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Achieving the Rio Target: CO₂ Abatement through Fiscal Policy in the UK

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I. INTRODUCTION

The research reported in this paper is an application of a large energy–environment–economy model² of the UK to the medium-term issue of stabilising carbon dioxide (CO₂) emissions at their 1990 levels by the year 2000, a commitment by the UK government made at the Earth Summit in Rio de Janeiro and taking the form of accession to the Climate Change Convention (the Rio Convention) in June 1992. This commitment has crystallised into a target of reducing emissions in the year 2000 by the equivalent of 10 million tonnes of carbon (mtc) below the level they would otherwise reach under a business-as-

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This paper is a revised version of that presented at a conference on 'Energy and the Environment', held at the University of Newcastle-upon-Tyne, 9–10 December 1993. However, it contains new results to allow for the government's compensation programme for pensioners and others affected by VAT on domestic fuels. The research draws on the work of Cambridge Econometrics in contributing to the development of MDM as an energy–environment–economy model. It should be noted that the scenarios described in the paper were modelled using MDM88, based on 1985 prices and the 1985 input–output tables. The assumptions and economic forecasts underlying the scenarios are close to those presented in the May 1993 issue of *Industry and the British Economy*.

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² See Barker, Baylis and Madsen (1993) for a description of the model and an analysis of the effects on the UK economy of the European Commission's proposed carbon/energy tax.

usual scenario (Department of the Environment, 1992, 1993 and 1994). Since there is considerable uncertainty in forecasting the level of CO₂ emissions in 2000 (157–179 mtc compared with 160 mtc in 1990 — Department of the Environment (1992, p. 7); the 1990 figure has subsequently been revised to 158.6 mtc), it seems sensible to focus on such a target, rather than on achieving a particular level.

The official statement of how this target is to be achieved was made after the November 1993 Budget when it was announced that the government plans to save the 10 mtc by means of increases in road fuel duty (giving an expected saving of 2.5 mtc), VAT on domestic fuels and other energy-saving measures directed towards homes such as stricter Building Regulations and more finance for insulation grants (4 mtc), voluntary energy conservation by business (2.5 mtc) and public sector energy savings (1 mtc) (Department of the Environment, 1994).

In this paper, the longer-term effects of the policies are not considered in detail, nor are the effects on non-CO₂ greenhouse gas emissions, nor the questions of equity and efficiency involved in imposing VAT on domestic fuels to meet emission targets. Instead, the emphasis is on the effects of the principal fiscal measures (VAT and petrol duty). An independent assessment is provided of their effects on emissions, and the measures are compared with the European Commission's (EC's) proposed carbon/energy tax in terms of reaching the target and raising revenues for the government.

The next section of the paper explains the modelling and the basis of the scenarios which have been constructed and how they relate to one another. Section III then describes the main fiscal measures introduced by the government to reduce greenhouse gas emissions (namely, VAT on domestic fuels and the escalating excise duty on road fuels) and their effects on CO₂ emissions, government revenues and expenditures, the main macroeconomic variables and finally on energy markets and the environment. Section IV compares the outcome of announced policies with that of the EC's carbon/energy tax, the measure proposed for all European Union (EU) Member States to meet European commitments. Finally, some conclusions are given in Section V.

II. MODELLING FISCAL POLICY OPTIONS TO MEET THE RIO TARGET

1. The Cambridge E3 Model

The Cambridge Multisectoral Dynamic Model (MDM) (Barker and Peterson, 1987), a large-scale model of the UK economy, has been extended to include energy–environment–economy interactions to become an E3 model (see Barker,

Ekins and Johnstone (1994, Ch. 9) for a more detailed description than given here). The model is a disaggregated econometric time-series model estimated on annual data for the UK from 1954 to 1992, using the 1985 input–output tables to provide the detail of industrial demand for goods and services.³ It represents the economy in much more detail than other macroeconomic models of the UK, with, for example, 43 industries and commodities, 68 categories of consumers' expenditure, 45 investing sectors, five non-financial assets and seven institutional sectors. It covers flows and stocks in current and constant prices, with many sets of equations estimated using co-integration techniques. Dynamic equations simulating short-term behaviour are estimated with convergence to a long-term co-integrating solution. The model is routinely solved over the period 1979-92 and used to provide regular projections and forecasts for the period 1993–2010.

The model has been designed to tackle medium- to long-term questions involving the use of fiscal instruments to reduce environmental emissions associated with the burning of fossil fuels. All the energy industries (coal, North Sea oil and gas extraction, oil refining and distribution, gas distribution and electricity) are distinguished in the 43 industries in the model along with the main energy-using industries such as chemicals and non-metallic mineral products (bricks, cement and pottery). The economic modelling is integrated with the energy and environmental modelling in a consistent framework which respects the definitions and conventions of the National Accounts, input–output tables, energy balances and data on atmospheric emissions. This integrated modelling structure, in which macroeconomic aggregates are typically built up from the sectoral detail, distinguishes the approach from that of other models of the UK and indeed from the multi-model approach adopted by DRI in its assessment of the EC's carbon/energy tax (DRI, 1991 and 1992). In the multi-model approach, three separate models (a macro-model, an industry model and an energy model) are solved together. Even if consistency problems can be overcome and the models solved iteratively until convergence, there remains a fundamental problem of being able to simulate the macroeconomic effects of policies taking effect at an industry level, for example the exclusion of energy-intensive industries from coverage of the carbon/energy tax.

2. The Energy Sub-Model

The energy sub-model is based on the approach of the UK Department of Energy (Department of Energy, 1989). It includes a detailed econometric analysis of the overall demand for energy as well as the substitution between fuels following the

³ The model is regularly revised and re-estimated on new data. An earlier analysis of a carbon tax (Barker and Lewney, 1991) did not include the detailed econometric analysis of energy demand described here. And since this paper was completed, the model has been updated to conform with the 1993 edition of the CSO's *National Accounts* and the 1990 input–output tables.

imposition of a carbon/energy tax. The projection of fuel use, distinguished by user and type of fuel, is then used to calculate emissions of CO₂, sulphur dioxide (SO₂) and other by-products from the burning of fuels, allowing for different qualities of the fuels. The solution for the economic variables yields changes in economic activity and general price levels to the energy sub-model. The sub-model then calculates energy demand by sector and the use of primary fuels in electricity generation. These results can be expressed as changes in the input–output coefficients for the electricity-generating sector and other industries, thus providing a feedback into the main model. Finally, the burning of fossil fuels generates emissions of CO₂ and other pollutants such as SO₂, nitrous oxides (NO_x) and carbon monoxide (CO) into the atmosphere, which are then added to other emissions generated by agriculture, industry and human population, calculated from changes in variables in the economic model.

The energy sub-model has five components, containing solutions for:

- electricity supply characteristics (fuel use, generating capacity);
- secondary energy demand in aggregate by user;
- fuel use by energy carrier and user;
- the prices of fuel use by user; and
- emissions to the atmosphere.

On the energy supply side, the electricity industry's plant profile is assumed to alter according to the demand for electricity and the cost of fuel and capital. The type of plant on the system and its utilisation in each year determines the fuels used and the price of electricity to the contract market.

On the demand side, aggregate secondary energy demand is determined by 10 final users in a set of equations very similar to those developed by the UK Department of Energy. These include the effects of economic activity, relative prices, deviations of temperature from normal values and the miners' strike of 1984. These aggregate demands are then allocated across the different fuels by means of a set of share equations. First, the share of electricity demand in the total is determined; then the non-electricity demand is divided between coal, oil products and gas. The relative prices for energy and the fuels are derived from world prices, the UK tax structure and regulatory rules. Finally, the energy industries' own use of energy is taken as a fixed proportion of the total by energy type.

The sub-model distinguishes household consumption of coal, heating oil (plus a small amount of gas oil), gas and electricity. Total household energy demand is calculated from an equation estimated on annual data for 1971–92 with the long-term own-price elasticity imposed at -0.3 , after a specification and literature search, and the short-term elasticity estimated as -0.12 . Within total energy demand, the cross-price elasticities indicate the possibility of greater substitution between oil and gas than for either fuel with electricity, reflecting

the fact that use of the first two fuels is limited to space and water heating and, in the case of gas, also cooking. Although the extension of VAT applies equally to all fuels, it is quite different in its impact from a tax on each fuel's energy content. Since the cost in terms of pence per therm is highest for electricity and lowest for gas, the application of VAT increases further the gap between the selling prices of 'high-cost' and 'low-cost' fuels.

The sub-model also explains the use of motor spirit and derv by road transport (freight and passenger transport, and private cars). The own-price elasticity is low, estimated to be -0.12 in the short term (current year) and -0.3^4 (imposed) in the long term. Within total energy use, the model then distinguishes the shares supplied by motor spirit and derv (and other fuels). The cross-price elasticities between oil products and other fuels (for example, electricity for electric cars and vans) are small, in line with the conventional view that the demand for road transport is price-inelastic in the short term and the fuel substitution possibilities are limited.

The feedback from the energy sub-model to the rest of the model is determined as follows: changes in fuel use by the domestic sector determine changes in consumers' expenditure (in constant prices) on electricity, gas, coal, heating oils and petrol; changes in fuel use for final demand in other sectors are used to determine the share of government expenditure on fuels. For industrial use of fuels, the implied changes in the input-output coefficients are calculated at the nine-industrial-sector level of the energy model and applied to the coefficients at the full 43-industry level of the economic model. The coefficients for fuel use by the electricity industry are entered directly into the full input-output coefficient table. Finally, the mix of regulated and contract-market prices for electricity is averaged to give the electricity price in the main model.

3. The Scenarios

Different scenarios were developed and then compared to measure the effects of different policies to reduce the growth of CO₂ emissions to the year 2000 while simultaneously achieving the same reduction in the public sector borrowing requirement (PSBR). The starting-point was a base case with no VAT on domestic fuels, no road fuel escalator and no carbon/energy tax (this scenario is labelled BASE below). The government's programme to achieve the Rio target, at the same time as reducing the PSBR below BASE-case levels, was modelled

⁴ In the later version of the model developed after this paper was written, a much higher long-term elasticity of -1.2 has been imposed from cross-section evidence. However, the higher elasticity does not have much effect on projections of road transport fuel demand to the year 2000, because the short-term elasticities are the same in both versions and the lagged response is very long, due to the long lags required for changes in engine design, changes in driver behaviour and changes in the composition of the vehicle stock. The response time is also affected by the high adjustment costs for relocation required to reduce journey lengths and the long life of associated transport infrastructure.

TABLE 1
Key Features of the Scenarios

	Tax Measures					Compensation	Reduction in PSBR
	Income tax allowances	VAT on domestic fuels	Petrol duty escalator	Carbon tax	Energy tax		
BASE	-	-	-	-	-	-	No target reduction
BAU	Lower, to raise revenue	-	-	-	-	-	Aim to achieve same as VAT/road fuel duty
VAT/road fuel duty	-	8 per cent from April 1994, 17.5 per cent from April 1995	4.2 percentage points in 1993, 5 percentage points from 1994 (real terms)	-	-	Indexed benefits plus rise in basic pension, insulation grants	£4.4 billion from BASE
Carbon/energy tax	-	-	-	\$0.75 per barrel in 1994, rising to \$2.9 per barrel from 1996	\$0.75 per barrel in 1994, rising to \$2.9 per barrel from 1996	As VAT/road fuel duty	Aim to achieve same as VAT/road fuel duty
EC tax	Higher, to recycle additional carbon/energy tax revenues	-	-	\$2 per barrel in 1994, rising to \$5 per barrel in 2000	\$2 per barrel in 1994, rising to \$5 per barrel in 2000	As VAT/road fuel duty	Aim to achieve same as VAT/road fuel duty

Source: Cambridge Econometrics.

using a scenario which includes the extension in the scope of VAT, the real increase in road fuel duties and the special compensation for pensioners and others to offset higher fuel bills (labelled VAT/road fuel duty). This scenario is compared with a business-as-usual scenario (labelled BAU) without these measures and without special compensation, but allowing for an increase in income tax revenues via reductions in the value of allowances (in addition to those announced in the November 1993 Budget) *to achieve the same reductions in the PSBR as achieved in the VAT/road fuel duty scenario.*

As an alternative to the VAT/road fuel duty scenario, another scenario was constructed based on a variant (labelled Carbon/energy tax) of the EC's proposed carbon/energy tax, with special compensation and income tax allowances at the same levels, and setting the rate of carbon/energy tax so that the PSBR in 2000 is also at the same level as in the VAT/road fuel duty scenario. The EC's original proposal for the carbon/energy tax, amended for a delayed start, was modelled in a further scenario (labelled EC tax) and the additional revenue raised was recycled through lower income tax allowances, so that the PSBR in 2000 is again the same as in the VAT/road fuel duty scenario.

The key features of each scenario are shown in Table 1. In order to make a detailed analysis of the measures, four further model projections were done: the VAT extension and the road fuel duties were introduced separately; and the carbon tax was separated from the energy tax. In addition, a number of projections were done to examine the effects of the special compensation for VAT on fuels.

III. THE GOVERNMENT'S FISCAL PROGRAMME: CO₂ ABATEMENT AND ECONOMIC EFFECTS

1. The Instruments: VAT on Domestic Fuels and Escalating Road Fuel Duties

The March 1993 Budget announced in advance the government's intention to extend the coverage of VAT to include expenditure on domestic fuel and power in two stages (8 per cent from April 1994 and the full 17.5 per cent from April 1995). The November 1993 Budget confirmed the change, but announced a range of measures to compensate pensioners and other low-income households for the tax increase, including a rise in the basic pension of some £1.40 a week from April 1995. The government estimated that the cost of these measures would amount to some 40 per cent of the revenues raised by the tax. In the VAT/road fuel duty scenario, the compensation takes the form of the normal indexation of pensions and other benefits to increases in prices, plus extra payment of pensions and other benefits. The March 1993 Budget also included a commitment to raise road fuel duties by at least 3 per cent per annum in real

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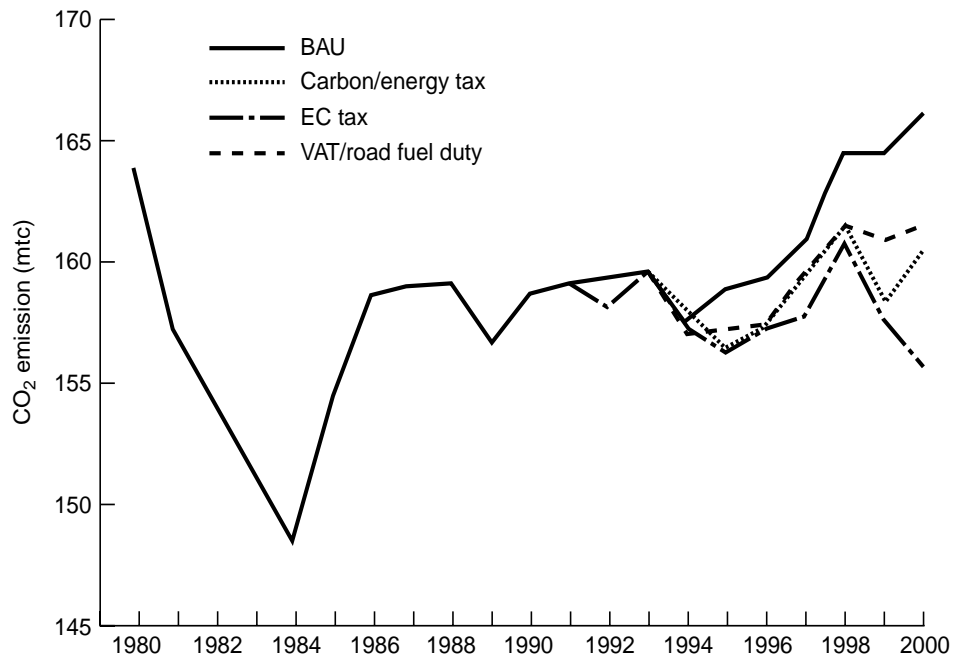
terms indefinitely, and in the December 1993 Budget the 3 per cent was increased to 5 per cent p.a.

TABLE 2
UK CO₂ Emissions

	<i>Million tonnes of carbon</i>			
	1970	1980	1990	2000
BAU	182.3	163.8	158.5	166.1
VAT/road fuel duty				161.3
Carbon/energy tax				159.0
EC tax				155.5

Sources: Department of the Environment's Digest of Environmental Protection and Water Statistics (DEPWS); Cambridge Econometrics.

FIGURE 1
UK CO₂ Emissions



Sources: DEPWS; Cambridge Econometrics

These changes are modelled entirely through their effects on prices of the fuels concerned (electricity, gas, coal and coke, other fuel and petrol, diesel and oil bought by private consumers, and petrol and diesel bought by industries and government for road transport). It is assumed that industries pass on the higher costs in the prices of their products, that wage negotiators react fully to the higher overall consumer prices and raise nominal wage rates, and that both export and domestic commodity markets clear at these higher prices. Since the wage equations also include a term for retentions from earnings in the form of National Insurance charges and income taxes, the higher income tax in the business-as-usual scenario compared with the BASE will also lead to higher nominal wage rates, although the effect of income tax increases on wage rates is smaller than the effect of increases in indirect taxes, for the same government revenues. One limitation of the study is that any effects of the higher taxes which are not directly associated with the price changes are ignored. In addition, no account has been taken of the large-scale tax avoidance of VAT in 1994 and 1995 through prepayment of gas and electricity bills by domestic consumers. This will affect revenues in the early years, but not by the year 2000.

2. CO₂ Abatement

The UK Department of the Environment announced at the time of the March 1993 Budget that the VAT extension and the 3 per cent p.a. real increase in petrol duty would each reduce CO₂ emissions by about 1.5 mtc a year by 2000. Other measures already in hand were at that time expected to save a further 4 mtc by 2000, leaving a further 2–3 mtc reduction (10 mtc in all) to be achieved by further measures. One of these was announced in November 1993, namely the increase in the road fuel duty escalator to 5 per cent p.a. The official estimate of the effect of the combined VAT and road fuel duty package is an annual 4 mtc saving by 2000. Apart from the impact on CO₂ emissions, the increased road fuel duty is also expected to cut emissions of local pollutants such as NO_x, hydrocarbons and smoke.

Table 2 shows the results for CO₂ emissions of the scenarios (the carbon/energy tax scenarios will be discussed in the next section of the paper). The government's combined package is estimated to reduce emissions by 4.7 mtc relative to business as usual (lower than Table 2 suggests due to rounding), including the effects of special compensation, slightly above the official 4 mtc estimate. The net effect on CO₂ emissions of VAT alone is estimated to be a reduction of 2.7 mtc and that of the petrol duties is 1.6 mtc. Table 2 is illustrated in Figure 1.

3. Energy Prices and the PSBR

An increase in the rate of duty of 5 per cent p.a. in real terms has the effect of raising the price of motor spirit by some 22 per cent above BASE by the year

2000. Table 3 shows the PSBR in the year 2000 as calculated in the scenarios. The VAT/road fuel duty scenario reduces the PSBR by some £4.4 billion in current prices in 2000 below the BASE with no extra revenue-raising measures. The yields on the extra taxes are much higher than this, being offset by increases in benefits due to indexation and loss of revenues from other taxes due to generally lower activity and spending. The increase in the VAT yield compared with that under business as usual is some £5.7 billion; the increase in the road fuel duty yield is some £8.5 billion. Therefore some £10 billion of the revenues are 'lost' in associated increases in benefits and reductions in other tax revenues. The road fuel duty yield is much larger than the VAT yield because the duty rises each year by 5 per cent in real terms, whereas the VAT change is once-and-for-all and stabilises in real terms after 1995.

TABLE 3
UK PSBR in 2000

	<i>£ billion</i>	
	<i>PSBR</i>	<i>Reduction in PSBR from BASE</i>
BASE	17.7	
BAU	13.3	4.4
VAT/road fuel duty	13.3	4.4
VAT	17.2	0.6
Road fuel duty	13.9	3.8
Carbon/energy tax	13.3	4.4
Carbon tax	15.9	1.8
Energy tax	16.0	1.7
EC tax	13.3	4.4

Source: Cambridge Econometrics

4. Macroeconomic Effects

Table 4 shows some macroeconomic indicators for the four scenarios over the period 1993–2000 or in the year 2000. Overall GDP and consumption growth are not significantly affected. Inflation is lower under business as usual with lower indirect tax effects (in the model, wage negotiators do not fully compensate for increases in income tax). Inflation, as measured by the RPI, is highest under the EC tax, which assumes the highest tax rate and in which there is no offsetting reduction in the rate of VAT (the effective revenue recycling here, to achieve the same reduction in the PSBR, is assumed to take place through higher income tax allowances which have less impact in reducing inflation compared with a reduction in VAT). Unemployment is very similar in each scenario, with lower rates in the carbon/energy tax and EC tax scenarios indicating switching between

energy and labour inputs. The balance of payments is in larger deficit in all three indirect tax scenarios as a result of higher wage rates and prices reducing competitiveness. However, the reduction is moderated in the road fuel duty scenario by the fact that the reductions in oil consumption also reduce imports directly since the output of North Sea oil and gas is held constant by assumption.

5. Special Compensation

The November 1993 Budget announced a substantial programme of special measures to compensate pensioners and other groups particularly disadvantaged by the VAT on domestic fuel use. It has not been possible to analyse the effects of this compensation on the spending of these specific groups, but it has been possible to treat them as if they behaved in the same way as the average consumer. From IFS work on taxation of fuels (Pearson and Smith, 1991), this is rather unlikely, but the effect is a second-order one working through the composition of consumers' expenditures which is unlikely to have much effect on the results reported here. The overall results for the VAT/road fuel duty scenario are largely unaffected, except that the net PSBR reduction is smaller.

TABLE 4
UK Main Macroeconomic Indicators

	<i>BAU</i>	<i>VAT/ road fuel duty</i>	<i>Carbon/ energy tax</i>	<i>EC tax</i>
GDP (% p.a., 1993-2000)	2.3	2.3	2.3	2.3
Consumers' expenditure (% p.a., 1993-2000)	2.1	2.1	2.2	2.1
Home unit costs (% p.a., 1993-2000)	4.6	4.8	4.9	5.1
RPI (% p.a., 1993-2000)	4.8	5.2	5.2	5.4
Unemployment (millions in 2000)	2.78	2.81	2.76	2.69
Balance of payments (% p.a., 1993-2000)	0.0	-0.2	-0.3	-0.2

Source: Cambridge Econometrics

6. CO₂ Emissions and Energy Markets

Tables 5 and 6 show the contributions to CO₂ abatement by fuel user and type of fuel respectively. Table 5 is illustrated in Figure 2 which shows the changes in emissions in mtc for 1990–2000 with 1990 as the base line. The results for the

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TABLE 5
Contribution to CO₂ Abatement in 2000, by Fuel User^a

Million tonnes of carbon

	1990	2000			
		<i>BAU</i>	<i>VAT/road fuel duty</i>	<i>Carbon/energy tax</i>	<i>EC tax</i>
Power generation	54.3	46.6	44.9	45.7	45.4
Energy-intensive industries	13.2	18.6	18.7	15.7	14.6
Other industry	22.0	19.4	19.5	17.6	17.1
Road transport	29.9	36.7	35.0	36.4	36.0
Other transport	3.0	4.9	4.9	4.9	4.8
Households	22.0	24.0	22.5	23.1	22.2
Commerce etc.	9.1	10.3	10.3	10.0	9.7
Total	158.5	166.1	161.3	159.0	155.5

^a Excludes energy industries' own use of energy.
 Sources: DEPWS; Cambridge Econometrics.

TABLE 6
Contribution to CO₂ Abatement in 2000, by Fuel Type^a

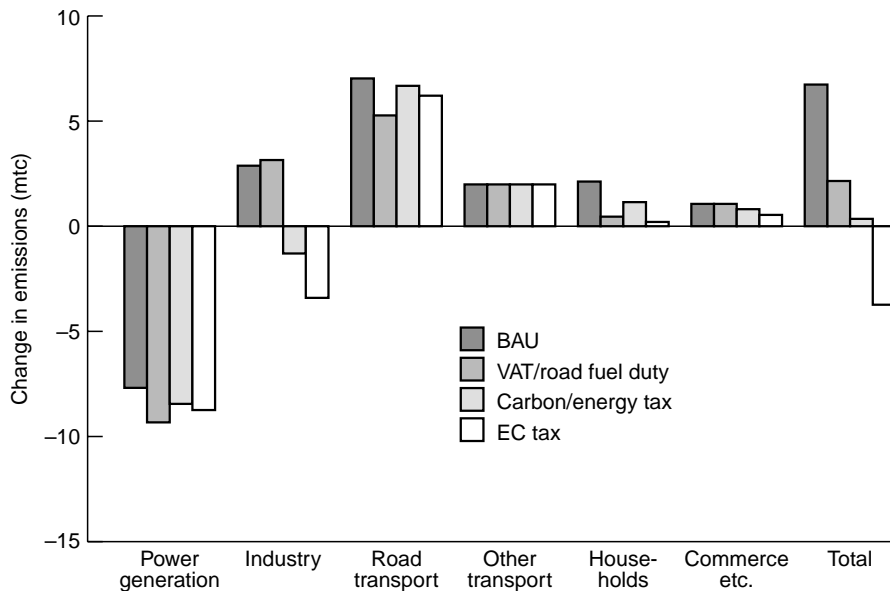
Million tonnes of carbon

	1990	2000			
		<i>BAU</i>	<i>VAT/road fuel duty</i>	<i>Carbon/energy tax</i>	<i>EC tax</i>
Coal	66.3	58.4	57.4	50.3	48.5
Motor spirit/derv	29.9	36.8	35.1	36.4	36.0
Other oil products	26.2	24.0	23.3	25.4	23.6
Gas	31.0	40.0	38.6	39.8	40.4
Other	5.1	7.0	7.0	7.0	7.0
Total	158.5	166.1	161.3	159.0	155.5

^a Excludes energy industries' own use of energy.
 Sources: DEPWS; Cambridge Econometrics.

total show that even under business as usual, emissions are only expected to rise by some 7 mtc and that the fiscal measures in the government's programme are expected to reduce this to some 2 mtc. One feature of all the projections is the large expected decline in the emissions from electricity generation, mainly due to the switch away from coal- towards gas-fired generation. The results for industrial emissions differ sharply between the scenarios, with the government's programme actually expected to increase emissions slightly. As might be expected, CO₂ emissions by road transport and households are reduced the most in the VAT/road fuel duty scenario.

FIGURE 2
**Contribution to CO₂ Abatement:
 Change in Emissions, 1990-2000**



Source: Cambridge Econometrics

7. Environmental Costs and Benefits

In assessing the costs and benefits of measures to reduce greenhouse gas emissions, the secondary benefits of reducing other social costs associated with the burning of fossil fuels are frequently discussed but rarely quantified (see Boero, Clarke and Winters (1991)). The principal associated social costs appear to be poor urban air quality, human illness, traffic accidents, congestion, damage and noise, reduced visibility, corrosion, and damage to crops, forests and fish stocks. The potential importance of these secondary benefits has been recognised in studies of greenhouse gas abatement (for example, Barker (1993b) and

Brendemoen and Vennemo (1994)) and it appears that they are substantial and may be larger than many of the published estimates of the GDP costs of abatement.

Although there are great uncertainties involved in making quantitative assessments of the associated costs of burning fossil fuels, calculations from the reductions in emissions from the scenarios described above suggest that they come to between 0.1 per cent and 0.5 per cent of GDP at 1990 prices in 2000, compared with business-as-usual results, magnitudes comparable with those published on the GDP costs of greenhouse gas abatement.

IV. THE CARBON/ENERGY TAX ALTERNATIVE

1. The Carbon/Energy Tax Proposal

A carbon tax is an instrument for reducing CO₂ emissions which is very close to being ideal in terms of economic efficiency, though not in terms of equity (Barker, 1993a). A carbon tax, if applied to all economic agents burning fossil fuels, would provide an incentive for industry and power generators to switch out of carbon-based energy; VAT and road fuel duty have no such effect. In comparison with value-based taxes such as VAT or road fuel duty, revenues and emission reductions will be more robust under conditions of fluctuating oil and coal prices, since the tax base is the quantity of carbon contained in fuel use, not the value of the energy consumed. Thus as an instrument to achieve the Rio target, a carbon tax would be more efficient than the value-based taxes and it would be more likely to be successful in the face of fluctuations in future oil prices and other uncertainties.

The original EC proposal was for a 50/50 carbon/energy tax introduced at \$3 per barrel of oil equivalent (pb) in 1993, rising by \$1 pb each year to \$10 pb in 2000 (European Commission, 1991, 1992a and 1992b). For one scenario (the carbon/energy tax), the rate was scaled down to produce the same outcome for the PSBR as the combined VAT/road fuel duty scenario, again with indexation of benefits for any rise in prices from the tax. The tax was introduced at a rate of \$1.5 pb in April 1994, rising to about \$6 pb by 1996 and held constant at \$6 pb to the year 2000. The differences between the results for this scenario and business as usual show how the Rio target might have been achieved by an alternative strategy to that being followed by the government. The original EC proposal for a higher tax was studied in another scenario (the EC tax), introduced at \$4 pb in 1994 and rising to \$10 pb by 2000. The additional revenues raised from the higher tax were recycled through higher income tax allowances to give the same outcome for the PSBR.

In both scenarios, the tax is assumed to be introduced throughout the European Union. Imports and domestic supplies of fuels bear the tax according

to their carbon and energy content, and exports are exempted from the tax coverage. The treatment is assumed to be very close to that adopted for excise duties on hydrocarbons (see Barker, Baylis and Madsen (1993) for a fuller analysis of the tax). In order to maintain comparability with the VAT measure, compensation is also included in this scenario at the same level as that included in the VAT scenario. It is also assumed that all the tax is passed on to the user of the fuels, and that the industrial user then passes on the extra costs in the form of higher prices; this allows the new prices for all goods and services in the economy to be calculated. The increase in price will be a result of the direct and indirect carbon and energy content of each of the 43 commodities and 68 consumers' expenditure categories (to take two important sets of prices in the model).

2. Modelling the Carbon/Energy Tax

It is worth explaining how the model predicts the impact of a carbon/energy tax on prices and tax revenues. The effects on total energy consumption and the use of fuels are derived entirely from the effects of the tax on prices. The carbon and energy components of the EC tax are treated separately. The carbon tax is converted from dollars per barrel of oil equivalent (1993 prices) to a rate in pounds sterling (using the fixed exchange rate \$1.75=£1) per tonne of carbon emitted for each year 1994–2000. The carbon tax liability of all fuels is calculated on the basis of their carbon content, and converted into pence per therm on the basis of their heat content. The energy component of the tax is expressed in pence per therm, again given the fuels' heat contents. Both components are indexed to the consumer price index. A matrix of total carbon and energy tax rates for each fuel and user is constructed for each year and average rates calculated for each fuel and each user. Tax revenues can then be calculated from energy consumption for conversion, for own use by energy industries and for secondary uses. Potential revenues are affected by the response of energy consumption to the imposition of the tax.

3. The Effects of the Carbon/Energy Tax

Table 2 and Figure 1, presented earlier, show that the introduction of the EC tax rising to \$10 pb by 2000 could well accomplish the whole target reduction (10 mtc) by one measure alone, compared with the broad set of measures required under the government's programme. Tables 5 and 6 also show the distinct effect of the road fuel duty on emissions from road transport and the effect of the carbon/energy tax on other industrial emissions. Overall, for the same PSBR reduction, the carbon/energy tax is more effective in reducing CO₂ emissions. The EC tax, with a higher rate, reduces emissions in 2000 to below 1990 levels. Electricity is more affected by VAT on domestic fuels than by the carbon/energy tax at the rates in the scenarios because consumers' demand for high-cost

electricity is reduced under the VAT scenario. Another feature of the carbon/energy tax scenario is that the special compensation required for comparability with the VAT/road fuel duty scenario leads to an extra saving of 1 mtc in CO₂ emissions, since the tax rate has to be higher to raise the extra revenues required.

Whereas extra road fuel duties will raise the price of motor spirit by some 22 per cent above BASE by the year 2000, implementation of the carbon/energy tax, introduced at \$1.5 pb in 1994, rising to almost \$6 pb by 2000, would raise the motor spirit price by some 5 per cent. This increase is lower because the carbon/energy tax is applied as a specific tax on the carbon and energy content of the fuel inputs; other taxes on road fuels and high value added in refining mean that the fuel input costs are a small percentage of the final product price and therefore any tax on the fuel inputs represents only a small percentage of the total price.

Table 3 shows the contributions to reducing the PSBR made by each component of the VAT/road fuel duty scenario and of the carbon/energy tax scenario. These are based on separate model runs in which, for example, only VAT or only the carbon tax component is applied and, due to second-round effects, the individual components do not sum to the net total effect. The carbon and energy taxes each reduce the PSBR by much the same amount, with rates set so that the combined effect matches the reduction in the VAT/road fuel duty scenario. The yield of the carbon tax component is £3.6 billion and that of the energy component is £4.5 billion, showing that the carbon tax is more effective in reducing carbon emissions than the energy tax is in reducing energy consumption.

V. CONCLUSIONS

The Budget measures will make a substantial contribution to reducing UK emissions of CO₂, but the measures have been targeted at areas of energy consumption where short-term price elasticities are low. If the objective were simply to reduce CO₂ emissions by a specified amount, the measures adopted in the Budget would not be efficient, since there are other areas where the energy use of carbon-intensive fuels will respond more to price increases. In fact, of course, other objectives have influenced the government's choice. Taxes that would directly affect UK industries' competitiveness have been avoided, and the fact that price elasticities are low in the areas chosen means that the measures can be relied upon to raise substantial revenues to reduce the PSBR.

VAT on fuels is a one-off measure and the rate is unlikely to be increased again; it will help towards the achievement of the Rio target for the year 2000, but may not have much effect on the underlying long-term growth of CO₂ emissions from households. The introduction of escalating duties on road fuels, which was a feature of both 1993 Budgets, represents a distinct and innovative

approach to long-term environmental problems associated with road traffic, and will almost certainly slow the growth of emissions of pollutants and greenhouse gases and associated social costs.

What is missing from the government's programme is a convincing solution to the long-term growth in emissions from the electricity generators and other industrial fossil-fuel consumers. The switch to gas will help over the next few years, but emissions are likely to resume an upward trend after the turn of the century. Furthermore, a reasonable long-term target according to the scientific consensus (International Panel on Climate Change, 1990) would be a 60 per cent cut below 1990 levels, rather than just stabilisation of CO₂ emissions.

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