CARBON TAXES AND CURRENT ENERGY POLICIES
IN OECD COUNTRIES

Peter Hoeller and Jonathan Coppel

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The authors are grateful for comments and suggestions by Andrew Dean, Jorgen Elmeskov, Robert Ford, Constantino Luch, John P. Martin, David Newbery, Peter Richardson, David Roberts, Ronald Steenblik and Bernard Wacquez. Special thanks are due to Anne Chergui, Jackie Gardel, Anick Lotrous and Francette Koechlin for technical assistance.
INTRODUCTION

Carbon taxes figure prominently in the debate over greenhouse gas (GHG) control policy, since they are an economic instrument that can be used directly to influence emissions of carbon dioxide (CO₂), the main greenhouse gas. The economic cost of imposing a carbon tax will depend not only on the size of the new tax but also on current policies, for instance taxes and subsidies.

This study focuses on the interaction between existing taxes on energy and the use of carbon taxes (taxes levied on the carbon content of fuels) to reduce emissions of CO₂. In this context, the paper poses four principal questions:

a) How large is the variation in energy prices among OECD countries and what factors contribute to it?

b) What are the major elements of an efficient energy pricing policy and how do they affect the implementation of a carbon tax?

c) How have energy policies changed recently?

d) Could a restructuring of current energy taxes alone achieve significant cuts in carbon emissions?

The article by Burniaux et al. in this volume also focuses on the effect of taxes and subsidies on CO₂ emissions. Three features distinguish our article from that of our colleagues: they focus on broader regions in a global longer-term context, while this article discusses policy in 20 OECD countries in more detail. They employ a general equilibrium model while numerical exercises in this article are comparative static in nature. Finally, data construction methods differ considerably.
I. ENERGY PRICES, TAXES AND OTHER DISTORTIONS

Energy-related carbon emissions largely depend on the fossil fuel consumed, with emissions varying by as much as a factor of two for a given heat content. Since the risk of global warming is linked to carbon dioxide and other principal greenhouse gas emissions, rather than the consumption of energy per se, it is instructive to examine energy volume and price data expressed in terms of the amount of carbon emitted. Measurement issues are discussed in the Box and the fuel coverage and method used to construct energy prices, taxes and consumption data expressed per ton of carbon emitted are discussed in the Annex.

Real fossil-fuel prices have changed dramatically over the 1980s, largely reflecting changes in oil prices and the tax burden (Figure 1). Since energy taxes are largely ad valorem, the relationship between end-use and tax-exclusive prices is stable in the absence of policy changes. However, following the collapse in oil prices in late 1985, many countries increased the tax burden on energy for wider fiscal reasons. In 1989, despite a higher tax share, real fossil-fuel prices were again close to their level in the late 1970s and differences in regional price levels hardly changed. Real energy

Figure 1  Real regional end-use fossil fuel energy prices
1989 prices and exchange rates

Source: Estimates based on IEA data
tax-exclusive prices, however, were at the lowest levels recorded for a considerable period of time (Figure 2). Fossil-fuel prices to final users differ considerably across countries (Figure 3). They are highest in Japan and Europe and lowest in North America and Australia.

Comparing different global models (see Dean and Hoeller in this volume) shows that the economic cost of a carbon-tax policy and its effectiveness in terms of abatement reduction, depends importantly on the existing level of energy prices. Countries with high energy prices may require larger absolute carbon taxes than low energy-price nations to achieve a certain degree of abatement, since they are already more energy-efficient. It is relevant, therefore, to analyse what factors explain the large difference in energy prices per ton of carbon across countries. Four key determinants are:

a) taxes and subsidies;
b) the composition of fuel demand and the proportion of each fuel consumed by the industry, household and power generation sectors;
c) non-tax market distortions, such as price-support measures, certain government policies and non-competitive industry structure; and
d) local distribution costs and quality differences.

Estimates of average implicit taxes per ton of carbon for 1988 are shown in Figure 3 for 20 OECD countries expressed in U.S. dollars. Among the major OECD

\[\text{Figure 2  OECD wide real end-use prices and taxes}
1989 prices and exchange rates\]
countries, the implicit carbon tax is low in North America, intermediate in Germany and Japan and high in France and Italy. It is also generally high in small European economies. The tax is much higher for oil than for gas in all countries and coal is usually untaxed (Figure 4). In many European countries, the oil product tax is above $250 per ton of carbon (equivalent to about $30 on a barrel of oil), which is much higher than the taxes suggested by recent energy tax reform proposals, for instance by the EC or the Swedish Government. The taxes on some specific oil products, such as gasoline and diesel, are higher still. Over the 1980s the amount of taxes paid per ton of carbon has increased slightly in all OECD regions, mainly due to higher taxes on oil products used in the transport sector (Figure 5).

While before-tax prices per ton of carbon show less dispersion across countries than end-use prices, the variation is still large (Figure 3 and 4). In Japan and some European countries, before-tax prices are close to double the U.S. price, or even more. Part of the remaining difference is explained by the sectoral composition of fuel consumption. Energy prices for industrial and power generation users are lower than for households, reflecting lower distribution and marketing costs. Household natural gas prices, for instance, are in nearly all OECD countries more than double industrial and power generation prices. Countries which have a large proportion of gas consumed by households, such as the 70 per cent share in the United Kingdom, have a considerably
higher average pre-tax gas price than, for example, Canada where household gas accounts for 45 per cent of total consumption.

Remaining differences in before-tax prices mainly reflect aggregation across different fuel types, trade restrictions and other market imperfections. In the absence of very detailed data, the effect of these factors on end-use prices is difficult to quantify. Using the available partial information, an attempt is made to calculate the aggregate contribution of various non-tax distortions on energy prices. First, reference prices are calculated for each country, which ideally should approximate before-tax prices prevailing in a deregulated competitive environment (for details see the Annex). The difference between the before-tax price and this reference price represents the residual component. The residual component is a measure of the non-tax distortions in fossil-fuel markets. However, given the degree of approximation necessary for these calculations, the size of the residual component also reflects measurement error and includes differences in refining and distribution costs. For natural gas, distribution costs are likely to vary significantly across countries.

The resulting reference prices and residual components are shown in Figures 3 and 4. The deviations in reference prices across countries reflect differences in the patterns of fuel use. Countries with a high share of coal, for instance, tend to have a lower reference price, while countries with a high gas share tend to have a higher reference price. While negligible in the United States, Australia and the Netherlands,
Figure 5. The tax and total wedge between a reference and end-use price, by fuel type
1989 prices and exchange rates

Source: Estimates based on IEA data
MEASUREMENT ISSUES

Since the structure of existing energy prices and taxes influences the costs of greenhouse gases abatement, it is important to correctly measure both domestic relative energy prices and relative prices across countries.

There are several methods for making international price comparisons, each of which has weaknesses and strengths. If there are no differences in price levels for goods and services across countries, then domestic prices can be converted to a common currency by using the market exchange rate. The approach offers the advantage of being computationally straightforward. However, evidence from international price comparison surveys suggests that, when prices in different countries are converted into a common currency at market exchange rates, average price levels are not the same. Countries with lower levels of per capita income tend to have lower prices than high-income countries (Hill, 1986). If data were converted at market exchange rates, price levels would differ. In practice the prices of goods and services in some OECD countries are as much as twice as high of those found in other OECD countries and there are differences in the pattern of relative prices. The prices of energy goods relative to other goods or services can vary substantially among countries.

Purchasing Power Parities (PPPs) are exchange rates which equate domestic purchasing power among countries. Converting the relevant data with purchasing power parities adjusts for price level differences between countries and allows a true comparison of volumes. The differences between price and emission intensity conversions using 1989 exchange rates and PPPs are shown for four OECD regions in the following table. Among European countries (not shown) exchange rates are much lower than PPPs for Portugal and Spain and considerably higher for Switzerland, Sweden and Norway.

<table>
<thead>
<tr>
<th>Region</th>
<th>Price per ton of carbon</th>
<th>Price per ton of carbon</th>
<th>Emission intensity</th>
<th>Emission intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$US</td>
<td>PPP</td>
<td>$US</td>
<td>PPP</td>
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<tr>
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<td>194.5</td>
<td>291.0</td>
<td>292.6</td>
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<td>361.7</td>
<td>374.9</td>
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</tr>
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<td>Japan</td>
<td>394.5</td>
<td>334.1</td>
<td>92.5</td>
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</tr>
<tr>
<td>Other OECD</td>
<td>306.5</td>
<td>266.7</td>
<td>156.1</td>
<td>196.8</td>
</tr>
</tbody>
</table>

1. Relative energy prices related to relative output prices, defined as the US price multiplied by the ratio of energy PPPs to GDP PPPs
2. Kilos of carbon emitted per million dollars of output

the calculated residual components suggest that non-tax distortions may be large in some OECD countries. Indeed, in New Zealand and several European countries, the residual component is large compared with the tax wedge. For Japan, it is even larger.

A decomposition of the residual components by fuel for the major seven economies is provided in Figure 4. Apart from Japan and Canada, the residual component is
small for oil products, where price differences are mainly explained by taxation. The residual component for gas is large in Japan and the European countries. For coal, large residual components in Japan, Germany and the United Kingdom account for all end-use price differences, while the residual component is zero or close to zero in the other major economies. The residual component on coal has increased over the 1980s (Figure 5).

It would be instructive to be able to quantify the contributions of different government policies and other factors to the size of the residual component. This is only possible with detailed knowledge and data on government policies and market structures. Some information is available for the coal industry. Steenblik and Wigley (1990) have computed producer subsidy equivalents (PSEs) for Japan and several European countries. PSEs measure the assistance to producers as gauged by the value of policy-induced transfers from consumers and taxpayers to producers. Their estimates of subsidies and price support for coal producers per ton of carbon, as updated in IEA (1991), also suggest that support for coal industries per ton of coal has increased during most of the 1980s. In recent years, however, assistance levels have declined in some countries as energy policies are reviewed in the context of their environmental impacts. Despite large subsidies, price support measures have kept coal prices far above world market prices in most of these countries. A large part of the residual component for coal in Figure 4, therefore, reflects the cost of policies to sustain production from inefficient coal mines.5

For the other sectors, contributing factors are more difficult to identify and even more difficult to quantify. In oil product markets, a large residual component in Austria and Finland (not shown) may reflect monopoly rents of nationalised refiners,6 while in Japan import restrictions are sizeable.7 In most European countries, gas distribution is in the hands of public monopolies. Monopoly rents from current marketing arrangements in most European countries could equally be viewed as tax revenue from implicit, and less transparent, taxes on natural gas.8 Recently, the EC Commissioner for Competition Policy has asked member states to justify their gas import and export monopolies, arguing that deregulation of the U.S. gas market was a success and prices in Europe could be much lower if markets were liberalised. The International Energy Agency argues in a recent report (IEA, 1991a) that liberalisation of gas markets in Europe may not necessarily lead to the same results as in the United States because the industry structure differs considerably.9 In Japan more flexible gas contracts and closer sources of supply have considerably reduced the gas residual component over the 1980s.

II. ENERGY PRICES AND EMISSION INTENSITIES

Cost effectiveness of carbon abatement policies is achieved when the marginal cost of abatement is equalised across regions. The factors which contribute to differing marginal abatement costs include the fuel composition of energy demand, the intra-fuel
price elasticities of substitution, the aggregate energy price elasticity of substitution and the current level of energy prices. Clearly, an examination of price distortions in energy markets is relevant in any evaluation of the effectiveness and economic cost of abatement policies. A fuller treatment of these issues requires a more rigorous specification of the relationship between energy prices and emission intensities.

The links between prices, aggregate output and energy demand can be represented simply via an energy demand equation derived from a constant-elasticity-of-substitution (CES) aggregate production function, where total energy demand (EN) depends on the price of energy (\( p_{EN} \)) relative to the output price (\( p_o \)), output (Q), an elasticity of substitution (\( e \)) and a scale parameter (k):

\[
EN = k \cdot \left[ \frac{p_{EN}}{p_o} \right]^e \cdot Q
\]  

As carbon emissions are fixed in proportion to the type of fuel used, energy-related carbon emissions will depend on the same factors as those shaping the demand for energy. The impact of relative price changes on energy demand depends critically on the elasticity of substitution among production inputs. In addition, substitution possibilities among fuels also matter for CO₂ emissions because emission factors differ among fossil fuels. In order to capture these two channels of substitution effects, an aggregate price of fossil fuels per ton of carbon (\( p_c \)) is calculated, which depends on the amount of fuels used (\( F_i \)), emission factors (\( a_i \)) and the price of fuels (\( p_{EN} \)):

\[
p_c = \sum_i F_i p_{EN} / \sum_i a_i F_i
\]  

where the "i" subscripts represent the seven fuels covered in this study – gasoline, diesel, light fuel oil, heavy fuel oil, natural gas, steam coal and coking coal. Price and volume numbers are further disaggregated into end-use by households, industry and electricity generation (see the Annex for detail).

Using relationships [1] and [2], one can infer the emissions of carbon (C) directly as a function of relative prices and output:

\[
C = l \cdot \left[ \frac{p_c}{p_o} \right]^e \cdot Q
\]  

Apart from prices, emission intensities are likely to be influenced by endowment, as with hydroelectric energy, and energy policy, as with nuclear energy. Other factors may also play a role: population density, urbanisation, climate and the stringency of energy efficiency or environmental regulations. While it is impossible to construct economy-wide summary measures for the stringency of regulations, proxies for the other variables exist.

An emission function like [3] has been estimated for 1988 across 20 OECD countries, with relative prices and output being based on PPPs. Correctly signed coefficients capturing factors other than relative prices and activity which were significant could only be found for the combined ratio of hydro and nuclear energy in total primary energy (HN). In the following regression energy prices relative to the United States are related to the output price levels relative to the United States and output is measured in PPPs:

\[
\ln C = -3.3 - 0.75 \ln \frac{p_c}{p_o} + 0.95 \ln Q - 1.53 HN \quad S.E.E. = 0.19
\]

\[
(-2.9) \quad (-4.9) \quad (28.1) \quad (-4.9) \quad R^2 \text{ adj} = 0.98
\]
Equation [4] suggests that relative energy prices have had a considerable influence on emission levels and that carbon taxes could be a useful policy lever to influence future emissions. The relationship presented in equation [4] is, of course, a partial equilibrium relationship. Scenarios of future emission abatement would need to be assessed in a full general equilibrium framework such as OECD's GREEN model (Burniaux et al., 1991).

Based on equation [4], the partial relationship between emission intensities and prices per ton of carbon is depicted in Figure 6. In order to plot the relationship between carbon intensity and prices, the coefficient on output has been restricted to one and an adjustment made for the average contribution from the hydro and nuclear energy share (HN). It shows that countries with a relatively low price per ton of carbon (e.g. the United States, Canada or Australia) have a high emission intensity, while the reverse is true for countries with a high price (Italy or Portugal). The share of carbon-free energies is also important. Countries with a high share of hydroelectric or nuclear power, such as France, Norway, Sweden and Switzerland are clearly to the left of the curve.

Figure 6. Prices per ton of emission and emission intensities
(Dollars 1988)

Source: Estimates based on IEA data
Note: The relationship between carbon intensity and prices is adjusted for the average contribution from the hydro and nuclear energy share (HN). This affects in particular France, Norway, Sweden and Switzerland.
III. CARBON TAXES AND THE PRICING OF ENERGY

Differences in the current level of relative energy prices are an important determinant of differences in emission intensities across countries. Two questions arise in this context:

a) How do existing taxes affect the cost of abatement?
b) Should current energy policies be changed before the imposition of a carbon tax, or should the tax be simply put on top of current prices?

As is well known, the deadweight cost due to a tax or tariff increases with the square of the tax or tariff rate, if the demand schedule for a good is linear and supply perfectly elastic. Hence, small taxes often have negligible economic cost, while the cost for large taxes increases disproportionately. Furthermore, the combined impact of two taxes on the same product is not just the sum of the individual deadweight losses, but could be much larger (Newbery, 1990).

The interaction between a carbon tax and current energy taxation can be illustrated in a simple way, as shown in Figure 7 (see also Newbery, 1992). Assume that two countries of about the same size impose an equal amount of carbon constraint and that the derived demand curve for carbon is the same for both countries. In country A, fuels are not taxed and the price $P_A$ is associated with emissions $C_A$. In the other country, fuels are taxed at $T_{FB}$ and the after-tax price $P_B + T_{FB}$ is related to emissions $C_B$. If emissions are then to be reduced by similar amounts in both countries ($C_B - C_B^* = C_A - C_A^*$) the carbon constraint will require two very different levels of carbon tax, $T_{CA}$ for one country and $T_{CB}$ for the other. In order to achieve the emission constraint, $T_{CB}$ is larger than $T_{CA}$, because for a given elasticity of energy demand the absolute price increase must be larger in order to increase energy prices by the same relative amount.\footnote{11}

The average cost of emission reductions in terms of loss of consumer surplus is measured by the shaded area $\text{ABC}$ in the case of country A. For country B, with an existing tax, the corresponding cost is measured as the difference in the cost of both taxes (EGA) less that attributed to the "current" tax (ADH), which is equal to area DEGH and not the smaller area DEF. The existing tax therefore amplifies the cost of imposing the carbon tax. In the case of a linear demand schedule, a carbon tax of the same size as the existing tax would approximately quadruple the cost, as the economic cost rises at the square of the tax rate. With a unitary demand elasticity, cost would increase at less than the square of the tax rate, but still more than proportionately. In the case of subsidies to energy production or use, the argument is reversed. Up to the world market price a carbon tax would not impose a cost to the subsidising country, but rectify an existing distortion (Shah and Larsen, 1991). Apart from OECD's GREEN model, global models have not taken account of existing distortions in calculating the average cost of emission abatement (see Burniaux et al. in this volume for more details). In many of these global models costs in developing countries are large even though energy prices are far below world market prices (Dean and Hoeller, 1992).

A further question arises as to whether current taxes on energy are mainly revenue raising or regarded as user charges for road use, construction, congestion or other
externalities. If they were the result of user charges set at the "right" level, then the economic cost would indeed be equal to the area of triangle DEF, since the remaining "cost" component (FDHG) would be offset by a compensating improvement in social welfare. At issue is what proportion of existing fuel taxes can be regarded as a tax on road use and congestion as opposed to raising revenues or protecting domestic production. In the United States, for instance, excise, transport fuel and vehicle taxes are paid into a road fund in order to finance road expenditure. In most European countries, such taxes are much higher, yet even higher taxes may be justified if account is taken of the capital cost of the road network, congestion costs and the cost of other externalities (Newbery 1988 and 1990a). On the other hand, the current way of collecting user charges by fuel taxes may be very inefficient in minimising the cost of road maintenance and construction and in its way of charging for congestion (Winston, 1991).

Current taxation of fossil fuels may also reflect an attempt to internalise other externalities from energy use, such as curbing the incidence of acid rain. However, this is not apparently the case, as coal and heavy fuel oil, the "dirtiest" fuels — not only with respect to climate change — are often untaxed or taxed relatively lightly in most countries, or even subsidised.

Since there is some complementarity between carbon dioxide and other airborne emissions, a reduction in carbon dioxide emissions will also reduce other damaging emissions. The complementarity of policy instruments, such as carbon taxes, underlines the necessity for comprehensive abatement strategies. But whereas carbon is
emitted in relation to its chemical composition, other greenhouse gasses, like NO, depend on the combustion process and location. Ideally, all GHG should be included in a global warming abatement policy. However, practicalities might make immediate complete coverage overly complicated and ineffective. A more realistic approach would be to design an efficient framework for policy and to build onto this framework incrementally. As such, the Montreal protocol is an example of this approach with amendments adding new chemicals to the list of controlled substances.

It is clearly difficult to judge the appropriateness of current energy pricing across the OECD Member countries. It is evident, however, that policy should not necessarily aim at a level playing field in terms of energy product prices as the incidence of externalities shows large regional differences and road financing schemes also differ widely. There seems, however, to be considerable scope to improve current transport policies, energy policies and environmental policies. Some of these changes could have large effects on the price of different fuels and reduce carbon dioxide emissions considerably. They would enhance welfare, even excluding the reduced risk of any future damage from climate change.

IV. RECENT REFORM PROPOSALS AND POSSIBLE EFFECTS

A. Recent policy changes and proposals

Tax systems in many industrialised countries are undergoing changes which reflect a growing public awareness of the externalities of fuel consumption. Carbon-related taxes have recently been introduced in Denmark, Finland, the Netherlands, Norway and Sweden. The Swedish carbon tax – at approximately $190 per ton of carbon – is the largest so far. However, existing energy taxes on oil products were halved and a carbon tax was introduced such that final oil prices were unchanged. The carbon tax is also levied on gas and coal. The energy tax on oil products is motivated by externalities from oil product use even in the absence of climate change. However, the tax rate for industry and commercial horticulture is one quarter of the general rate and there are thresholds for total tax payments by industry. Energy tax reform in Sweden was also more comprehensive. For example, a charge on the sulphur content of fuel oil and coal was imposed at the same time. The effect on carbon emissions from the tax is, however, likely to be small as oil product prices are little affected and the use of gas and coal represents less than 10 per cent of total energy needs.

The broader proposal by the EC to introduce progressively an energy-cum-carbon tax starting at $3 per barrel of oil and rising to $10 by the year 2000 (roughly equivalent to $80 per ton of carbon), is – if adopted – also likely to exclude energy-intensive industries. As the tax seems unlikely to achieve the EC's commitment to stabilise emissions by the end of the decade at the 1990 level, such a proposal is only part of a larger package of policy measures ranging from larger spending on research and development programmes to changes in the regulatory framework (Commission of the European Communities. 1991)
The United States Government does not have a specific target for carbon dioxide emissions, but is committed to stabilise all greenhouse gas emissions by the year 2000 at the 1990 level. This can largely be achieved by phasing-out chlorofluorocarbons (CFCs) and the Clean Air Act Amendments of 1990 and recent measures proposed in the National Energy Strategy are also likely to reduce other greenhouse gas emissions. Such measures, like the new trading scheme for sulphur emissions, tighter energy efficiency regulations and increased use of renewables and nuclear energy all fit into the U.S. Government's policy approach: only those measures which also have benefits for other reasons than just alleviating the greenhouse effect are pursued (OECD, 1991).

The Japanese Government is committed to stabilising emissions in per-capita terms. While there are no concrete plans for action, Japanese emission scenarios show that this could be achieved by the expansion of nuclear and other non-fossil fuel sources (MITI, 1991).12

B. Evaluating the effects of restructuring energy taxes

Most studies which analyse the imposition of carbon taxes assume that existing energy taxes do not change. One advantage of the method used to compute the data base underlying this paper is its scope to analyse the impact of reforming existing taxes, adding new energy taxes or a combination of the two. In all countries where a carbon-related tax has been introduced, existing energy taxes have indeed been reformed at the same time. It is clearly important, therefore, to understand the differing impacts from adjusting current energy taxes compared with imposing new taxes.

To help quantify the differences entailed a small, highly simplified energy demand system based on the translog cost function originally developed by Christensen et al. (1973) is employed.13 Using such a function, fuel-cost share equations can be derived in which fuel shares depend on own-prices and the prices of other fuels, as follows:

\[
S_o = A_o + b_{o.o} \ln P_o + b_{o.g} \ln P_g + b_{o.c} \ln P_c - (b_{o.o} + b_{o.g}) \ln P
\]

[5]

\[
S_g = A_g + b_{g.o} \ln P_o + b_{g.g} \ln P_g + b_{g.c} \ln P_c - (b_{g.o} + b_{g.c}) \ln P
\]

[6]

\[
S_c = A_c - (b_{c.o} + b_{c.g}) \ln P_o - (b_{c.o} + b_{c.g}) \ln P_c + cc \ln P
\]

[7]

where \(cc = S_o + (b_{o.c} + b_{g.c}) \ln P_o + (b_{o.c} + b_{g.c}) \ln P_c - A_c/\ln P\)

[8]

and \(o, g, c\) stand for oil, gas and coal respectively.

Adding-up conditions are also imposed \(i.e.:\)

\[
A_o + A_g + A_c = 1, \quad b_{o.g} = b_{g.o}, \quad b_{o.c} = b_{c.o}, \quad b_{g.c} = b_{c.g}
\]

and \(b_{o.o} + b_{g.g} + b_{c.c} + b_{o.g} + b_{g.c} + b_{c.o} + b_{o.c} + b_{g.g} + b_{c.c} = 0.\)

in order to have a well behaved demand system.

Such a model does not allow substitution between fossil fuels and non-fossil fuels. But it is unlikely that a massive non-fossil fuel expansion could take place in response to price changes during the next 15 to 20 years. The framework is partial equilibrium and comparative static and, as such, is unable to shed light on economy wide effects and on the path of adjustment.
The price, quantity and tax data are the same as presented in Section I for the year 1988, but are now expressed in tons of oil equivalent. The relevant parameters were based on a limited survey of the literature. Country-specific elasticities depend on actual fuel shares. The higher the fuel shares are, the lower the cross-price elasticities are and vice versa.14 Evaluated at the average OECD fuel shares, own-price elasticities are -0.4, -1.3 and -0.9 for oil, coal and gas respectively, while cross-price elasticities are all positive. A substitution elasticity of 0.75 is assumed between aggregate energy and other inputs.

Within this framework four scenarios have been evaluated:

a) replacing existing taxes on oil, gas and coal by the current average implicit carbon tax in each country;

b) the same tax changes in case a) but with an additional $80 carbon tax (equivalent to about $10 per barrel of oil);

c) an $80 carbon tax but with existing taxes unchanged;

d) a combined carbon/energy tax of $40 per ton of carbon and $33 per ton of energy with existing taxes unchanged; this roughly corresponds to the amount by which taxes would be increased in the EC's proposed tax changes.

These simulations do not mimic current tax reform proposals one-to-one but rather capture the key elements of energy tax reforms.

The first of these scenarios examines the potential to achieve emission reductions at the same ex ante tax level by changing the existing tax structure. Currently, most OECD countries tax oil products relatively more than gas and leave coal largely untaxed. Country-specific results therefore, differ fairly widely and a priori an increase in emissions cannot be excluded altogether. Whether, for example, emissions from fuels with a low carbon content increase or decrease would depend on the initial price and tax levels on gas and other fuels. The second scenario is compared with the first simulation rather than with the base case, so that changes in the composition of energy consumed due to a realignment of existing taxes are abstracted from. The tendency will be for a substitution away from coal and oil towards gas, the magnitude of the shift depending on the initial price levels of fossil fuels and the elasticities of substitution.

Aggregate results for the OECD area are summarised in Table 1. On this basis replacing current taxes on fuels by country-specific average carbon taxes increases the OECD-wide average energy price by 8 per cent. The restructuring of end-use prices favours oil products, which are currently the fuels most heavily taxed in all countries. The average price of oil falls by about 15 per cent, whereas gas and coal prices increase by 16 and 69 per cent respectively (Table 2). As a result, the composition of fossil fuels in energy demand moves to being less coal and gas intensive and CO2 emissions are 12 per cent lower. The average carbon intensity (the ratio of carbon emissions to energy use) falls from 0.83 to 0.79 and fuel substitution contributes 4 percentage points to the area-wide decrease in emissions. Less tax revenue is produced, despite higher prices, compared with the current tax regime. Replacing existing taxes with a pure carbon tax more than halves the economic cost15 to 0.1 per cent of GDP. The reduction in economic cost mainly occurs because of a reduced dispersion of fuel-specific tax rates. The finding is in line with a large number of studies which have shown the beneficial effects resulting from a reduced dispersion of statutory tax rates or tax exemptions.16
<table>
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<th>Per cent change in</th>
<th>$ tax per</th>
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</tr>
<tr>
<td>$80 carbon tax add-on</td>
<td>-28.7</td>
<td>41.2</td>
<td>75.4</td>
<td>171.4</td>
<td>134.2</td>
</tr>
<tr>
<td>Half energy/half carbon tax</td>
<td>-28.2</td>
<td>41.5</td>
<td>77.7</td>
<td>172.6</td>
<td>136.2</td>
</tr>
</tbody>
</table>

1. Percentage point contributor to the change in emissions.
2. Expressed as a percentage of GDP
3. Per cent changes are computed using the carbon tax scenario as the base.
### Table 2. Energy price and emission changes

<table>
<thead>
<tr>
<th></th>
<th>Change in prices</th>
<th>Change in emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oil</td>
<td>Gas</td>
</tr>
<tr>
<td><strong>Carbon tax</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>-12</td>
<td>12</td>
</tr>
<tr>
<td>Other OECD¹</td>
<td>-19</td>
<td>23</td>
</tr>
<tr>
<td>OECD</td>
<td>-15</td>
<td>16</td>
</tr>
<tr>
<td><strong>Carbon tax equivalent plus $80 carbon tax add-on²</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>24</td>
<td>23</td>
</tr>
<tr>
<td>Other OECD¹</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>OECD</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td><strong>$80 carbon tax add-on</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>5</td>
<td>31</td>
</tr>
<tr>
<td>Other OECD¹</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>OECD</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td><strong>Half energy/half carbon tax</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America</td>
<td>26</td>
<td>37</td>
</tr>
<tr>
<td>Other OECD¹</td>
<td>15</td>
<td>24</td>
</tr>
<tr>
<td>OECD</td>
<td>20</td>
<td>32</td>
</tr>
</tbody>
</table>

---

1. Other OECD includes Greece, Iceland, Luxembourg and Turkey.
2. Per cent changes are computed using the carbon tax scenario as the base.

The second simulation examines the effects of replacing existing taxes by the implicit carbon tax equivalent (as in the first simulation) and adding a further $80 per ton of carbon tax. To isolate the impact of the additional carbon tax the results are compared with case a. Average energy prices increase 24 per cent. The composition of the price changes is markedly different from case a. The gas price increases by 20 per cent, slightly more than the average oil price increase. The price of coal, the high carbon and low-cost fuel, increases by 59 per cent. The improvement in the relative competitiveness of gas encourages a switch from both coal and oil into gas. The carbon intensity declines further to 0.78 and the economic cost is 0.5 per cent of GDP.

The third case – an increase in current end-use prices by an $80 tax per ton of carbon – is applied to all 20 countries. This is approximately equivalent in aggregate to a doubling of average existing energy taxes. The major source of emission reductions is an average 41 per cent increase in end-use prices. Although the carbon tax imposes a larger wedge on oil and coal vis-à-vis gas, the current energy tax base is predominantly on oil. As a consequence, the price level of oil is greater than gas or coal for a unit of heat. The percentage price increases from the imposition of an $80 carbon tax are therefore lowest for oil. Fuel substitution contributes 3.9 percentage points to the 29 per cent aggregate reduction in emissions. The reductions are largest in those countries with low prices before the tax imposition and with a high share of coal.
The fourth scenario examines the effects of maintaining existing taxes and adding a combined carbon/energy tax such that the total tax increase is the same as in the third scenario. Here the carbon tax is set at $40 per ton of carbon and the energy tax at $33 per ton of oil equivalent raising the average energy price by 41 per cent. However, the gas price is higher and the coal price lower than under a carbon tax (Table 2), because such a tax takes less account of the different carbon content of these fuels. For this reason the substitution effect is smaller, although the difference in the reduction in emissions (in both cases close to 28 per cent) is negligible. The economic cost for cases c) and d) are insignificantly different from each other at 0.65 per cent of GDP, but are higher than in case b) where existing energy prices have already been put onto a carbon basis before the introduction of the new carbon tax.

These results suggest that both emissions and the economic cost of taxation could be reduced by a realignment of existing taxes to better reflect the externalities associated with fossil-fuel consumption. Welfare gains will, however, also depend on the extent to which energy taxes reflect other externalities associated with fossil-fuel consumption. In the first case – switching existing energy taxes to a carbon basis – aggregate energy prices change only marginally and both emissions and the economic cost of taxation fall. The aggregate price movement masks considerable compositional changes. Because the existing energy tax base falls almost solely on oil products, leaving coal and gas largely untaxed, the reform package actually decreases average oil prices. The change in relative prices motivates substitution from coal and gas (the lowest carbon-emitting fossil fuel) into oil. The substitution effect from scenario a) is, therefore, partly weakened by this switch from gas into oil. The direction of the substitution effects usually expected from a carbon tax only show up in scenario b) where a carbon tax is added after environmental tax reform.

V. SUMMARY

The challenge to policymakers responding to global warming is to design a flexible policy framework capable of efficiently reducing the concentrations of greenhouse gases in the atmosphere. The analysis is complicated by the different radiation effects of GHGs, their average atmospheric lifetime, the presence of sinks, distributional effects, different baseline scenarios, etc. This paper has necessarily avoided much of this detail by limiting its scope to analysing conceptual issues and the importance that existing conditions play in determining the effectiveness and eventual design of a carbon tax. In terms of the four questions initially posed:

Variations in energy prices. End-use prices show a large variation across countries, with the degree of variation also depending on whether current exchange rates or purchasing power parities (PPPs) are used to convert domestic price levels into a common currency. For example, the average relative energy price in countries with high output price levels, such as Japan, is 15 per cent lower using PPPs than when prices are converted with market exchange rates.
Energy taxes account for a large part of the differences in end-use energy prices among countries and between fuels. The current implicit average taxes on the carbon content of energy vary from as little as $28 per ton of carbon in the United States to over $200 per ton in France, Italy and Sweden. There is, however, also some variation in before-tax prices. For instance, coal prices in Germany are three times higher than in the United States. In order to estimate the size of non-tax distortions, a residual component is calculated for each fuel as the difference between the before-tax price and a so-called "reference price", which ideally should reflect prices in competitive markets. The estimates presented here suggest that non-tax distortions are large for most energy products in Japan, for natural gas in Europe and for coal in European coal-producing countries.

Carbon taxes and energy pricing. Carbon taxes should be added to after-tax energy prices, if current energy taxes are the most efficient way to charge for road use, (i.e. set at the right level to charge for congestion and externalities resulting from airborne emissions). Whether optimality is achieved in practice is very difficult to judge but there seems considerable scope to better integrate energy, transport and environmental policies.

Recent policy changes and proposals. Many governments are currently proposing changes to their energy tax systems in order to bring them more into line with the perceived externalities of fuel use. Denmark, Finland, the Netherlands, Norway and Sweden have already introduced carbon taxes, and European Community (EC) governments are discussing a proposal by the Commission for a combined carbon-cum-energy tax. In the United States, where the government espouses a "no-regrets" policy, the recent Amendments to the Clean Air Act and proposals in the National Energy Strategy are likely to help reduce CO₂ emissions.

Restructuring taxes. Simulations with a simple energy demand system are used to show the likely effects of proposals to change the tax system on emissions, energy prices, tax revenues and carbon intensity.

The treatment of existing fossil-fuel taxes is shown to be an important determinant of the simulation results. Replacing existing taxes by a carbon tax, for instance, might reduce CO₂ emissions by 12 per cent. One reason for the rather small contribution from tax reform is the existing structure of end-use prices. The current implied average carbon tax equivalent across OECD countries is $70 per ton of carbon, of which oil contributes about 90 per cent. Moving from existing energy taxes to a carbon tax or hybrid carbon/energy tax would therefore imply an important switch in the taxation of different fuels, which would result in a fall in end-user oil prices and increases in coal and gas prices. Such a tax-switch policy would give an incentive to substitute from gas, a low carbon-content fuel, into oil, a higher carbon-content fuel, but would nevertheless penalise coal. On the other hand, the economic cost of taxing energy would be reduced because of a lower dispersion among fossil-fuel tax rates. Adding an $80 carbon tax after such a tax reform would, however, lead to the substitution effects normally expected (i.e. from coal and oil towards gas and non-fossil fuels). Finally, it is shown that the difference in terms of emission reductions, energy prices and economic cost, between a carbon and a hybrid carbon/energy tax is likely to be small.

The negative relationship between energy prices and emission intensities suggests that there is scope for a carbon tax as an effective instrument of environmental policy. In some countries, however, there could be scope to reduce both carbon
emissions and the economic cost of taxation by reforming the current tax and regulatory structure — a "no-regrets" policy. Given the uncertainty surrounding the timing, form and magnitude of the greenhouse effect, any abatement strategy should start with these policies. However, large cuts in carbon emissions are likely to require sizeable increases in fossil-fuel taxation.
NOTES

1. These are methane, nitrogen dioxide and chlorofluorocarbons. CO₂ is the most important greenhouse gas and 75 per cent of man-made CO₂ emissions arise from the burning of fossil fuels.

2. In 1989, the standard deviation on end-use price data was 84 compared to 46 for tax-exclusive prices.

3. Deviations in reference prices across countries also reflect, in a few instances, country-specific product prices below the reference price due to lower domestic transportation and distribution costs.

4. For the United Kingdom, the residual component on coal is substantially lower, if the actual import price and not the average import price for the European countries is used. The higher price reflects the lack of large bulk-handling import terminals, which itself is the result of past restrictions on imports of coal. The U.K. and Irish import prices are the only European import prices which differ substantially from the average.

5. The amount of assistance due to price support measures, as calculated by Steenblik and Wigley (1990), is smaller than the residual component calculated here. The difference largely stems from the use of different reference prices.

6. In mid-1991 the Finnish authorities relaxed import restrictions on oil products and since 1 January 1992 all import licences for fuel were abolished, effectively ending the monopoly structure on oil products. Since the changes gasoline prices exclusive of tax have come closer to the OECD average.

7. In Japan, a large amount of crude oil is burnt directly for power generation and is absent from the calculations. Since the taxation of crude oil is low, the inclusion of crude oil burnt directly would lower the non-tax residual component.

8. The regulated structure of the gas industry in Europe makes it extremely difficult to identify relevant gas prices since they are linked in many countries to the price of the nearest competing fuel. Indeed, published information is very patchy and is not necessarily representative of the marginal opportunity cost.


10. For the reference country, the United States, a relative aggregate energy price cannot be established. Concerning household expenditure the price level for heat and light was 15 per cent below the aggregate price level in 1985.

11. With a linear demand function TCa and TDb will be identical and if a slightly convex demand function exists TDb < TCa.

12. Nuclear energy does, however, have other problems related to disposal of hazardous wastes.
13. This approach has frequently been used. See, for example, Griffin (1977) who analyses fuel substitution in the power-generating sector, or Hogan (1989) who uses it to analyse inter-fuel substitution in the United States and Japan.

14. $\sigma_i = (b_i + S_i)/(S_i)$  
   $\sigma_i = (b_i + S_i - S_i)/(S_i)$

   $i, j = \text{coal, gas, oil for } i \neq j$

   $i = \text{coal, gas, oil}$

   For a derivation see Berndt and Wood (1975).

15. For small price changes, the economic cost of taxation is approximated by the Harberger triangle:

   $W = \frac{1}{2} t \Delta E$

   where $W$ represents economic costs, $t$ the tax and $\Delta E$ the change in energy consumption. Base energy consumption is computed from simulating the removal of existing energy taxes. If

   $\Delta E = (vP_v) u E_v$ then

   $W = \frac{1}{2} t^e u E_v/P_v$

   where $P_v$ and $E_v$ are baseline prices and energy consumption respectively, and $u$ is the price elasticity of energy demand.

   Note that the calculations are partial in nature and the assumptions for computing Harberger triangles need to hold. If energy supply prices fall, for instance, because of the imposition of carbon taxes, there could be a welfare gain for energy-importing countries and a loss for energy producers.

16. See, for example, Shoven and Whalley (1984) and Hagemann et al. (1988).
Annex

DATA CONSTRUCTION METHODS

The database underlying the tables, charts and simulation scenarios have been constructed from IEA energy price and tax data. Price and tax numbers are subdivided into three sectors: industry, households and power generation. Included within industry are the products heavy fuel oil, light fuel oil, diesel, natural gas, steam coal and coking coal. The household sector includes light fuel oil, gasoline and natural gas. Within power generation the three fossil-fuels oil, natural gas and coal are covered. Hydro, nuclear and other renewables are excluded from the analysis.

The price and tax data cover approximately 65 per cent of all commercial energy consumed in 20 OECD countries. Due to lack of data Greece, Iceland, Luxembourg and Turkey are excluded. There is variation in data coverage among countries largely depending on the relative share of nuclear and hydro in total energy consumed. For France, a significant nuclear producer, the coverage is slightly less than 50 per cent whereas in Italy it is around 80 per cent. Among fossil fuels under-coverage is mainly in the business sector. Price data are not available, for instance, for agriculture, service sectors or railways.

Tax numbers include excise taxes and VAT for households. A split between household and business consumption of diesel and gasoline consumption is not possible. The calculations assume that all gasoline is consumed by households (includes VAT) and all diesel is used by businesses (excludes VAT). For the United States, local taxes on fossil-fuel use are not available in IEA Energy Prices and Taxes. Small import duties in Austria, Finland and Portugal are not taken into account. In a few instances, such as taxes on natural gas for residential use in the United States, taxes on steam coal for industrial use in Canada and taxes on natural gas and steam coal for electricity generation numbers were not available. In these cases a zero tax was assumed. In other cases where tax or price numbers were not available an estimate has been made.

Reference prices for each of the fuels are based on world market prices or prices close to world market prices. For oil products the simple average of U.S. and German domestic prices are employed. Both countries have a deregulated domestic market and imports are not constrained. For coal, the European import price is taken as a benchmark. For natural gas in power generation a price somewhat above the pipeline price is used. For households and industry an average of the low price countries is employed. In the case of Japan which consumes mostly liquefied natural gas sourced from distant producers the reference prices are adjusted upwards to account for the additional transport and revapourisation costs. When a domestic price is lower than the reference price the lower price is taken.

In order to estimate end-use prices each products pre-tax numbers are the starting point. Taxes are then added on. This implies that the products not included are assumed to have a zero tax rate. This is likely to provide a good approximation for end-use prices as under-coverage of products is mainly in the business sector.

All quantity data is originally expressed in terms of tons of oil equivalent. To compute pre-tax prices per ton of carbon equivalent expenditure on a specific fuel is divided by the carbon emitted by the consumption of that fuel. The following emission factors were applied to the TOE data:
<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Fuel Oil</td>
<td>0.89</td>
</tr>
<tr>
<td>Gasoline</td>
<td>0.81</td>
</tr>
<tr>
<td>Diesel</td>
<td>0.84</td>
</tr>
<tr>
<td>Light Fuel Oil</td>
<td>0.84</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.60</td>
</tr>
<tr>
<td>Steam Coal</td>
<td>1.09</td>
</tr>
<tr>
<td>Coking Coal</td>
<td>1.09</td>
</tr>
<tr>
<td>Peat</td>
<td>1.23</td>
</tr>
</tbody>
</table>

As under-coverage is likely to be of little importance for tax data, tax revenue is directly related to IEA emission numbers and pre-tax prices and taxes per ton of carbon added to form the end-use price per ton of carbon.

End-use prices are converted into a common currency by the U.S. market exchange rate, GDP PPPs and energy PPPs. The energy PPPs are calculated using the price and quantity data detailed above in the same manner as the GDP PPPs. For a description of how PPPs are estimated see OECD (1987).
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