-km for different types of railway passenger train and from this, via the emission coefficients for different fuels, emissions of carbon dioxide, nitrogen oxides, VOCs, and carbon monoxide per passenger-km.

Forecasts were derived by combining the emission coefficients with the passenger-km demand forecasts. Forecasts are provided both where electricity is generated by coal, and where electricity is generated by gas.

Greenhouse gas emissions for bus travel

Emission forecasts for the local bus fleet were derived by presuming that average passenger loads remain constant. (Since bus passenger-km in our model depend partly on the service levels operated in the form of bus passenger-km, this means that passenger-km and bus-km are determined simultaneously by imposing a fixed ratio—the average passenger loading—between passenger-km and bus-km.)

Our bus forecasts were disaggregated into three types of vehicle, double-deckers, single-deckers and minibuses. There have been marked increases in the proportion of the fleet consisting of minibuses rather than conventional single- and double-deckers, both in London and elsewhere. However, discussions with industry experts lead us to believe that this trend will not continue indefinitely, both because of concerns about minibus life and also because they are only suitable for certain types of route. Our forecasts therefore assume that vehicle fleet splits between the three types of vehicle outside London will stabilise at 27 per cent mini, 41 per cent single-decker and 32 per cent double-decker from 1999. We presume that in London the split will continue at its 1993/94 level.

Bus fuel consumption figures for different types of vehicles have been derived from a number of published sources. From these we have used figures which we regard as representative of the different types of vehicle of 6 kms per litre for minibuses, 3 kms per litre for single-deckers, and

2.3 kms per litre for double-deckers. These figures (which we presume not to change over time) permit us to forecast total fuel consumption, and hence carbon emissions, from local bus services.

Other greenhouse gas emissions from bus services are estimated from urban emission rates published in Eggleston (1992). Our emission forecasts allow for changes due to the introduction of new vehicles with lower emissions from October 1993 and October 1996. To estimate the demand for new buses we take average lengths of life for existing buses to be ten years for minibuses and twenty years for conventional-sized vehicles.

RESULTS

In this section of the paper we discuss emission coefficients of greenhouse gases per passenger-km of different modes, and present forecasts of emissions from cars under alternative policy scenarios.

Emissions of greenhouse gases per passenger-km by mode of transport

Table 1 shows our estimates of greenhouse gas emission rates by mode of transport. The car estimates are presented both for the 1993 car fleet, and for the year 2000 fleet: differences in the emissions other than carbon dioxide reflect the effects of the introduction of catalytic converters. Considering the carbon dioxide figures across modes, the 1993 car is the heaviest emitter. This emission level is forecast to drop by 5 per cent by the year 2000 as a result of more fuel efficient technology but the car remains the heaviest polluter. The bus has the next highest emission level, being only 11 per cent lower than the 1993 car. British Rail InterCity has higher emissions when diesel powered compared to electric, and of the two electricity estimates, gas generation gives significantly lower emissions levels than coal. British Rail Network South East has the highest emissions when coal-generated electricity is used, with gas-generated electricity and diesel producing similar emission levels. London Underground is electrically powered, and again gas-generation leads to lower levels of emissions. Overall the public transport modes result in between 11 and 63 per cent lower carbon dioxide emission rates per passenger-km than the 1993 car.

Table 1 Emissions per passenger-km (grams) by various modes in the UK

Mode	CO_2 as carbon	NOx	VOC	CO
Car(1993)	33.3	1.34	0.98	10.28
Car(2000)	31.7	0.57	0.52	5.57
Bus	29.7	1.75	0.66	0.8
InterCity(diesel)	22.9	1.35	0.35	0.52
InterCity(electric-coal)	19.5	0.30	0.005	0.017
InterCity(electric-gas)	12.2	0.21	0.001	0.002
NSE(diesel)	17.2	1.02	0.26	0.39
NSE(electric-coal)	28.6	0.44	0.007	0.025
NSE(electric-gas)	18.0	0.31	0.002	0.003
LU(electric-coal)	23.4	0.36	0.006	0.020
LU(electric-gas)	14.7	0.25	0.001	0.002

Considering NOx emissions, the bus has the highest level. Diesel power produces the highest rates of NOx emissions and so the British Rail diesel-powered estimates are higher than the year 2000 car figure as a result of the introduction of catalytic converters. The electrically-powered rail services show a similar pattern to the CO2 emission levels, with higher figures resulting from coal-generated power as compared to gas.

The highest emission rate for VOCs is from the 1993 car. The bus and year 2000 car are the next highest emitters with 33 and 45 per cent lower emissions than the 1993 car. Slightly lower emissions result from diesel-powered rail services. However, significant reductions result from the use of electric power for rail services, cutting VOC emissions by over 99 per cent compared to diesel traction.

Carbon monoxide emission rates exhibit a similar pattern to VOC rates, although the car is significantly higher than all the public transport modes. The 1993 car emits 10.28 grams per passenger-km compared to 0.8 grams from the bus—the highest public transport emitter—and the year 2000 car still emits 5.57 grams. The diesel-powered rail services result in slightly lower emission rates than the bus: but again the electrically-powered rail services result in significantly lower rates than all the other alternatives.

Emissions from the car fleet under alternative policy scenarios

The British Government has rejected European Commission proposals to introduce a general carbon tax to deal with the problem of global warming. The Commission's proposed tax would not be a pure carbon tax since it would also tax nuclear power. In addition, it would grant short-term exemption to certain heavy industries which are particularly fuel-intensive in order to preserve their international competitiveness. Nevertheless, it would have the advantage that the fossil fuels with the greater carbon content (particularly coal) would be taxed more heavily than those with the lower carbon content (particularly natural gas). This would encourage fuel-switching as well as fuel saving.

The British Government has adopted a two-pronged fiscal approach to reducing carbon emissions. First, Value Added Tax (VAT) was to be extended to domestic fuel, which had previously been zero-rated. This policy was announced in the March 1993 Budget. VAT was introduced on domestic fuel at 8 per cent in April 1994, and was to be increased to the standard rate of 17.5 per cent in April 1995. However, the move was very unpopular. Although a generous compensation package for pensioners and others on low incomes was proposed, the Government failed to pass the increase in its November 1994 Budget. Consequently, VAT on domestic fuel remains at 8 per cent.

The second prong of the fiscal measures to deal with global warming was increases in motor fuel duty. In early 1993 duty on unleaded fuel stood at 23.4 pence a litre. VAT was also levied at the standard rate. This meant that duty plus VAT accounted for some 65 per cent of the typical pump price of 47 pence a litre. In the March 1993 Budget the Chancellor of the Exchequer announced that the duty would be increased by at least three per cent a year every year to combat global warming. In the November 1993 Budget this was increased to a commitment to raise duties by at least five percent a year ["This will complete Britain's strategy for meeting our Rio commitments to restrain carbon dioxide emissions": Chancellor's Budget speech]. In November 1994 this pledge was re-affirmed, [".. forms an important part of the Government's strategy to return carbon dioxide emissions to their 1990 level in the year 2000"] and duties on unleaded were actually increased by 7.5 per cent to 30.44 pence a litre. After the VAT increase on domestic fuel had been defeated in Parliament, an emergency mini-Budget imposed a further 0.88 pence (2.9 per cent) on petrol—1.03 pence including VAT- ["The increase will also play a part in our strategy for curbing emissions of $C0_2$. We remain fully committed to the target of reducing $C0_2$ emissions to 1990 levels by the year 2000"], together with increased duties on alcohol and tobacco, to cover the anticipated shortfall in revenue.

The effects of increases in petrol (and diesel) prices

Our forecasts of carbon emissions from cars are based on the following fuel price scenarios:

Base case: Here the real price of fuel remains constant at the post-1994 mini-Budget real price.

Scenario 1: This scenario involves a five per cent duty increase over the base case every year after1994. This is presumed to be imposed indefinitely, although the Government have not made any commitment as to how long "every year" will be. Scenario 1 presumes that there will be no changes in real production costs after 1994.

Scenario 2: This Scenario involves the same duty increases as Scenario 1, but it assumes some increases in real production costs based on current UK assessments of possibilities. These assessments might be regarded as giving a "high" fuel price, whereas a "low" assessment would be one of stability as presumed in our Scenario 1.

Scenario 3: This is based on the November 1994 report of the Royal Commission on Environmental Pollution on *Transport and the Environment*. The Commission recommended that real petrol prices be doubled by the year 2005 (Royal Commission 1994, pp.114, 240). This implied a nine per cent annual increase in duties when based on the NRTF fuel production costs used by the Commission. Since these NRTF projections are now a little out-of-date, our Scenario 3 simply assumes that real fuel prices do double by 2005 whatever the underlying trend in production costs. The Commission recommended that fuel duties be reviewed after 2000 to see what further changes would be needed after 2005 to meet the Commission's proposed target of reducing carbon emissions from surface transport by twenty per cent from their 1990 level. In our Scenario 3 we presume that real duties remain constant after 2005 (as in the Commission's projections in their Figure 7-II), but that real production costs rise in line with the "high" projections in our Scenario 2.

Figure 1 shows past trends, and projections under our different scenarios, of fuel prices at 1994 price levels. The model was run under both "low" and "high" GDP and car ownership growth scenarios, but only the results for the "low" growth scenario are presented here. The "low" growth scenario projects GDP to grow by an average of 1.9 per cent per annum between 1995 and 2015, while the "high" growth scenario projects it to grow by an average of 3.1 per cent per annum. Between 1970 and 1992 UK GDP actually grew by 1.87 per cent a year on average, and we regard the "low" growth scenario as better reflecting future UK growth potential.

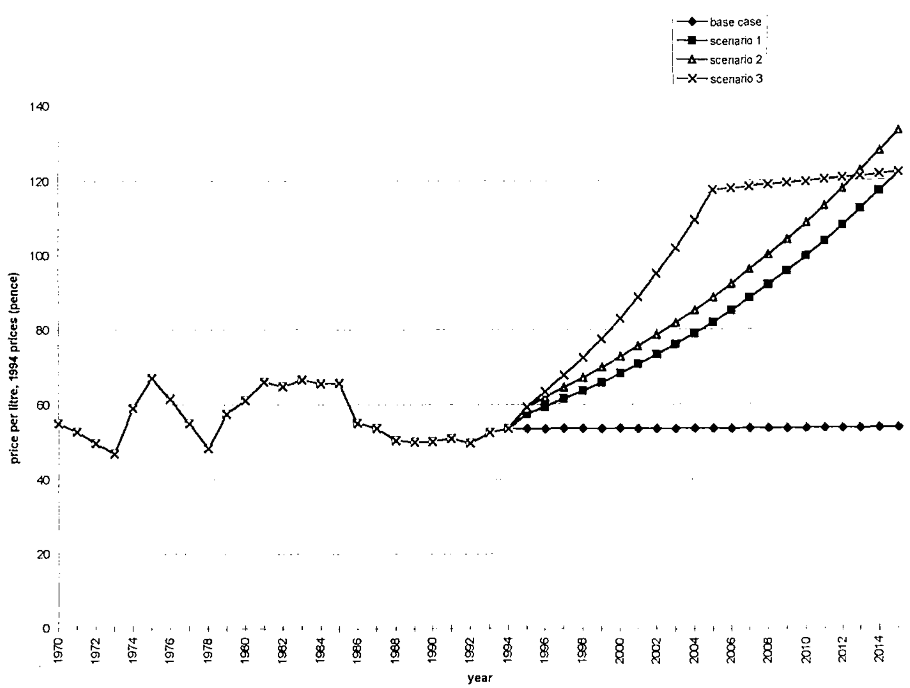

Figure 1 Real petrol prices, 1994 prices

Figure 2 shows projections of carbon emissions from cars. The Figure shows that carbon emissions are projected to continue to rise, but at a decreasing rate, with stable real fuel prices. With increasing real fuel duties, carbon emissions would peak before the end of the century. They would return to their 1991 level by 2004 under Scenario 3, by 2006 under Scenario 2, and by 2009 under Scenario 1. Note that none of these policies succeed in reducing carbon emissions to their 1990 levels by the year 2000, partly because traffic continues to grow, and partly because the effects of improved fuel efficiency technology have a lagged effect as new vehicles are added to the fleet. Nevertheless the projections show that carbon emissions in the year 2000 are reduced below the base case projection for that year by 1.18 mtC under Scenario 1, by 1.56 mtC under Scenario 2, and by 1.76 mtC under Scenario 3.

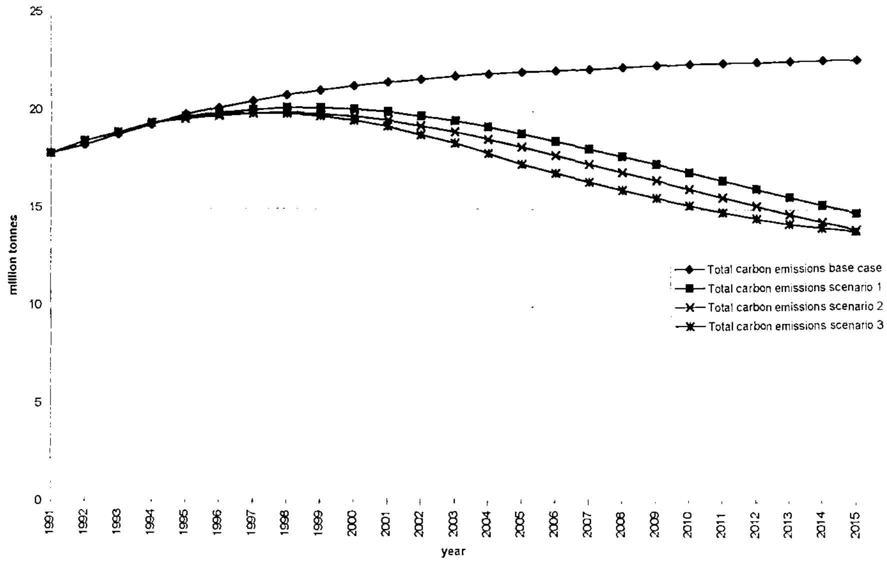

Figure 2 Total of CO_2 (as carbon) from cars

Another interesting result of the projections is that the differential effect of the five per cent annual duty increase compared to no duty increase is much greater than the differential effect of the Royal Commission's proposals compared with the five per cent increase. The main explanation for this is that price increases cannot go on increasing fuel consumption technology indefinitely. This is reflected in our fuel efficiency equation, which also incorporates a time trend reflecting improved efficiency whatever the underlying fuel price change. Note also that the carbon emission curve under Scenario 3 converges with those under Scenarios 1 and 2. As Figure 1 shows, the fuel price curves cross and this will lead, via the lagged effects on fuel consumption of the vehicle stock, to convergence of the emission projections.

The other factor which needs to be borne in mind is how large the real fuel price changes required to achieve these changes in carbon emissions are. This is shown clearly by Figure 1, where the real fuel price changes of the 1970s and 1980s (regarded as substantial at the times, but subsequently reversed) are dwarfed by the projections for the future. The Parliamentary defeat of the proposed increase in VAT on domestic fuel may have delivered a salutary lesson to Government on the political feasibility of imposing large tax increases, even for environmental reasons.

Figures 3, 4 and 5 show, respectively, emissions of nitrogen oxides, volatile organic compounds, and carbon monoxide from the car fleet under the different fuel price scenarios. The main factor causing emissions to fall is the impact of the mandatory fitting of CATS to new vehicles from 1993. The speed of decline reflects the speed of absorption of these new vehicles into the fleet. Eventually nearly all the fleet is fitted, and the impact of rising traffic levels takes over. However, the new vehicles are so much cleaner than the old that there is no chance that pollution levels will return to their original levels. In addition, our projections take no account of the possibility that solutions, such as pre-warming, may be found to the "cold-start" problem. Differences between the projections reflect the impact of fuel price changes on kilometres driven (though it should be noted that the vehicle-km-based emission coefficients used do not allow us to take account of any changes in emissions because of changes in the amount of fuel burned per vehicle-km).

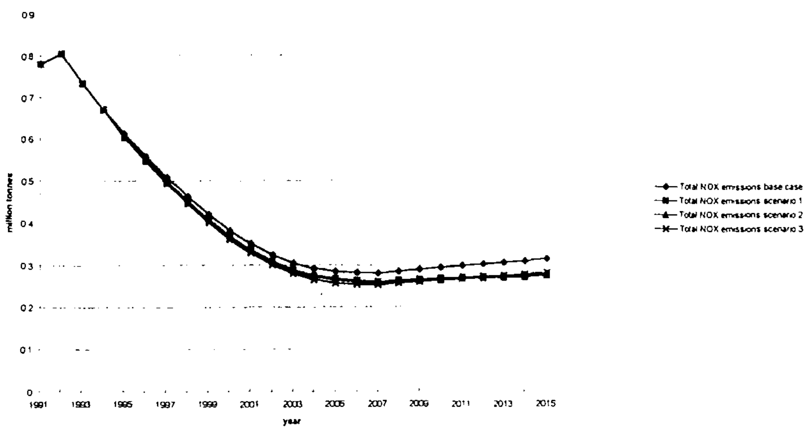

Figure 3 Total emissions of NOX from cars

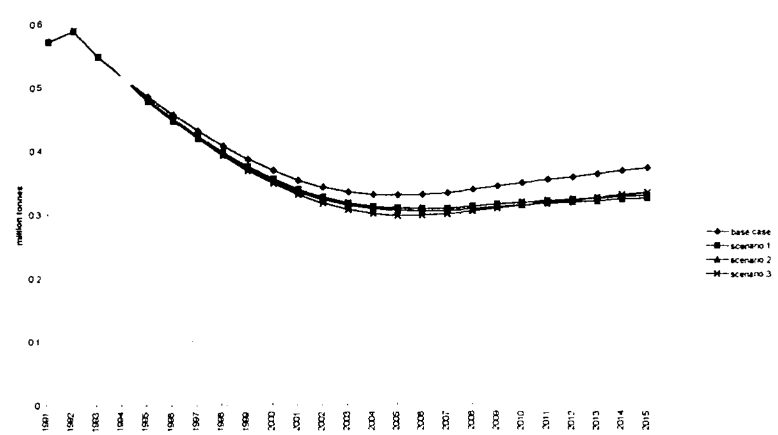

Figure 4 Total emissions of volatile organic compounds from cars

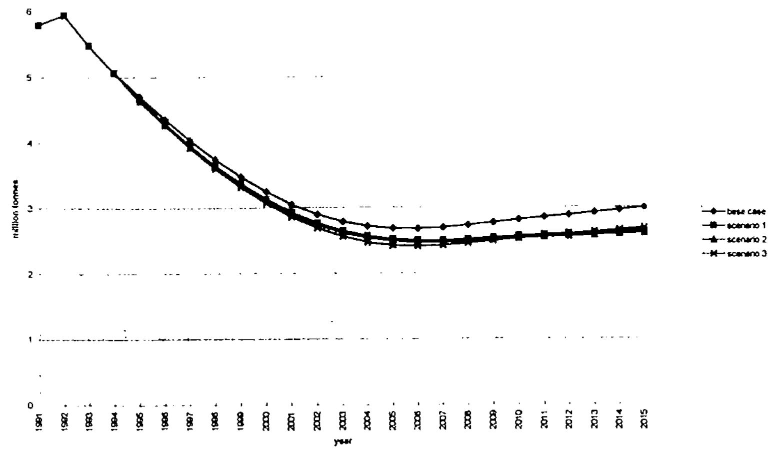

Figure 5 Total emissions of carbon monoxide from cars

The effects of public transport fare changes

We next consider the impact of public transport fares on greenhouse gas emissions from cars. We have done this by projecting a massive reduction in all public transport fares, by 50 per cent, in 1995. Fares are then kept at this level for the rest of the forecasting period. Scenario 4 shows the effects of these public transport fare reductions combined with the petrol price changes in Scenario 1 (the five per cent increase in duty, with no underlying change in production costs), while Scenario 5 shows the effects of the public transport fare reduction combined with the petrol price changes in Scenario 3 (the Royal Commission's proposed doubling of prices by 2005). Figure 6 shows carbon projections under these four Scenarios. The results show how small are the effects of this massive reduction in public transport prices compared with the effects of the direct (though equally substantial) changes in petrol and diesel prices.

In addition, this policy will increase greenhouse gas emissions from public transport because of the effect of the public transport fare changes in generating substantial extra demand for public transport, and hence a need for significant increases in capacity in the form of extra train-kilometres and extra bus-kilometres. Figure 7 shows the combined total carbon emissions from public transport and cars under the four scenarios shown in Figure 6 and outlined above. The total transport emission level rises significantly higher in 1995-96 under the public transport fare reduction scenarios (4 and 5) compared to the constant fare scenarios (1 and 3).

The increased public transport emissions resulting from the reduced fares ensure that the two fare reduction scenarios give higher total emission levels over the whole period up to 2015 than the corresponding petrol price scenarios with fares held constant. When comparing all four scenarios the initial modal-change effect is soon outweighed by the continually strong effect of the different petrol prices. By 2001 the lower petrol price without the public transport fare reduction (Scenario 1) results in higher emissions levels than the higher petrol price with the public transport fare reduction (Scenario 5).

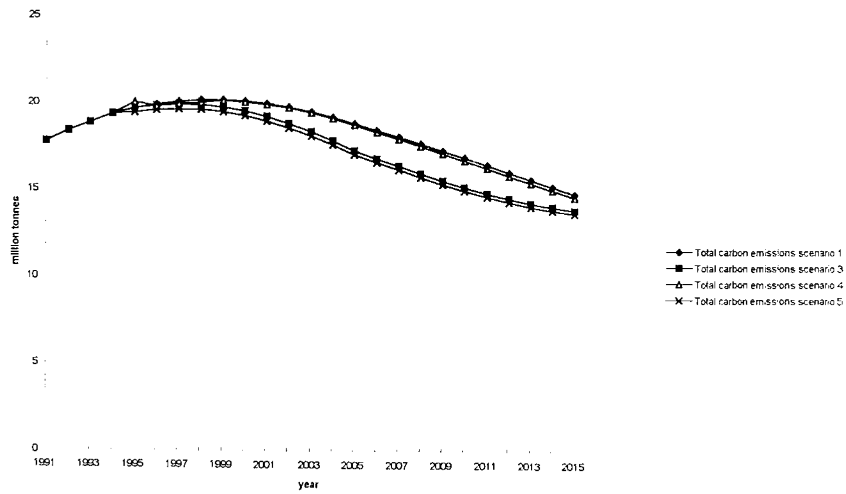

Figure 6 Total of CO_2 (as carbon) emissions from cars

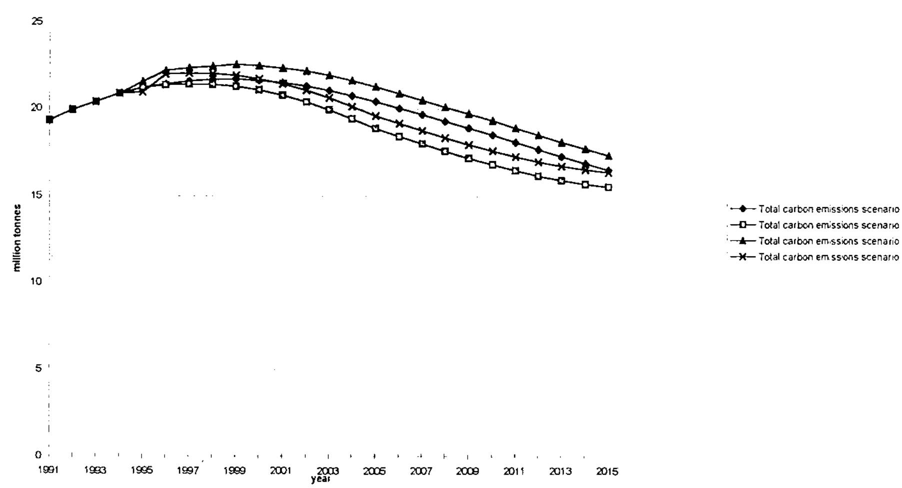

Figure 7 Total of CO_2 (as carbon) emissions from public transport and cars

CONCLUSIONS

We have outlined a price-sensitive model which provides predictions of greenhouse gas emissions from the transport sector in the United Kingdom. By including petrol price elasticities and inter-modal cross-elasticities, the model permits analysis of the effect of various economic policy instruments on emission levels. One result is that none of the policy options advocated could restore passenger transport carbon dioxide emissions back to their 1990 levels by the year 2000. Another is that direct action on car emissions by means of increases in petrol prices will be much more effective than indirect action by means of increased support for public transport: indeed the latter policy could well be counter-productive because of the impact of increased public transport demand on service levels and hence on public transport emission levels. With regard to the impact of petrol price increases, the forecasts show how the marginal impact of price increases declines as the scope for improving fuel efficiency is exhausted: hence the doubling of petrol prices advocated by the British Royal Commission on Environmental Pollution has a noticeably smaller marginal effect than the already large annual increases set in motion by successive recent Budgets.

The paper has also indicated relative greenhouse gas emissions from different passenger transport modes in the United Kingdom. These emission levels will vary from country to country, both with regard to average car engine size in different countries, and with regard to operating characteristics and average passenger loads on public transport vehicles. In turn, the latter will depend in part on regulatory regimes: certainly the bus emission factors in Britain will reflect the competitive nature of the deregulated urban bus markets, which are often characterized by competitive bus operators with excessive capacity and hence low average passenger loads.

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