Cambridge Working Papers in Economics CWPE 0508

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Why Tax Energy?

Towards a More Rational Energy Policy

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CMI Working Paper 72

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CMI Working Paper Series

Why tax energy? Towards a more rational policy

David M Newbery[*]

The same fuels are taxed at widely different rates in different countries while different fuels are taxed at widely different rates within and across countries. Coal, oil and gas are all used to generate electricity, but are subject to very different tax or subsidy regimes. This paper considers what tax theory has to say about efficient energy tax design. The main factors for energy taxes are the optimal tariff argument, the need to correct externalities such as global warming, and second-best considerations for taxing transport fuels as road charges, but these are inadequate to explain current energy taxes. EU energy tax harmonisation and Kyoto suggest that the time is ripe to reform energy taxation.

JEL: Q4, Q48, H21, H23, L71, R48
Key words: tax, energy, oil, optimal tariff, externalities, exhaustible resources, global warming, road charges

INTRODUCTION

Fossil fuels are exhaustible resources that are the prime human contributor to the stock pollutant, carbon dioxide (CO_2), the main greenhouse gas. Oil reserves are concentrated in geo-politically sensitive countries, and managed, with varying degrees of success, by the OPEC cartel. Oil price shocks have global macroeconomic significance and oil is essential for transport, which in turn is essential for modern economies. Domestic energy consumption is income inelastic, and so its cost bears relatively more heavily on the poor than the rich, leading to political concerns about "fuel poverty".[1] Coal has lost its earlier dominance to oil and increasingly gas, but continues to employ large numbers of well-organised labour in many countries. Coal has higher damaging pollutants per unit of energy than other fuels, and has been put under further pressure by the trend to address emissions through market instruments. The European Emissions Trading System (ETS), which has been trading forward CO_2 allowances since 2003, is perhaps the best example. At its start date, the 2005 carbon price quoted on the ETS would increase the ten-year average cost of imported coal by 60%.[2] Coal, oil and gas are important fuels in electricity generation, but are taxed at very different rates, while nuclear power and renewables are carbon-free, but will be affected by the design of the ETS, and already attract various subsidies.

For all these reasons, energy is a politically sensitive subject, and at various times most countries have felt the need to articulate (or redefine) an energy policy. In a market economy the natural expression for such a policy lies in the various taxes and subsidies that

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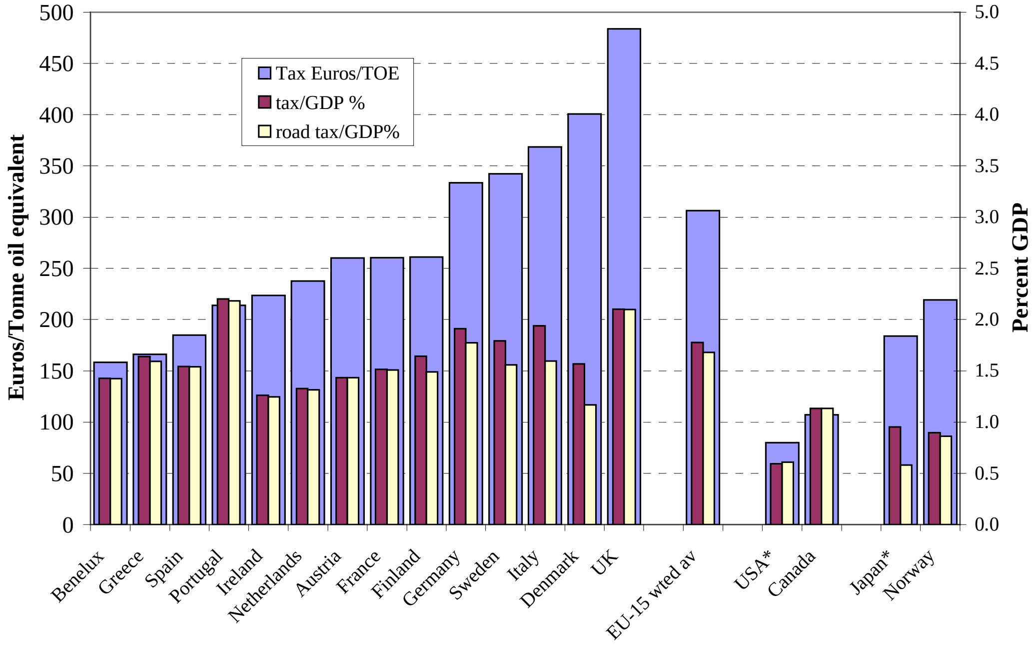
[*] Professor, Faculty of Economics, University of Cambridge, Sidgwick Avenue, Cambridge, England CB3 9DE (E-mail: dmgn@econ.cam.ac.uk). This paper is a very modest adaptation of a paper of the same title to be published in the *Energy Journal* in July 2005, but stressing the importance of energy taxes for the electricity sector. I have drawn heavily on joint work with Larry Karp, to whom I am greatly indebted, and also for his calculations on carbon taxes. I would also like to thank Toke Aidt, Denny Ellerman, Hill Huntington, Colin Rowat and Campbell Watkins for comments on and help with the paper, with the usual disclaimer.

[1] The UK *Family Expenditure Survey* for 2000/01 shows expenditure of gas and electricity as 6.1% of total expenditure for the bottom quintile of the income distribution, and 1.9% for the top quintile.

[2] The EUA price for delivery in Dec 2005 started at 8.4 €/tCO_2 = 31 €/tC, and the average c.i.f. price of coal into Western Europe was 34 €/tonne.

impact on energy production and consumption decisions, although licenses, standards and regulation also play an important part. Given the diversity of concerns, it is perhaps not too surprising that energy taxes are so variable, across fuels, countries and over time. The question this paper addresses is whether the basic principles of public finance can introduce some order and rationality into to discussions of how energy taxes might rationally be set. That is not to deny that changing taxes is always politically fraught, and different polities will find some changes difficult, if not almost impossible. Nevertheless, the recent trend towards explicitly charging for external energy costs, through prices determined by emissions trading, requires a reconsideration of the pricing and taxation of energy, where such principles may provide better guidance than past ad hoc interventions. Positive theories of instrument choice can go some way in explaining the observed trend from command and control to tradable permits or taxes (e.g. Aidt and Dutta, 2004), and the conditions likely to favour tax instruments, and they support the pressure for a more rational approach to the choice of instruments as environmental standards become increasingly demanding.

Figure 1 Taxes on oil and oil products, 2002



Note: * 2001 data

Sources: EU countries: *EU Excise Tax Duty Tables* 2003; others: OECD *Environmentally Related Taxes Database*, 2003; oil from OECD: *Energy Balances for OECD Countries 2000-2001*

Evidence that there is remarkably little agreement on how heavily energy should be taxed is readily available. There is a wide divergence in taxes on the same fuel in different countries and also on different fuels within each country. Figure 1 shows the variation in oil taxation across various OECD countries in the tax per tonne oil equivalent (TOE) in 2002.[3]

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[3] The data for EU countries are comparable, but data for the four countries at the right come from a different source, which for EU countries seems to understate tax revenue on oil as a base (perhaps

The average EU tax was 306 €/TOE but the coefficient of variation (CV) was 33%. To put the level of taxes into perspective, oil product prices in 2002 (spot Amsterdam) were about 200 €/TOE (190 $/TOE), although they were about 250 €/TOE (230$/TOE) in 2000.[4] Figure 1 also shows the oil tax revenue as a share of GDP (reading on the right hand y-axis), where the EU-15 average was 1.8% (CV 21%), and on the same axis, the road fuel tax revenue as a share of GDP. In most countries oil taxation is overwhelmingly concentrated on road fuels.

Several points stand out from the empirical evidence. First, the weighted average share of energy taxes in total tax revenue in 2001 is about 5½%, a slight fall from the 6% in 1994 (OECD, 2003). (The simple arithmetic average across OECD countries was higher, at 7% of tax revenues in 2001, and 2.5% of GDP, reflecting the low energy tax rates in the largest country, the US.) Energy taxes are indirect taxes, and account for about one-fifth of indirect tax revenue in the EU-15. As such, energy taxes are fiscally important, and although they may appear modest compared to other major taxes, such as income taxes, energy tax *rates* can be extremely high – the average EU-15 oil tax *rate* in figure 1 in 2002 was 180% of the pre-tax (c.i.f.) price, although as the price of oil fluctuates more than excise taxes, the rate varies and was 115% of the pre-tax price in 2001.

Second, energy tax revenue is overwhelmingly oil tax revenue – 93% of all OECD energy tax revenue came from oil (OECD, 2003). The UK in particular stands out as having high oil taxes (essentially high road fuel tax rates). In the UK, real hydrocarbon tax receipts grew at 6.2% p.a. in the decade 1989-99, and accounted for 6.7% of total tax receipts by the end of the decade. They accounted for 20% of all indirect tax receipts (including VAT), and 46% of indirect taxes if VAT and import duties are excluded. Taxes on Light Fuel Oil (LFO) even for industrial uses (see figure 2) can be over 100% of the pre-tax price, while gasoline taxes were 180% in the EU-15 in 2002, and over 250% in the UK (figure 4). Rates were even higher in the period 1994-99 when oil product prices were lower. As the deadweight loss of a tax increases as roughly the *square* of the tax rate (for small rates of tax), such high rates are potentially very costly sources of revenue.

The variation of excise taxes for different fuels for the industrial sector is shown in figure. 2. Light fuel oil (LFO) stands out as heavily taxed in some countries, notably Greece and Portugal, presumably where there are difficulties in preventing tax evasion with the even more heavily taxed road diesel fuel, for which kerosene can readily be substituted. The same is true in Austria and Sweden where tax evasion might be less of a problem.[5] Heavy fuel oil (HFO) is relatively heavily taxed in the Nordic countries, and both Norway and Denmark appear to have the most uniform tax system across fuels, as the base is primarily carbon content.

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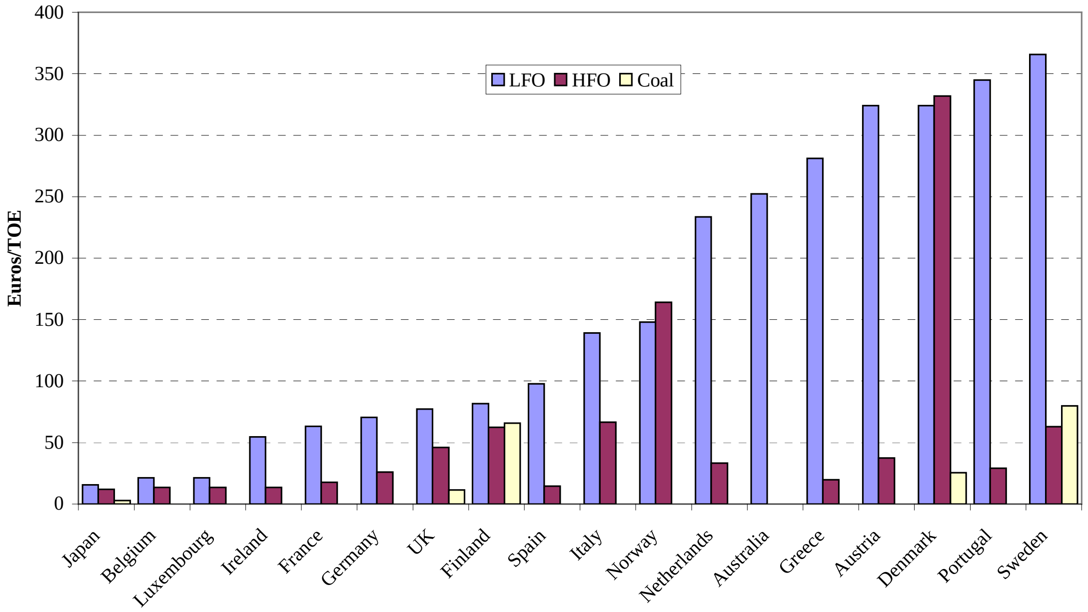
because revenue is allocated to the base, such as sulphur or carbon, and not then aggregated up to the carrier fuel). Conversion factors for products taken from BP (2004) and IEA (2004).

[4] Weighted average (by EU consumption) of light, middle and heavy distillate spot prices from IEA (2004), 1.09 TOE/tonne product.

[5] The rates for the same fuel in different uses often differs dramatically, and appears to account for discrepancies between the EU Excise source used here and IEA's *Energy Prices and Taxes*. For example Greece is shown in the IEA source as having an excise 21 €/'000 litres, while the EU source has 245 €/'000 litres for industrial commercial use and 21 for heating. Italy similarly sharply distinguishes between gasoil for industrial use, where its tax rate is 120 €/'000 l compared to 400 €/'000 l as a propellant.

Figure 2 Excise taxes on industrial fuels 2002 (€/TOE)

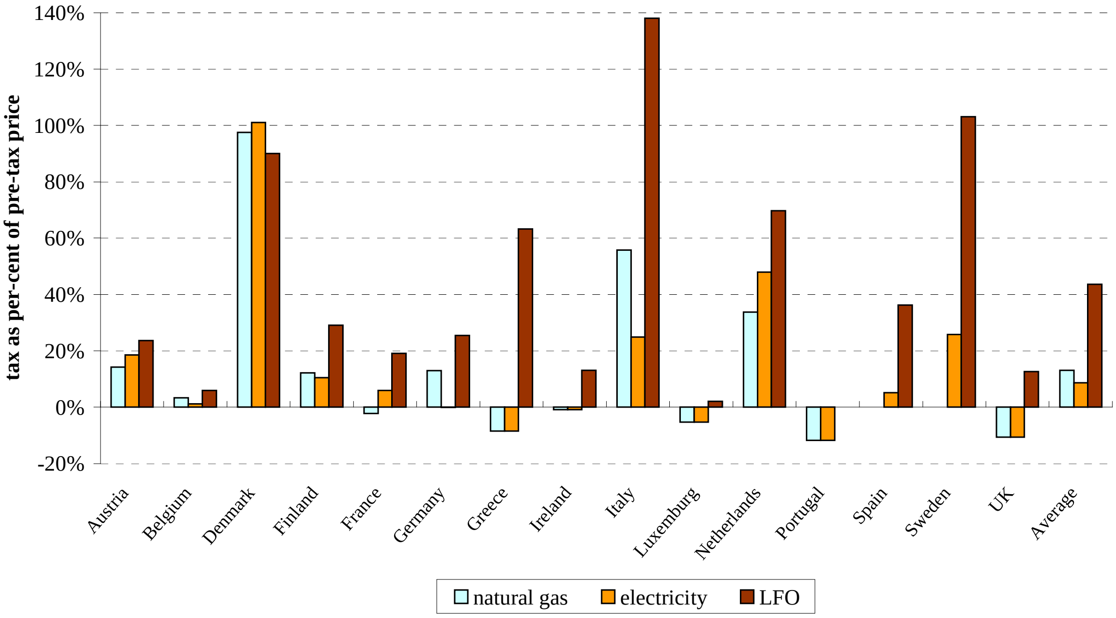


Source: EU countries: *EU Excise Tax Duty Tables* 2003; others: IEA *Energy Prices and Taxes 2004*

Figure 3 shows the effective tax *rates* (as a percentage of pre-tax prices) on fuel consumed in the domestic sector (excluding road fuel, which is shown in figure 4). The tax rates are net of the standard rate of VAT, and reveal that some countries like the UK effectively subsidize some (but not all) domestic fuels by subjecting them to a lower rate of VAT than for other normally taxed goods. Domestic LFO is primarily used for central heating, as is natural gas, but they are taxed at very different rates (except in Denmark), again probably to prevent tax evasion through fuel substitution. The variation across countries is considerably larger than for industrial use, as one might expect on efficiency grounds. The average tax rates are typically higher than for industry, again as expected.

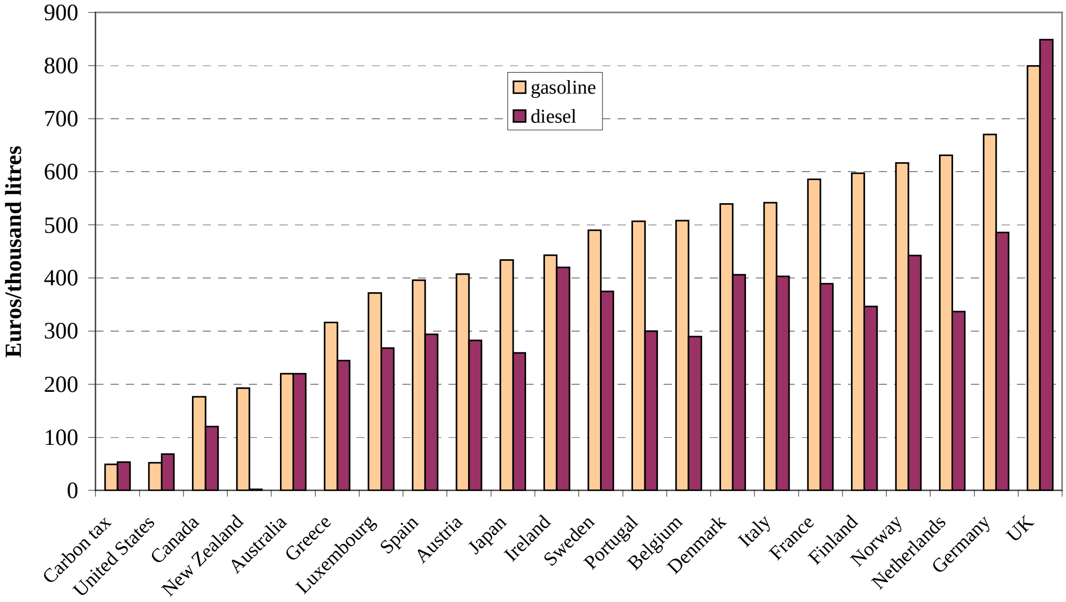
Figure 4 completes the picture by comparing taxes on road fuel ranked by gasoline taxes. The average EU gasoline tax rate was 180% of the pre-tax price, and over 240% for Germany and the UK. The average rate of diesel tax is slightly lower at 130% (but again over 240% in the UK). As figure 1 showed, road fuel taxes contribute the overwhelming proportion of energy taxes, and raise the greatest conceptual issues, as a considerable part of these taxes are more properly considered as road user charges. As such they will have to be considered along with other forms of road user charge, but even taking that into account it is hard to reconcile the variations in fuel taxes with corresponding variations in road user costs.

Figure 3 Effective tax rates on domestic fuels, EU 2002, net of standard VAT



Source: IEA *Energy Prices and Taxes 2004*

Figure 4 Road fuel excises 2002



Source: IEA *Energy Prices and Taxes 2004*

Most oil taxes are excise taxes at fixed rates per unit, rather than *ad valorem*, and so their rate as a percentage of the pre-tax price varies with the oil price, falling as oil prices rise and rising when oil prices fall. This may even be exaggerated by the consumer/voter resistance faced by tax authorities when oil prices rise, sometimes placing a cap on the nominal value of the tax per unit, and eroding both its real value and its rate. Conversely, governments find it easier to raise oil taxes when oil prices fall. Thus in $1994/barrel of oil and for OECD Europe, the absolute tax rose from \$26/bbl in 1981, when the pre-tax oil price (including refining and distribution) was \$63/bbl, to \$46/bbl in 1994 when the pre-tax oil price had fallen to \$23/bbl. The tax as a share of the pre-tax price thus rose from 41% in 1981 when oil prices were high to 200% in 1994 when prices were low (Austvik, 1997).[6] Such counter-cyclical taxing is even more likely in developing countries with state ownership of refining, where final fuel prices are set by the government. In such cases the distinction between explicit taxes and implicit charges collected as higher profits by the government as owner becomes obscured, but can amplify such counter-cyclical taxation. We shall need to investigate to what extent this variation is consistent with sound economic policies.

Several recent events have come together to suggest that the time is ripe to re-examine the logic (or lack of it) in the current patterns of fuel taxation. First, the European Commission is attempting to harmonize energy taxes within the EU, which has recently grown from 15 to 25 member states. Second, the Kyoto Agreement is attempting to achieve a unified and ultimately global approach to reducing greenhouse gas (GHG) emissions. Efficiency requires that each country and GHG source face the same charge per tonne of carbon dioxide equivalent, as the damage done is independent of where or how the GHG is emitted.[7] The Kyoto Protocol was finally ratified at the end of 2004, but even before that the European Commission has issued a legally binding requirement that member states meet agreed reduction targets and participate in a Europe-wide Emissions Trading Scheme (ETS). Trading started in January 2005, ensuring a uniform traded price for carbon dioxide (but not yet other GHGs) across Europe. Finally, market economies are increasingly attracted to using market-based instruments to address pollution, of which the ETS is a leading example.

The ostensible reason why the European Commission wishes to harmonize energy taxes is that the Commission is mandated to create a single market for goods and services, and to foster efficient trade within and between member states. That requires either removing tax distortions that fall on production, or harmonising their rates so that producers in each country face similar input prices. The great attraction of the Value Added Tax (VAT) is that it falls on final consumers and does not distort production decisions. Excise taxes, of which energy taxes are an important part, do not have that property, and hence there is pressure from the European Commission to harmonise their rates. We shall need consider whether there is a case for a positive level of excise taxes, for if not, then one might argue that tax competition between member states would put downward pressure on energy excise taxes, moving them closer to the "correct" level.

2. WHY IMPOSE ADDITIONAL EXCISE TAXES ON ENERGY?

Energy taxes are primarily input taxes, and as such fall on production as well as consumption. Standard tax theory (Diamond and Mirrlees, 1971) argues that distortions should be confined to final consumption, leaving production undistorted. In the absence of externalities or other market failures, that suggests that all indirect taxes should be Value Added Taxes (VAT).

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[6] For the total OECD region, including low tax countries such as the US, the tax rate rose from 27% in 1981 to 100% in 1994 as the pre-tax oil price fell by 50%. Sorenson (1999) gives figures for a slightly longer period, showing that the tax rate rose from 22% in 1980 to 96% in 1995..

[7] The damage done by different greenhouse gases differs in both its instantaneous impact and over its varying lifetime, but for any single gas the location of the source is irrelevant, in contrast to more local pollutants such as sulphur dioxide or nitrogen oxides.

Clearly, the energy taxes identified in the figures, which exclude standard rate VAT,[8] violate this precept, raising the question what market failures or externalities might account for these taxes.

There are four main economic reasons for energy excise taxes: as an optimal import tariff, to reflect and internalise external costs (mainly from pollution), as a second-best instrument for charging for transport infrastructure, and, more generally, as part of a second-best tax structure to improve the redistributive and/or efficiency properties of the remaining feasible taxes.[9] In practice, taxes on each fuel may reflect a mixture of these reasons, as well as the inertia of past politically expedient tax choices, but it is still useful to consider each argument separately, and then ask how far they are simply additive in setting the final excise tax. The optimal tariff and the externality arguments are particularly relevant to the EU agenda of energy tax harmonisation, as the EU is a trading bloc that collectively has more market power in international markets, while most energy pollutants cross national boundaries and are of direct concern to neighbouring countries.

The main focus of EU energy tax harmonisation is on oil products, and the two main reasons for an EU-wide set of minimum oil product taxes is that the EU has potential market power in the world oil market and to prevent inefficient cross-border trade within the EU. Excise taxes can be a substitute for oil import tariffs, providing countries cannot choose to free-ride on their neighbours by setting low excise taxes, and enjoying the lower world oil price that reduced oil consumption should produce. Harmonising oil excise taxes is therefore a way of preventing free-riding. Excise taxes also avoid the perception that countries are imposing protective duties and undermining their WTO commitments to free trade.

Oil consumption accounted for 43% of world total final energy consumption in 2000, and 53% of OECD total final energy consumption (OECD, 2002a). International trade accounts for a significant share of oil supply – 59% in 2003 (BP, 2004). Oil reserves are concentrated, with a Herfindahl Hirschman Index,[10] or HHI, of 5963 in 2003 if we consider OPEC as an effective cartel, although only 1022 if each country acts separately. Oil production is rather less concentrated, with an HHI of 1900 if OPEC acts cohesively, or 571 taking each country individually. Oil consumption is slightly more concentrated than production if we consider each country acting individually, with an HHI of 876 compared to 571, but somewhat less so if we consider country coalitions. If the EU harmonises its oil taxes, consumption has an HHI of 1200 compared to a cohesive OPEC cartel with a production HHI of 1900. Figures 5 and 6 show the relative market structure for exporting and importing countries.[11]

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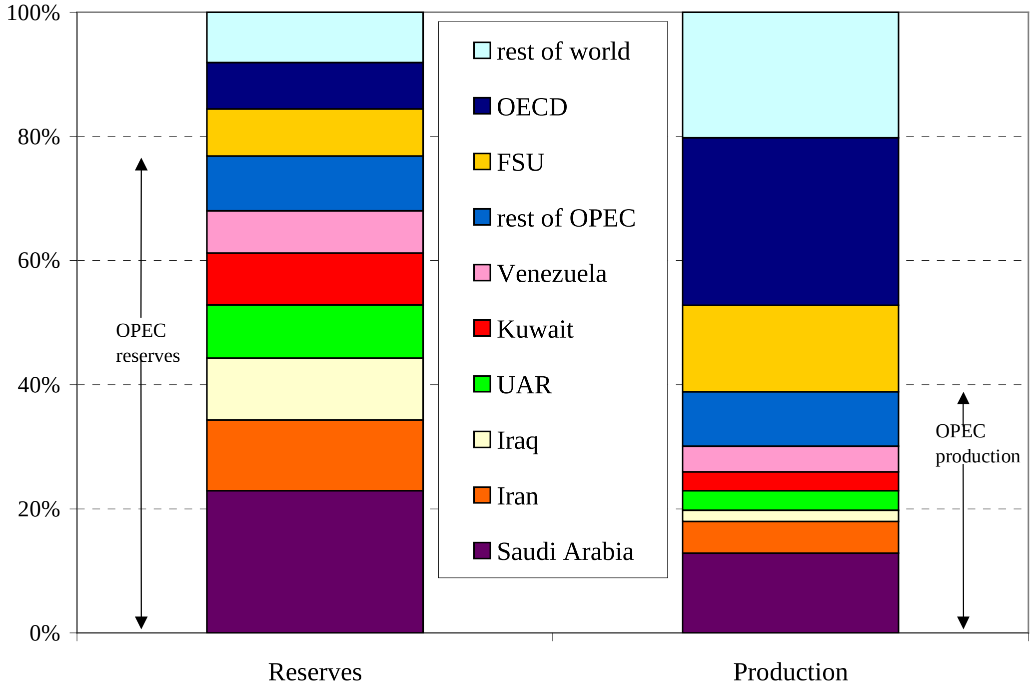
[8] In some countries, notably the UK, domestic energy consumption attracts a lower rate of VAT, and as such is relatively subsidised. This departure from uniformity has been allowed for in fig. 3.

[9] In all cases the standard (Welfare and Public Economics) criterion for optimality is that of maximising a Benthamite social welfare function.

[10] The sum of the squared percentage shares, with 10,000 being a pure monopoly, and an HHI of 1800 or above giving rise to anti-trust concerns in the US (and elsewhere).

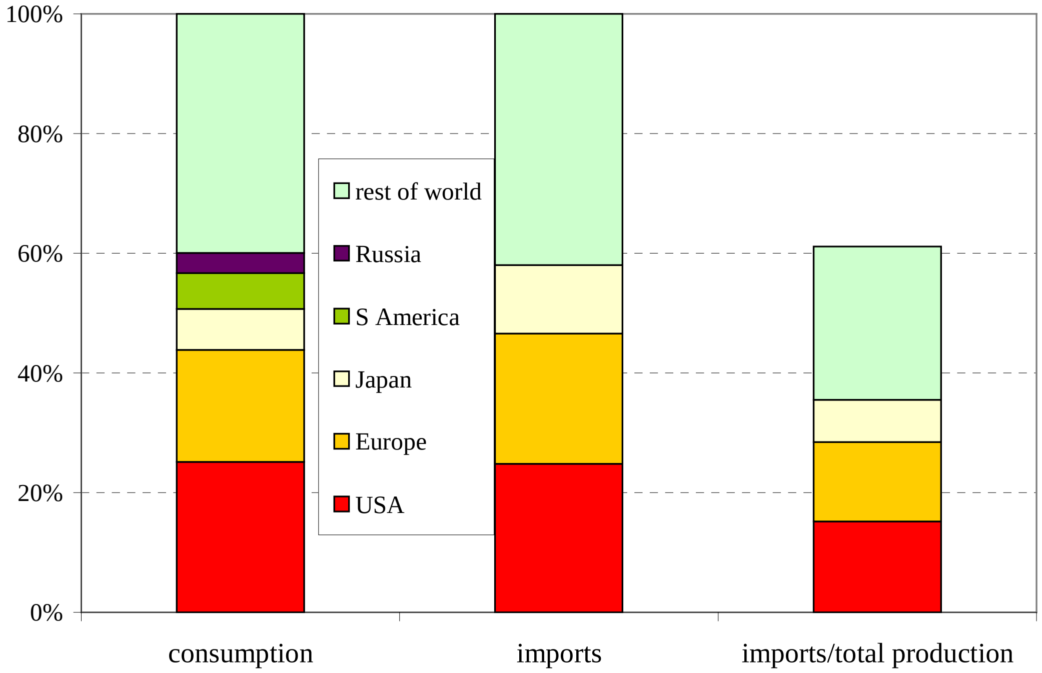
[11] The reserve and production data used to produce figure 5 show that the Reserve/Production ratio for the top 70% of total reserves is greater than 70 years, while with a few exceptions the R/P ratios for the remaining 30% are less than 30 years.

Figure 5 OPEC reserves and production 2003



Source: *BP Statistical Review of World Energy 2004*

Figure 6 Consumption shares 2003



Source: *BP Statistical Review of World Energy 2004*

Oil taxes are easy and cheap to collect, and in most oil-importing countries (the US being a notable exception) oil producers had little political influence at the time the oil tax system was put in place. Taxing oil was therefore politically attractive as reducing import dependence had economic and geopolitical advantages. When the international oil market is turbulent (as at present) and security of supply under threat (through embargoes and conflict), normal excise taxes may be supplemented by an additional oil security levy. This may take the form of the requiring companies to hold oil stocks (in which case it does not appear as an explicit tax) or as a charge to finance a strategic oil reserve. It is therefore useful to consider how an oil import tariff might be set, recognising that it may take the form of an agreed minimum set of oil excises. The two features of oil that distinguish it from a normal traded good are that oil is an exhaustible resource, and oil exporters have market power.

3. OPTIMAL TAXES ON DEPLETABLE RESOURCES

Exhaustible resources like oil and gas enjoy scarcity rents. Under simplifying assumptions (perfect certainty, extraction costs independent of remaining stocks and flows, and perfect competition) the rent of an exhaustible resource should increase at the rate of interest during the period that a particular field is in production, as Hotelling (1931) first pointed out. The size of this rent depends on the demand for the resource, so taxes that reduce demand should transfer some of this rent from resource owners to consumers. Using Austvik’s (1997) data for OECD-Europe, if the extraction and transport cost of OPEC oil is $(1994) 5/bbl, producers claimed just over two-thirds of the $86/bbl rent plus consumer taxes in 1981 but only one-quarter of the $61/bbl in 1994. In the US, if the extraction cost is taken as $10/bbl, the producer share fell from 85% of the $57/bbl rent plus tax in 1981 to 50% in 1994, as the share of domestic production in consumption fell from 63% to 47% (and to 37% by 2003).

Most energy tax revenue comes from oil and it therefore makes sense to examine the case for optimal oil import tariffs and then to see if there is any case for tariffs on other fuels (gas and coal).

3.1 Optimal oil taxes and tariffs

Rational producers of an exhaustible resource have to decide whether to sell now or retain the resource for later sale, which will be attractive if the present value of the profit from selling in the future is higher than that from selling it now. Future oil tariffs will affect future oil demand and hence the price and profit from delayed sale. More precisely, the whole future time path of oil import tariffs will affect the current price of oil and hence the attractiveness of imposing tariffs. This raises an immediate problem, for (rational) oil producers need to predict future oil tariffs in order to decide at what price they are willing to sell oil today. In a (very) simple-minded case, the oil importers would announce their tariff plans (or the oil exporters would work out their optimal future tariff plans), and then producers would decide their current level of supply, which would determine the current price.

Newbery (1976) derived the optimal open-loop import tariff for a perfectly certain world of competitive oil producers.[12] If extraction costs are independent of remaining stocks, the open-loop optimal tariff increases at the rate of interest, so it has constant present value. As rent also rises at the rate of interest, such a tariff is in effect a lump sum tax on rent and creates no distortions, as producers have no incentive to reschedule their time pattern of

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[12] Open-loop here means that the optimisation at the initial date finds a forward-looking solution

supply.

The problem with this line of argument is that except in very special cases, the apparently optimal (open-loop) oil tax is dynamically inconsistent (Newbery, 1976; Kemp and Long, 1980; Maskin and Newbery, 1981; Karp and Newbery, 1991a, b, 1992, 1993). The optimal open-loop time path of oil taxes is based on the assumption that the tax authority can credibly commit to follow this plan and that all oil producers believe this to be the case. To illustrate this, suppose that demand for oil falls to zero at some choke price, p^*. The importing country will have a domestic tax-inclusive price $P_t = p_t + \tau_0 e^{rt}$ where p_t is the import price at date t, r is the rate of interest and τ_0 is the initial tariff. At some date the domestic price will have risen to p^* and the country will stop consuming oil, even though oil is available on the international market at a lower price. Having driven down the price of oil by announcing the original import tariff trajectory, the importer would now like to depart from that plan. In consequence, that plan is dynamically inconsistent. Without some method of committing to follow the old plan, rational producers will expect that the plan will be revised, and will adjust their price expectations and hence their current supply. In such cases the original plan will not be credible, and a different way of computing the appropriate tax rate will be needed.

The same problem also arises in some cases where there is market power on the producer side. The typical model of the OPEC cartel has a core group of countries with low extraction costs facing a fringe of high cost producing countries. In a competitive equilibrium the low cost countries would sell their oil before any high cost field started production, but if the low cost producers have market power they will determine when to sell based on comparisons of the present value of the *marginal* profit at each date. This can easily lead to a situation in which the price-taking high-cost fringe will sell early and the rent (price *less* extraction cost) will initially rise at the rate of interest. The cartel will delay and eventually sell along a path at which the marginal revenue rises at the rate of interest (if costs are taken as zero), but the price rises less rapidly than the rate of interest, so that the high cost producers would not find it attractive to delay extraction.[13] Such a path would be dynamically inconsistent if the cartel would find it attractive to raise prices sharply once the fringe had exhausted all its oil and lost the ability to limit future price rises by delaying extraction. More generally, an intertemporal equilibrium is dynamically inconsistent if an agent makes a plan from which at some future date he would like to depart, assuming that he cannot precommit to that plan.

Karp and Newbery (1993) discuss the problem of choosing a suitable equilibrium concept for exhaustible resource games in which some players (either producers or consumers or both) have market power and must choose optimal strategies. The minimal requirement of intertemporal rationality is that the resulting equilibrium should not be dynamically inconsistent. A time path is a *time-consistent* equilibrium if the continuation of the original or reference path is an equilibrium of the game whose initial condition is any point on the reference path. A stronger requirement is that the equilibrium is 'perfect'. Suppose that at some date t the strategic agent departs from his original plan so that the present state $\boldsymbol{S}_t$ (e.g.

(e.g. for the tariff) as a function of time and not of the state (e.g. the stock of oil).

[13] This requires that the elasticity of demand rises with the price, as for example with linear demand. It also assumes that low cost producers have no higher discount rates than high cost producers, which is plausible if the decision makers are concerned with their successors within the country, and are capital surplus countries lending abroad, but unstable regimes may have higher effective discount rates. The Reserve/Production ratios of the major producers are high and consistent with this view.

stocks of oil) no longer lies on the reference path. Perfection requires that continuations of the reference strategies be equilibrium strategies in the game that begins at date t with the initial state given by $\boldsymbol{S}_t$. This must hold for all t and for all states that could possibly be reached from the initial state (i.e. for all possible deviations). The Markov perfect equilibrium is the Nash equilibrium in decision rules in which each agent chooses its optimal state-contingent decision (a tariff or output level) taking the rules of other agents as given.[14]

Karp and Newbery (1991a) show that the form of the Markov perfect optimal import tariff depends critically upon the order in which decisions are taken. If producers choose their extraction strategies first, and then importers select their import tariffs (or if both importers and producers make simultaneous decisions) then each will condition their current decisions on the remaining stocks of oil (assumed well-defined and known) held by each producer, given by the vector $\boldsymbol{S}_t$ at date t.

The optimal tariff is then easy to characterise. Suppose that the sellers condition their output on the current vector of stocks $\boldsymbol{S}_t$ and that the resulting aggregate supply function is $X(\boldsymbol{S}_t)$. If the importers take this as given then at each date total supply is given as $\boldsymbol{S}_t$ is given, and the importers play a series of static games, choosing tariffs just to maximise instantaneous welfare and ignoring the future (which they cannot credibly influence by their current decisions). As such they play a sequence of Nash-Cournot games. Standard optimisation then shows that if the world price of oil is p, and country i imports an amount q_i and sets a tariff (or excise tax) at rate τ_i so that the domestic price is $p + \tau_i$, then τ_i, is given by

$$\tau_i = \frac{-q_i}{\sum_{j \neq i} \partial q_j / \partial p} = \frac{\alpha_i p}{\sum_{j \neq i} \alpha_j \varepsilon_j}, \qquad (1)$$

where α_j is the market share of country j in world imports, q_j / Q, and ε_j is the price elasticity of demand for oil (as a positive number)[15]. For the case of linear demand with a choke price p^*, where the aggregate (untaxed) demand schedule is $Q = \beta\,(p^* - p)$, and consumption is $q_i = \alpha_i \beta\,(p^* - p - \tau_i)$, the formula for the tariff is just

$$\tau_i = \alpha_i (p^* - p). \qquad (2)$$

The contrast with the open-loop tariff is dramatic in this case, for while the Markov perfect (or Nash) tariff falls as the oil price rises, the open-loop tariff would increase at the rate of interest over time as the oil price increases. Austvik’s (1997) finding that both the real oil tax and the tax rate decrease as oil prices rise is certainly consistent with the Nash story (although the decrease of oil prices and rents over the period 1981-1994 is rather harder to reconcile with exhaustible resource theory).

If, at the other extreme, importers choose their tariff first, and then producers are free to change their extraction plans after observing the tariff, the solution will be quite different. In the standard (if unrealistically simple) case in which producers are free to reallocate output between any dates, importers know that when they select their tariff, the effectively face a completely elastic supply schedule at that date, as producers will respond to the tariff and rearrange their extraction plans accordingly. In the Nash case considered above, supply decisions have already been made when importers choose their tariff, so the supply is completely inelastic.

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[14] Markov here means that decisions only depend on the current state, and not on previous history.

[15] The convention throughout the article is that all price elasticities, ε, are defined as – *dlog*

Solving for the Markov perfect tariff when producers can respond to the tariffs is more difficult, involving a set of differential equations derived from the value function (as set out in Karp and Newbery, 1991a). Not surprisingly, the fact that importers face a short-run elastic supply means that the optimal tariff is typically lower than when they face an inelastic supply. Deciding which assumption best describes reality is difficult. Clearly tax decisions are not reconsidered every moment (or even every time the world oil market changes), arguing for the case in which oil producers respond to the prevailing set of oil taxes. On the other hand, competitive oil producers often make durable investment decisions that limit the profitability of changing their depletion profile. OPEC members do periodically meet to decide their output quotas to support particular prices (although they are often less willing to act on their decisions). The two extreme assumptions should bracket the correct result.

Finding the dynamically consistent strategy for oil exporters with market power is also challenging, but the open-loop Nash-Cournot equilibrium in which each producer takes the time path of production of the other producers as given satisfies the weaker concept of time consistency. Karp and Newbery (1991b) then show that one can analyse the oil market equilibrium in which exporters exercise their market power in this way, and importers set (Markov perfect) Nash-Cournot import tariffs. If producer j has constant unit extraction costs c_j then the marginal revenue of that producer satisfies

$$MR_j(t) \le \mu_0 e^{rt} + c_j\,, \qquad (3)$$

where μ_0 is a constant that will be determined by the backstop price and the stock of oil at time zero.

If we are willing to assume that both importers and exporters play time-consistent Nash-Cournot strategies, then it is possible to solve for the equilibrium world price of oil and the optimum import tariffs. Karp and Newbery (1991b) adopt this model of the world oil market with linear demand as for (2), and assume that OPEC is represented by a symmetric duopoly with zero extraction costs. The rest of the world is taken as a competitive fringe with extraction costs c. The producer HHI in this case would be 3000, compared to 6000 for a cohesive OPEC cartel and 1000 for a completely fragmented cartel. They find that the extraction pattern is one in which the high cost fringe extracts more rapidly in the early period, and is gradually replaced by the cartel, consistent with the production and reserve positions shown in figure 5.

Adopting the Nash assumption for importers also makes it easy to solve for the US and the EU import tariffs from equations (1) or (2).[16] Interestingly, the US had the roughly the same value for their world consumption share *less* production share of 16% in 2003 as the EU’s value of 15%. The higher US share in world consumption of 25% compared with the EU’s share of 19% is offset by a higher share in production. The HHI for net importers assuming the US and the EU act as independent but cohesive blocs is 1652, lower than the modelled value for producers.

The implication of this over-simplified theory is that because the US has the same net import share as the EU, US oil taxes should be comparable to EU oil taxes, whereas in fact they are much lower.[17] To estimate the value of the optimal import tariff we need to calibrate

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quantity/dlog (final price) and hence are positive numbers.

[16] Equation (1) continues to hold if importing countries also produce oil, except that α is now to be interpreted as the share in world consumption *less* the share in world production (strictly, the shares that would prevail in the absence of any tariffs). See the appendix for details.

[17] The linear demand assumption complicates the analysis as shown below but if anything

this very simple model. If all demand elasticities are the same and constant at ε, and the delivered c.i.f. price plus any refining margin is p, equation (1) gives the import tariff rate τ/p as $\{\alpha/(1-\alpha)\}.1/\varepsilon$. For a country with a share $\alpha = 0.15$, the rate is $0.18/\varepsilon$, showing the critical importance of the price elasticity of demand, ε. In the linear model of equation (2) this dependency is less obvious, and the elasticity will increase with the domestic (tax-inclusive) price, P. The implied final price elasticity of oil demand is $P/(p^*-P)$ where p^* is the backstop price (for the average mix of products in the barrel, and including any environmental taxes specific to oil such as a carbon tax). If we take the OECD averages given above in \$1994, in 1981 the delivered c.i.f. price p was \$63/bbl and P was \$89. If the back-stop price were \$135/barrel, the implied price elasticity would be 1.9. (The same calculation for 1994 when P was \$69 and p was \$23 gives an elasticity of 1.1.)

Gately and Huntington (2002) estimate the price and income elasticities of demand for energy and oil for OECD and non-OECD countries, but they take the world price of oil, not the final tax-inclusive price, in their estimations. Their preferred estimate for the c.i.f. oil price elasticity for OECD countries is 0.64. The relationship between the c.i.f. elasticity, ε_c and the final oil price elasticity ε_f is given by $\varepsilon_c = \varepsilon_f\,(p/P)(dP/dp)$. The average value of p/P for the two dates is 0.52 while $\Delta P/\Delta p = 0.5$, so $\varepsilon_c = 0.26\ \varepsilon_f$. The relevant domestic price elasticity in this case would be roughly four times the crude price elasticity, or for the OECD higher (in absolute value) than 2. This seems high, and may be largely driven by the one-time large switch out of oil into coal and gas for electricity generation following the high oil prices from 1974-85. Certainly their estimates for non-OECD countries are much lower (less than 0.2), while Pesaran et al’s (1999) estimate for the long-run price elasticity in Asian developing countries if also lower for final consumption prices (at about 0.3 but with a very wide spread).

Atkinson and Manning (1995, p98) estimate oil price elasticities (using final prices) of 0.43 for four EU countries using three lags, but 0.73 with two lags. Franzén and Sterner (1995, p119) find the long-run price elasticity for gasoline is typically above 1 (for the EU is 1.41), but some of this reflects a switch into diesel and overstates the elasticity of transport fuel demand. Graham and Glaister (2002) survey the evidence and find transport fuel price elasticities between 0.6 and 0.8 (mean 0.77, median 0.55). Goodwin et al (2004) finds a value of 0.64 (again with a considerable range up to 1.8). They note that elasticities increase with price (as expected with a linear demand, but also as it is a joint input with the value of time into transport). One imagines that the demand elasticity for other oil products should be at least as high as for transport fuels, for which there are few substitutes.

The 2002 EU-15 average oil tax was \$39/bbl (300 €/TOE) and the c.i.f. product price was about \$26/bbl. If we take a backstop price of \$130/bbl final product and compute the optimal tariff using the linear equation (2) the implied price elasticity of demand for the EU would be 1, and the optimal tariff is 15% of (130-26) = \$15.6/bbl, or two-fifths the actual tax (as shown in the right hand column of Table 1 on the line “Linear Nash”). If we do the same calculation for the US with a 2001 tax of \$10/bbl, the implied price elasticity of final demand would be somewhat less than 0.4 (again assuming linear demand) and the tariff element should be 16% of (130-26) = \$16.6/bbl. On that calculation the US would seem to be under-taxing oil, even before allowing for other corrective taxes. In this over-simplified model the US tax would need a backstop price of less than \$73/bbl for the optimal tariff to be no greater than the existing tax.

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strengthens the case for increasing US tariff-equivalent taxes.

If, on the other hand, we suppose that the final demand has constant elasticity at unity, the optimal import tariff would be almost the same in both the EU and US at $4.6/bbl, but twice as high at an elasticity of 0.5. These examples show the substantial sensitivity of the tariff to both the shape of demand and the value of the elasticity.

Table 1. Optimal oil import tariffs

$(2002)/bbl

Oil tariffs	Low	Moderate	High
Oil price cif + processing margin	35	65	26
Backstop price	85	115	130
Price elasticity of final demand	2	1.5	1
Implied domestic taxes	21.7	4.0	39.0
		Optimal import tariffs $/bbl	
Linear Nash	7.5	7.5	*15.6*
Constant elasticity Nash	3.1	*6.5*	4.6
Elastic supply, linear demand	*3.8*	*3.8*	7.8
Range of tariffs $/bbl	3.8	5.9	15.6

If we assume linear demand with a backstop price of $115/bbl and an average oil product price of $65bbl, then the implied price elasticity in the US would be just over 1.9 and the optimal import tariff would be $7.5/bbl in the US (leaving little room for any other taxes). All the assumptions (shape of the demand schedule, backstop cost or demand elasticities) are suspect, but the exercise illuminates the difficulty of simultaneously rationalising both US and EU oil taxes.

If importers know that they cannot rapidly change oil taxes, and if they consider that oil producers will choose their extraction plans after they have observed oil taxes, then the balance of advantage shifts to the producers, and importers would optimally levy lower import tariffs (or equivalent oil taxes). As a very rough rule, with linear demand, the optimal tariff might then be only half as high as with short-run inelastic supply.

Summarising the conflicting evidence on the critical value of the oil price elasticity, one can argue that the long-run elasticity could be as high as unity, and might be considerably higher. The lower the elasticity, the higher is the optimal import tariff.

The various possible assumptions about supply and demand elasticities gives a wide range of possible tariffs, summarised in Table 1, which is interpreted as follows. The three columns of figures give assumptions that are consistent with low, moderate or high estimates of the optimal tariff, which will depend on the oil import price including all the margins to deliver to final consumers, and the determinants of the price elasticity of final demand. If demand is linear, then the backstop price anchors its position and, with the domestic taxes, determines the elasticity. The High tariff column is consistent with the EU in 2002, with an import price of $26/bbl, domestic oil taxes of $39/bbl, which with a backstop price of $130/bbl gives an elasticity of unity.

The optimal import tariffs are then calculated on three assumptions. The first two lines assume Nash-Cournot tariff setting, when the importers choose their tariffs at the same time or after the producing countries have determined their output. The first line shows the results with linear demand – in the High tariff case giving $15.6/bbl. The second line gives the result ($4.6/bbl) assuming a constant price elasticity of final demand (in this case of unity).[18] The third case assumes that exporters choose their output level after the tariff has been set, and in the linear case this is set to half the Nash case or $7.8/bbl. The range of tariffs shown in the last line takes the lowest of the Low tariffs, the average of all the Moderate tariffs, and the highest of the High tariff.

3.2 Import taxation of gas and coal

Gas, like oil, is an exhaustible resource, and on the logic of the previous section, might also attract an optimal rent tax. The main difference between oil and gas is that to deliver gas to market requires heavy investment in pipelines (or LNG facilities), and that until the pipeline network is mature and connected to sufficiently many different producers, the market relationship is more like bilateral monopoly than a competitive or oligopolistic market. Gas has typically been very lightly taxed compared to oil, mainly because it is not much used in transport (where the bulk of oil taxation falls), but possibly to encourage a shift of dependence away from oil and to support the development of the necessary infrastructure. Given that gas is often linked to the price of oil (particularly for imports from Russia and in LNG trade) one might argue that oil taxes depress the price of gas and as such gas is taxed. This is unconvincing, as it begs the question at what parity gas prices are linked to oil. If producers set gas prices on the basis of the consumer price of oil, then the producers collect the consumer rent extracted by oil taxes. Logically, if oil is taxed to transfer rents to consumers, gas should also be similarly taxed.

A more telling objection to an import tariff on gas is that it is hard to determine the scarcity rent, and unclear whether it is sufficiently appreciable after taking account of extraction and delivery costs to justify significant gas taxes on these grounds. Nevertheless, the suspicion is that gas is indeed under-taxed relative to oil on rent tax grounds, at least if the EU (a major market for internationally traded gas) were able to coordinate on a minimum gas excise tax.

Coal is quite different, at least if one accepts the argument that reserves are extremely large relative to oil and that costs are high relative to value so that rents are negligible. Oil and gas each had proven reserves of 15% of total energy reserves in 2002, with coal the remaining 70% (BP 2003). If the supply of coal is moderately competitive (the HHI of production in 2003 was 1786),[19] the supply elastic and rents negligible, then rent taxation is irrelevant. If, on the other hand, supplies of cheap surface mined coal are limited, and current prices are affected by the current rate of use (as in an exhaustible resource model), then imported coal might also be a target for import tariffs (or their equivalent). We shall return to this after considering the impact of carbon taxes or CO_2 limits on energy resource depletion.

4. EXCISE TAXES TO DEAL WITH EXTERNAL COSTS

The main external cost caused by energy use is the damage caused by environmental pollution. Efficiency requires that the marginal benefit of using the fuel should equal the marginal social cost, where the marginal damage cost of the pollution should be added to the marginal cost of

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[18] The large difference is partly explained by the considerable variation in the elasticity of the linear demand at different prices. Thus if the import tariff were 35 €/TOE, the elasticity of demand assuming no other taxes at the domestic price of 235 €/TOE would be 0.31, implying an optimal import tariff of 115 €/TOE.

[19] Surprisingly, the HHI of net imports is only 1226, even taking the EU as a single trading bloc

production (and/or import, thus reflecting the optimal tariff). This might be attempted by command and control policies (standards, regulation, etc.), but market instruments, if they are feasible and not too costly, are superior. The two main market instruments are taxes (set equal to the marginal externality damage) or tradable permits, whose price will be determined from demand given the initial allocation of quotas. Tradable permits (‘cap-and-trade’) are increasingly used for area-wide pollutants such as SO_2, NO_x, and CO_2. Thus the EU Emissions Trading Scheme (ETS) for CO_2 became mandatory in 2005.

An efficient level of pollution will have equality between the marginal cost of reducing pollution (either by abatement or reducing fuel use) and the marginal benefit of reducing pollution (which is just the negative of the marginal damage done by the pollution). If there is complete information and no uncertainty, the efficient level could be achieved either by issuing the correct number of permits or setting the pollution tax at the marginal damage cost at the efficient level. This equality of outcome breaks down under uncertainty or with asymmetric information. Weitzman (1974) started a lengthy debate by observing that in the presence of uncertainty, permits are only superior to taxes if the marginal benefit schedule had more curvature than the marginal abatement schedule. This might be the case if marginal damage were low until some threshold level, at which point it suddenly increases. For most pollutants the marginal abatement cost schedule is fairly flat and low for modest abatement, but rises rapidly as a higher fraction of emissions is to be curtailed, arguing for taxes rather than quotas.

There are two additional differences between taxes and permits that are important, although opposed. Pollution taxes raise revenue and allow other taxes to be reduced, thus reducing deadweight costs. The so-called “double dividend” is discussed in section 6 below. Permits could be auctioned to produce revenue, but are normally allocated to those already polluting, effectively to buy off their opposition to the new policy. Thus the ETS requires that 95% of allowances are so allocated. We shall need to see for which other pollutants this political economy argument is relevant.

The main damaging combustion products are particulates, (PM_{10}),[20] sulphur dioxide (SO_2) and sulphates, nitrogen oxides (NO_x) and nitrates (the salts are primarily harmful to health in their small particulate form), various volatile organic compounds (VOCs), other combustion products such as carbon monoxide (CO), ammonia (NH_3), and of course greenhouse gases (GHGs). Figure 7 illustrates for the UK the role of different sources in the amounts of some of these emissions, where the three major GHGs (CO_2, methane, and N_2O) have been converted into carbon equivalents and added. Carbon dioxide accounted for 80% of total UK GHG emissions in 2002.

Ideally all should be taxed or charged for the damage they cause, which, with the single but critical exception of CO_2, depends on the composition of the fuel, how it is burned, whether it is subject to tailpipe cleanup, and where and when the combustion takes place. In the case of CO_2, charging for the carbon content of the fuel is the logical solution as the resulting damage is directly proportional to carbon content. GHG are also very long-lived pollutants, in contrast to most other combustion products. Acid rain has long-term impacts on sensitive soils, but its precursor emissions, SO_2 and NO_x, are the cause of the most costly damage to human health, where exposure occurs in a relatively short period after emission. Because GHGs are global stock pollutants, proper charging for the damage they cause requires international co-operation and an intertemporal perspective. Given its salience, it has attracted extensive analysis (e.g.

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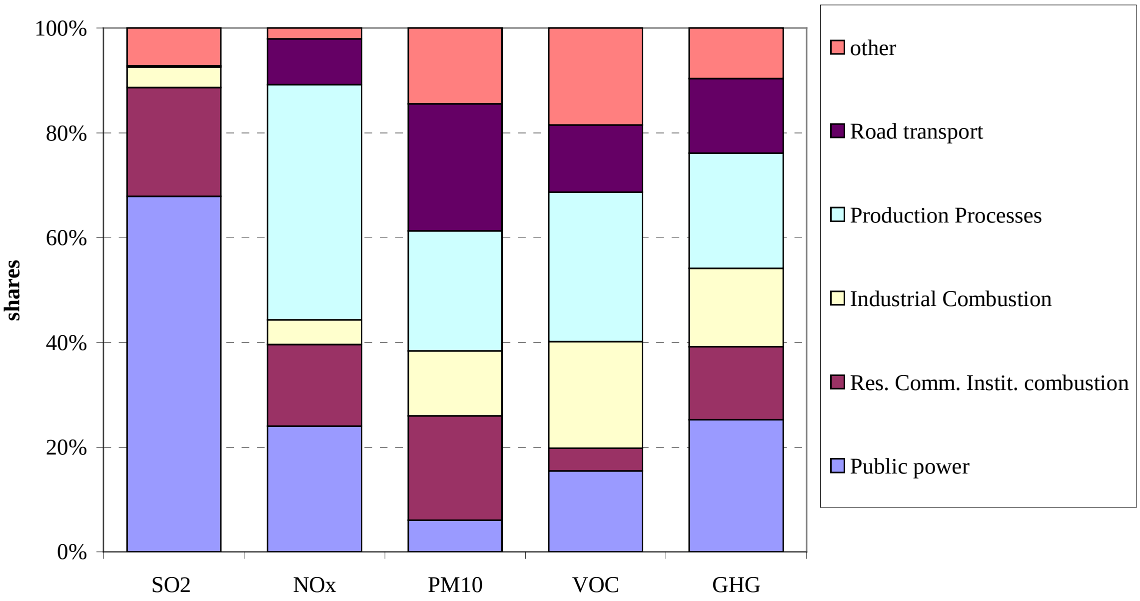
[20] i.e. particulates of size less than 10 microns. Smaller sizes may be even more damaging, but statistics on their prevalence are less readily available.

through the InterGovernmental Panel on Climate Change, http://www.ipcc.ch/), and the following is a necessarily brief and incomplete treatment.

Figure 7 Emissions of air pollutants by source, UK 2002



Souce: DEFRA *Environment Statistics 2004*

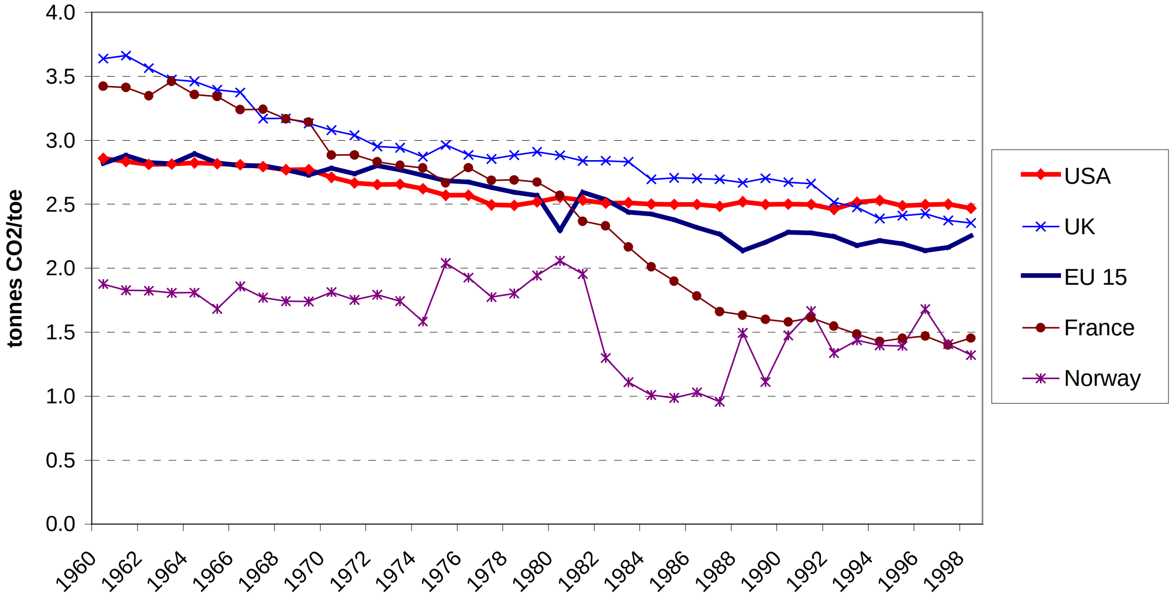
4.1 Carbon taxes and emission allowances

Greenhouse gas emissions contribute to an atmospheric stock with a very slow rate of decay. Higher concentrations raise the ambient average global temperature with damaging impacts on future populations and the biosphere. The damage contributed by emissions today is effectively the same as those tomorrow, and so the marginal benefit of abatement is essentially flat at each moment, while the marginal cost of abatement rises rapidly beyond a certain point. The scale of the hazard of global warming is very uncertain, as are the future costs of reducing carbon intensity. All these are arguments for a global carbon tax rather than tradable permits. Hoel and Karp (2001) explore this question more carefully in a calibrated linear-quadratic dynamic model of global warming and confirm this claim robustly.

The obvious problem is that there is no supranational authority to which countries would be willing to entrust such tax powers. Instead the Kyoto Protocol defines a target path of emissions for each of the Annex 1 (largely developed) countries, and then allows trading between them to encourage efficient reductions within this group. This would not stop each country auctioning off permits (collecting the same revenue as a tax at the market-clearing price on that level of emissions), but in practice the European ETS requires 95% of these permits to be allocated or “grand-fathered”. If permits can be banked and borrowed (as with the US sulphur cap-and-trade system) the inter-temporal carbon price should be arbitraged, but this would not ensure that it remained constant even in present value over time (as the volatility of the futures price of storable commodities demonstrates).

If we continue with the question of how to set the carbon price (whether by taxes or permits), there is a potentially important interaction between the price of carbon and energy resource depletion decisions, just as there was in setting the import tariff. Ulph and Ulph (1994) reminded us that a constant ad valorem carbon tax on costless oil has no impact on the time path of extraction and hence no impact on carbon emissions from oil. The only way to reduce global warming is to delay carbon release, so that natural decay of atmospheric CO_2 reduces concentrations, and in a world of rational resource producers, that means making future extraction more attractive than current extraction, or lowering the rent now relative to the future. Subsequent papers (e.g. Farzin and Tahvonen, 1996; Tahvonen, 1997) have elaborated the standard exhaustible resource model to examine the shape of the optimal time path of a carbon tax, although these models all assume a co-operative solution (i.e. a comprehensive Climate Change Agreement), thus avoiding issues of dynamic consistency.[21]

Figure 8 Carbon intensity of energy consumption for selected countries



These models are also misleading in other ways, for by ignoring the importance of coal and the impact that carbon taxes have on fuel choice they tend to understate the impact of such taxes on the carbon-intensity of energy use, which, as figure 8 shows, shows considerable potential for reduction. At some price of carbon, sequestration (notably in enhanced oil recovery) becomes economic and further reduces ultimate emissions.

The evolution of carbon prices is more likely to be upwards, as the EU ETS cap is tightened in the second period beginning in 2008 when the Kyoto Protocol enters into force, and from 2012 when the Kyoto limits are to be revisited. The penalty for being short of EU allowances is € 40/t CO_2 until the end of 2007, but then rises to € 100/t. Looking further ahead emissions will have to be reduced much further if global warming is to be seriously addressed.

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[21] Other writers have explored non-cooperative games in the context of the “tragedy of the commons” in which the players act strategically. They are able to characterise dynamic consistent solutions for stochastic games with stock externalities (e.g. Wirl, 2003; Rowat, 2000) but it is hard to translate their findings into useful policy guidance for the Kyoto world of partial coverage (both geographically and temporally).

Rising carbon prices are plausible if there is a reasonable chance that the ETS will succeed, the threats of global warming are more widely heeded, and the US accepts the need to reduce emissions even if it does not sign the Protocol. Would a forecast of rising carbon prices have the perverse effect of accelerating depletion, offsetting the benefits of the carbon tax? This seems unlikely compared to the alternative in which oil and coal use are depressed, gas use increases, and nuclear power again becomes attractive. At present, coal is under-taxed and nuclear power viewed with suspicion, neither of which seems sustainable with a durable carbon tax (or equivalent allowance price).

Deciding on what level to set the carbon tax is non-trivial (and would be needed even under emissions trading to judge whether the emission limits had been appropriately set). The range of estimates is considerable. A recent survey (Clarkson and Deyes, 2001) cites figures for the social cost of carbon (defined as the level of carbon tax required to reach the global optimum) ranging from $9-200/tonne of carbon (tC) in 2000 prices (€ 10-220/tC). Their best estimate of the marginal damage of extra carbon (not assuming optimal emissions) is £70/tC (€ 110/tC, 2000 prices) with a (rather arbitrary) confidence interval from £35-£140 (€ 55-220/tC).

Karp and Zhang's (2004) paper represents state-of-the-art quantitative analysis, taking account of the stock nature of GHG emissions, uncertainty and learning about the cost of global warming, and asymmetric information about the costs of abatement. They calibrate their model for three values of the damage cost (measured by the percentage reduction in gross world product, GWP, from a doubling of GHG): low (0.3% reduction in GWP), medium (1.33% reduction) and high (3.6% reduction. Given these costs, the optimal reductions in emissions in the first decade would be 3%, 9.5%, and 22% relative to Business As Usual. The optimal carbon taxes for the three damage levels are per tonne of carbon and 1998 US$, $6.7, $21.3 and $49.3/tC.[22] These estimates are reproduced in Table 2 below, updated to 2002 prices and exchange rates.

We can compare these figures with various policy proposals. The original proposed EU carbon tax was set at $10/bbl (though as a political compromise half was to be levied on carbon content, and half on energy). Updating that to current prices, and retaining the assumption that half should be levied on carbon yields a tax of € 50/tC, consistent with estimates of the marginal cost or the (higher end of the) optimal tax. If we leave on one side the selfish aspect of international negotiations, then one might argue that all EU countries acting together ought to set the same carbon tax, and that this tax might be as high as € 50/tC. That translates into 4% of the 2001 EU (weighted) average tax on gasoline, 6% of that of diesel, 34% of that of LFO for industry, and 25% of that for heating oil.

These figures can also be compared with the opening price of 2005 EU Allowances, which at about € 9/tCO_2 correspond to € 33/tC, rather lower than most of these estimates, but higher than all but the highest estimated optimal carbon tax. In Britain, Renewables Obligation Certificates issued to certified generators of renewable energy pay a premium of € 60-70/MWh, which equates to an implied cost of displacing carbon from conventional generation of perhaps € 450/tC (with a range from € 220-750/tC depending on which stations are at the margin). Most of this subsidy is best considered a subsidy to learning-by-doing rather than an implicit carbon price.

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[22] The paper does not report the implied optimal taxes, which were supplied by Karp.

Table 2 Carbon taxes and their impact with import tariffs on oil taxation

2002 prices

Carbon taxes $/tC		Low	Moderate	High
Damage ($-\Delta GWP/\Delta GHG$) %		0.3	1.33	3.6
Optimal carbon tax $/tC		7.2	23.0	53.1
Optimal oil tariff in $/bbl		3.8	5.9	15.6
Oil tariff + carbon tax			€/TOE	
Oil tariff in €/TOE		*29*	*46*	*121*
Carbon tax €/tC	*8*	36	53	128
	24	51	68	143
	56	79	96	171

Table 2 summarises Karp and Zhang's (2004) estimates and combines them with the table 1 results on optimal import tariffs to give oil taxes in €/TOE. The three columns of figures give assumptions that are consistent with low, moderate or high estimates of oil taxes. The first two lines give the three different damage assumptions (impact on Gross World Product of a doubling of CO_2 concentrations) and the implied optimal carbon taxes in $/tC. The next line repeats the range of optimal tariffs in $/bbl from table 1. This is converted into €/TOE in the next line. The final block adds carbon taxes (expressed now in €/tC in the column at the left) and optimal tariffs to give a range of possible outcomes. The lowest carbon tax (€8/tC) added to the lowest import tariff (29 €/TOE) gives the lowest combined tax of 36 €/TOE. The highest carbon tax (€56/tC) with the highest import tariff (121 €/TOE) gives the highest combined tax of 171 €/TOE, nearly five times as high. The median figure is 79 €/TOE.

4.2 Other emission taxes and prices

It may make sense to tax or charge fuels on their sulphur content (with credits for abatement), but other pollutants should preferably be charged as emissions, not on the fuel. Where this is difficult or too costly, some combination of input fuel-specific taxes and environmental standards may be second-best. The special tax treatment of leaded gasoline is a good example on a well-targeted input tax on a pollutant. Standards are common for large plants (under the EU Large Plant Combustion Directives 88/609/EEC and, more recently, 2001/80/EC), for sulphur (under the Second Sulphur Protocol) and for NO_x. There are also various standards for road vehicles. Tradable permits for NO_x and SO_2 have been introduced in the US, and if carefully designed are a superior tax-like solution for internalising these emissions externalities than standards. The obvious problem is that the damage done by both is location-specific, and for NO_x, depends on daily weather (or meteorological) conditions, so there is a defined NOx season during which permits are required in some areas of the US.

Although politicians have frequently argued that energy taxes, particularly road fuel taxes, are to be justified on environmental grounds, with a few exceptions the case is unconvincing. In most cases the taxes predate environmental concerns, the taxes are not related in any systematic way to environmental damage, and they do not meet minimal consistency criteria for so doing. Coal is almost invariably the most environmentally damaging fuel, but it is usually the least heavily taxed, and in many countries its production is heavily subsidised (Newbery, 1995). Transport fuels account for a relatively modest share of air pollution, with other fuels such as coal and heavy fuel oil also contributing to acid rain and particulates. Figure 7 showed the share of road transport in the total production of these (and other) air pollutants in the UK. Road transport is a major contributor to the total emissions of NO_x, particulates and GHG, though not of sulphur dioxide, SO_2. In all cases road transport causes less than half the UK's emissions, and in the case of CO_2, singled out in the past as the reason for fuel tax increases, less than one-fifth of the total GHG in 2000 (though one of the fastest growing components).

If taxes are to be levied on fuels or fuel emissions, the damage caused will have to be quantified. This is increasingly recognised, and estimates are available for the EU.[23] The major source of the social cost is the impact on health. Newbery (1998) argued for estimating the social costs of the health effects of pollution by estimating the number of quality adjusted life years (QALYs) lost through premature mortality and morbidity. These costs should then be compared with what it costs the taxpayer to enable the Health Service to achieve an extra year of quality life and should be consistent with numbers used elsewhere in health economics. This would enable the money raised in environmental taxes to be used by the National Health Service to buy an equal number of quality life years from improved health services.

Recent work presented at a UN/ECE symposium *The measurement and economic valuation of the health effects of air pollution*, London, Feb 19-20, 2001 suggests encouraging convergence in estimates of the costs of the more damaging pollutants.[24] Severe urban pollution reduces life expectancy, and a *permanent* increase in air pollution of 10 $\mu g/m^3$ of PM_{10} is estimated to raise the daily mortality rate by 1 per cent. That in turn would reduce average life expectancy in Britain by 34 days (weighted by the British age distribution and based on current age-specific mortality rates). In order to relate the loss of QALYs to the annual consumption of fuel, the correct calculation is the total loss of QALYs for a one-year increase in emissions, leaving future mortality rates at the base emission level.

Newbery (2004) argues that road transport may account for 4.4$\mu g/m^3$ of PM_{10} in Britain, causing a loss of life expectancy per person exposed to 0.21 days per year of exposure. If we err on the high side and suppose that QALYs do not decrease with age (as they do), and take the exposed population as all 58 million people, the total QALYs lost by one year’s traffic particulate emissions is 34,000. If we attribute half to traffic (figure 7 suggests rather less, but most people have greater exposure to local traffic pollution that other sources), then the annual loss from all particulates might be as high as 68,000 QALYs.

If we work backwards from the value of a statistical life, the value of a life year lost seems to be about £30-50,000. The UK National Institute of Clinical Excellence was reported (*Times*, 10 Aug, 2001) as tentatively accepting a figure of £30,000 per QALY, suggesting a convergence on the valuation side. If we take the lower figure for a QALY, then the cost of air pollution (mostly from particulates) might be as high as £2 billion, of which half would be attributed to road transport. If this is attributed to about 200,000 tonnes of PM_{10} emitted, the implied average cost is £10,000/tonne.[25] This is comparable to the EU BeTa average rural estimates for $PM_{2.5}$ for the EU-15 of € 14,000/tonne, although this estimate should be scaled by a factor of 7.5 for emissions in a city of 1 million. Correcting for the relationship between the

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[23] The EU has commissioned a series of studies to estimate the social costs of various emissions, and a recent set of marginal external cost estimates are provided in BeTa, the Benefits Table Database listed on the EC DG Environment website.

[24] The NEBEI website of the conference is at http://www.unece.org/env/nebei

[25] Particulate emissions are falling rapidly, from 210 kt in 1998 to 160 kt in 2002 (Defra, 2004).

weight of $PM_{2.5}$ which is only about 70% that of PM_{10} (using US EPA data) the BeTa estimates averaged over the population appear high. It would be unwise to take these figures as definitive, as other estimates suggest an extremely wide range. Thus EPA (1996) gives an extremely wide range for the marginal damage from \$500 to \$13,000/ton (in 1995 \$). As the level of particulate emission depends critically on the form of combustion and tail-pipe controls, it is unlikely to make sense to levy a fuel tax to internalise these costs.

The EU BeTa figures for SO_2 and NO_x are very high with rural EU averages of 5,200 €/tonne and 4,200 €/tonne respectively, again with large multipliers for urban areas.[26] The BeTa figures imply a cost of 10.4 €/kg of sulphur, which for heavy fuel oil with 3% sulphur would imply a marginal damage of € 312/tonne HFO, substantially more than its import price. Dubroeucq and Ellerman (2004) report average traded SO_2 prices in 2002 of \$150/short ton (€ 175/tonne). The average US-wide price from 1998 until the end of 2003 was \$167/ton, but rose to about \$450/ton in 2004 with the announcement of tighter future limits (and banking), ending the year at \$700/ton, with forecasts of around \$500/ton (400 €/tonne). EPA (1996) gives a range for the marginal damage of \$375-2,000/ton (again, 1995 \$). Taxing fuel on sulphur content makes sense, with rebates for clean-up (such as Flue Gas Desulphurisation). At 400 €/tonne SO_2 (800 €/tS), 3% HFO would impose a damage of 24 €/tonne. Note that traded prices at best give an estimate of the marginal cost of abatement, *not* the marginal damage.

NO_x prices are considerably more volatile as they are specific to air sheds and are time limited with less opportunity for banking. Thus during the California electricity crisis of 2000/01 East Coast prices were around \$400/ton but reached a peak of \$80,000/ton in California (Laurie, 2001). This reflected temporary scarcity (and possibly market power) caused by tight time-limited quotas, and illustrate the dangers of setting “quantities vs. taxes” in Weitzman’s phrase. The NO_x Budget Program for Northeastern states began in 1999, imposed a lower cap in Phase 3 of that program from 2003 and was geographically extended westwards in 2004. In its 2003 report (EPA, 2004) reports future prices, showing a convergence to a range from \$2000-\$3000/ton in 2004, as figure 9 shows.[27]

The cost of clean up for power stations lies in this range for Urea injection, although low-NO_x burners may have marginal costs in the range \$6,000-12,000/ton. These prices or costs seem high compared with the EPA (1996) estimated marginal damage costs of \$10-122/tonne. Again the wide range casts doubt on the precision with which we can estimate the marginal damage of these pollutants, and as with particulates, emissions depend on combustion and control equipment and so is not best treated by a fuel tax.

Figure 9 US NO_x Budget Trading prices for various vintages

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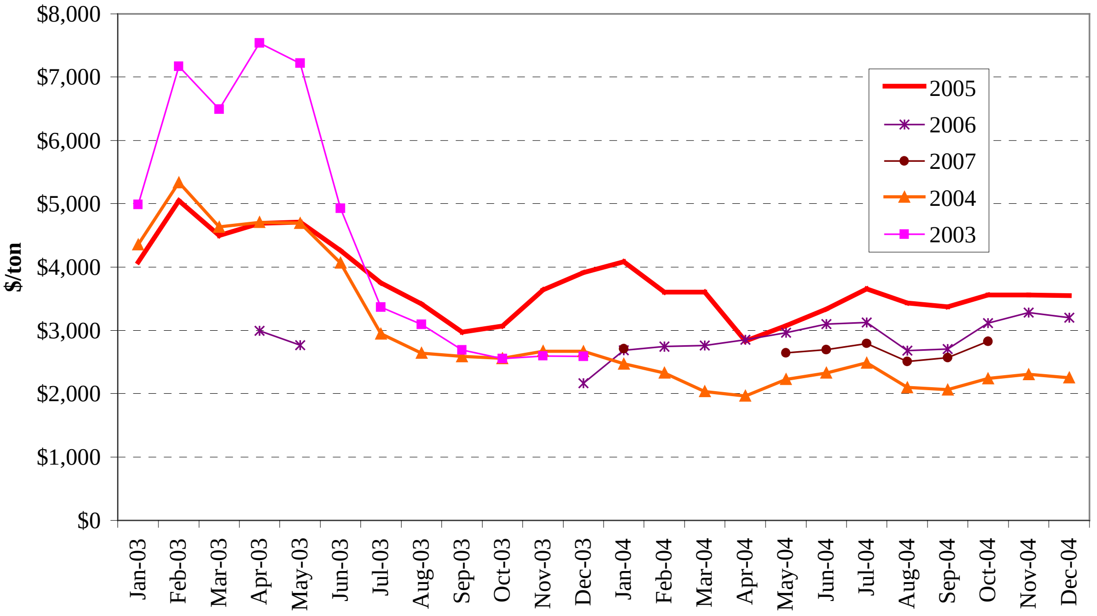
[26] A considerable part of the cost may be attributable to damage caused by particulates formed from sulphates, and hence already included in that cost, although for taxing sulphur they should be properly attributed.

[27] I am indebted to Denny Ellerman for the data for figure 9.



Even if we take the (high) BeTa rural figures for $PM_{2.5}$, SO_2 and NO_x of € 14,000, 5,200 and 4,200/tonne, the UK 2002 emissions factors for oil were 0.55, 1.9 and 11.5kg/tonne respectively (DEFRA, 2004), suggesting emissions taxes (or their equivalent) of € 8, 10 and 48/tonne for the three pollutants separately or € 66/tonne together (of which 73% is attributable to NO_x). The emissions factors for coal are 1, 21 and 8.85 kg/TOE, with BeTa costs of € 14, 109, and 37/TOE, adding to an implausibly high value of € 160/TOE, over four times the average import cost of coal. This supports the claim that there may be a considerable exaggeration in the BeTa estimates.

4.3 Sumptuary taxes and distributional arguments

The most obvious reason why gasoline is singled out for heavy taxation is that in Europe, high fuel consumption can be argued as wasteful and acceptable to tax (and because it is so easy to conceal the actual tax rate). Heating oil, domestic natural gas use, and domestic electricity are in contrast (income) inelastically demanded (see footnote 1), and in colder climes, such as the UK, fuel poverty (defined as spending more than 10% of income on energy) is a serious issue (with 20% of UK households fuel poor in 2000). The exceptions to low taxes on domestic heating fuels are interesting: Italy and Greece, perhaps less efficient at collecting other taxes (at least when the current tax regime was chosen) and with Mediterranean climates, Denmark (carbon tax) and Sweden (heavily reliant on cheap hydro electricity for heating), have higher taxes on these fuels.

The theory of optimal taxation sets out conditions under which consumption tax rates on goods and service should be uniform, in which case there would be no case for differential consumption taxes. These conditions are stringent but in many cases difficult to reject empirically (Deaton, 1987). If there is an optimal non-linear income tax, individuals differ only in the wage rate, and the direct utility function $u(.)$ has goods, $\mathbf{x}$, weakly separable from labour, L, (so $u(\mathbf{x},L) = u\{\phi(\mathbf{x}),L\}$), then optimal indirect taxes are uniform (Mirrlees, 1979; Stern, 1987).

Weaker conditions not assuming optimal income taxation apply with linear Engel curves and weak separability between leisure and goods (Deaton and Stern, 1986). The argument that separability removes the case for differential commodity taxation is that, in such cases, the only determinant of the supply of labour is the cost of goods consumed, and this is minimized when relative prices are undisturbed. The case for differential commodity taxes therefore requires that separability breaks down, in which case there is an argument for more heavily taxing goods that are complementary with leisure (Corlett and Hague, 1953).

If we consider the argument that domestic heating (gas) and electricity are both price and income inelastic and are therefore attractive subjects for (relative) subsidies (i.e. lower rates of VAT, as in Britain), then unless it can be shown that lowering their price increases the willingness to work, the efficiency case is weak. It would be more efficient to achieve any redistributional goals through lump-sum transfers or via the expenditure side of the budget. This appears to have been partly recognised in Britain, where the Government now provides winter fuel payments automatically in cash to those over the age of 60.

4.4 The special case of coal

Coal is nominally untaxed except in Denmark and Finland, neither of which mine coal. Coal production has until recently been heavily subsidised in most significant coal producing countries, and until recently the protection was provided by a combination of hydrocarbon taxes and above world-market domestic prices. In the early 1990s, Germany had the largest indigenous coal industry and one of the most protected in Europe, as measured by the producer subsidy equivalent (PSE) per tonne. Thus IEA (1992, p38) estimated Germany's PSE as $105/tonne coal produced in 1992. Germany also paid the highest prices for coal for generation, and had the highest industrial electricity prices. The UK had the lowest PSE/tonne of the European coal producers ($18/tonne of coal in 1992) but one of the highest coal prices for generation. Interestingly, it also had one of the lowest industrial electricity prices of coal-intensive countries, as British coal was protected by high contract prices with the generators that were passed on primarily to non-industrial customers. Spain had an even more protected coal industry. Newbery (1995) estimated that the PSE raised the effective domestic price for coal producers about 450% above import parity in Spain (compared to the IEA's estimate of 100%), about 250% in Germany, and about 50% in the UK.

Since then, the system of supporting coal producer prices in Germany has changed so that industrial consumers (mainly power stations) can buy at import prices. Coal-backed power generation contracts have essentially ended in the UK, so many of the past distortions have disappeared. On the other hand, the Climate Change Levy in Britain has been carefully designed not to be a carbon tax, but an energy tax, and electricity is taxed on production, not inputs, to protect coal. In addition a natural gas moratorium was imposed in 1998 to prevent the building of gas-fired Combined Cycle Gas Turbine (CCGT) generating units, and hence protect the market for coal (but not necessarily for British coal). Coal escapes carbon taxes (except in Denmark) which at € 100/tC would be about € 67/tonne for bituminous coal. Import prices into the EU were $35/tonne or about € 40/tonne in 1999, so a carbon tax of 167% of the producer price (but specified as € 100/tC) could be justified. Clearly coal is still treated rather leniently compared to most other fuels.

4.4 Summary on emissions charges and energy taxes

The main case for taxing fuel for the pollution damage it causes is that it is the least-cost way of reflecting the external costs. The best case is a tax on carbon content, as global warming damage is directly proportional to carbon content. The trend here is away from explicit carbon taxes and towards emissions permits, which is less satisfactory from an economic viewpoint, even if it is understandable as part of the multilateral Kyoto process. Taxes on sulphur content with rebates for abatement may be less costly and more comprehensive than global emission permits, although permits could in principle be made more time and location-specific if damage variations warranted such fine-tuning. The main objection to cap-and-trade solutions is that the price may depart significantly from a plausible estimate of the marginal damage cost, but that could be addressed by gradually reducing the number of grand-fathered permits and issuing additional permits at a fixed price. The present system of tradable permits and fuel standards for dispersed sources may remove most of the case for energy taxes for this reason. The case for an energy tax to internalise NO_x damage is even weaker, as permits and standards are better able to reflect the damage done by the actual emissions and hence better able to encourage optimal abatement.

5. ROAD FUEL TAXES AND ROAD USER CHARGES

Road fuel taxes can be justified to a considerable extent as road user charges (Newbery, 1988, 1990, 2004, Newbery and Santos, 1999), pending the political and technical development of more finely targeted road pricing. Fuel taxes are relatively blunt instruments, for whereas fuel consumption per km increases in congested urban conditions (by 50% relative to uncongested roads),[28] marginal congestion costs can exceed fuel taxes by a factor of 20 or more there, while interurban car travel is typically substantially overcharged. Nevertheless, a case can be made that on average road users should pay the average total cost of road provision (primarily road damage, maintenance, and interest on capital), just as other users of privately owned infrastructure (e.g. electricity and natural gas transmission) must pay a regulated, usually price-capped, charge that covers such costs. Note that the case for an additional scarcity price to reflect marginal congestion costs must rely on either inefficient undersupply, or significant diseconomies of scale in road building (Newbery, 1989).

Although the long-run marginal cost of expanding roads (or the scarcity price where this is infeasible) might be expected to differ across countries, there is little evidence that road taxes are set to charge this long-run marginal cost. Nevertheless, there are strong arguments for proposing that, until better instruments such as road pricing are available and accepted, road fuels should be set on this basis. Using UK data, Newbery (2004) argued that the road cost alone might be 2.6 p/km in 2000, or 4 Eurocents/km (2000 prices).[29] That would translate into € 400/'000 litres for gasoline, and perhaps € 500/'000 l or more for diesel.[30] Setting equal tax rates on gasoline and diesel can be defended if the balance is collected through annual licence charges. The EU average (unleaded) gasoline tax in 2001 was € 577/'000 litre, for the UK was € 815/'000 litre, and the minimum required by EC Directive 92/82/EEC was only € 287/'000 litre. The average diesel rate was € 443, for the UK was € 865, and the minimum requirement was

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[28] http://www.fueleconomy.gov gives fuel consumption for 2004 year autos, and the typical ratio of fuel consumption of city to highway driving is 1.33. Fuel consumption rises rapidly as speed drops below 35mph (56kph) and is twice as high at 5mph (8kph) as at 30mph (50kph).

[29] The largest uncertainty is about the capital value of the road network, which is taken as.120 billion for the UK, with interest calculated at 6% real.

[30] For diesel cars, Eur 540/'000 l, and for heavy vehicles much would depend on the balance between the annual vehicle excise duty, which can discriminate between vehicles on the basis of their road damaging impact, and fuel duty, which is less well designed for that purpose.

€ 245, all per thousand litres (EC, 2001b). It is hard to justify the under-taxation of diesel relative to gasoline. Diesel is both more polluting, and used by heavier vehicles that cause more road damage, but diesel engines are more fuel-efficient. Unless diesel vehicles use congested areas relatively less than gasoline vehicles, a higher tax per litre would be justified to achieve even the same charge per km.

If environmental taxes are levied on road fuels (as would be logical for carbon, sulphur and lead) then the price of fuels will be higher by the amount of these taxes. Newbery (2004) estimated the sum of air pollution costs at £1.6 billion (€ 2.6 bn), although using the BeTa (average rural) figures and DEFRA (2004) allocation of pollution to transport gives a rather higher figure of € 4.4 bn. Water pollution costs were estimated at £750 m and noise pollution at £1.3 bn. If the carbon cost were taken on the high side at € 50/tC the carbon tax would collect £1 billion, making the total road fuel charges add to £16.6 bn. That compares with the 2000 total from fuel tax of £22.3 bn, and from all road taxes (but excluding VAT) of £27.7 bn. Road *costs* were thus only 60% of UK road *taxes*.

One appealing method of setting such road user charges is to devolve responsibility to an independent regulatory agency (as is done for setting the charges for using other infrastructures, such as the electricity grid and gas pipelines). The charges would then be set on similar principles (to recover operating costs including maintenance, as well as interest and depreciation on the replacement cost). As more sophisticated forms of road pricing are introduced, they would replace the road user charge element of road fuel tax (and vehicle excise duty) on an equal revenue basis, minimising the disruption to both voting motorists and the budget. It may also be possible to discriminate between more and less polluting vehicles through the annual vehicle license fee (which varies by type of vehicle).

If we return to the question of the justifiable total tax on road fuel, we need to add all environmental taxes and optimal import tariffs. If all the estimated UK environmental costs (excluding any carbon tax) were loaded on to fuel taxes, it would add an extra € 95/’000 litres to gasoline and € 165/’000 litres to diesel (which emits more PM_{10}). If carbon were charged at the ETS price of € 33/tC it would add € 29/’000 litres, or less than 6% to the total road user charge. The object of the oil import tariff is to reduce consumption of crude oil. As both crude oil and products are traded, the object would be to reduce the total demand for crude oil at least cost to consumers. If the demand for HFO is more price elastic than the demand for lighter fractions, this would imply a higher tax per tonne on lighter than heavy products. If the optimal EU oil import tariff were taken as an intermediate value of € 40/TOE (i.e. the moderate tariff case in Table 2), and if gasoline and diesel were subject to an import tariff twice as high as heavier fractions, then the effective tariff on gasoline and diesel would be € 48/TOE or about € 38/’000 litres.

The pre-road user charge gasoline tax (covering all emissions and tariffs) would then be € 95+29+38 = 162/’000 litres, and the justified total gasoline fuel tax would then be € 562/’000 litres. For diesel the non-road charge element would be € 165+29+38 = €232, giving a total road diesel tax of € 732/’000 litres, although in both cases some fraction could be recovered from annual license fees. At these (high estimates of) appropriate tax levels the UK would still be overtaxing both road fuels. If we take a lower optimal import tariff of € 29/TOE these taxes would be reduced by € 10/’000 litres, and other EU countries would be still be undertaxing diesel (and most would be undertaxing gasoline), unless they have high annual license fees.

5.1 Interactions between road user charges and other fuel taxes

The effect of charging all road users the average road and emissions cost by a fuel tax would be to cause road users to invest in more fuel-efficient vehicles. In order to charge the same amount per vehicle-km as before, road fuel taxes would need to be higher than if road users were charged by other means, such as the electronic devices now used on trucks in Germany (Newbery, 1992). On the other hand the distortionary costs of charging for road use through fuel taxes rather than road pricing, and for pollution on fuel rather than emissions argues for reducing the rates of tax somewhat (as discussed in section 6 below).

5.2 Other reasons for taxing road fuels

Parry and Small (2002) claim that additional taxation is justified by the impact of road user charges on labour supply. They argue that if leisure is weakly separable in utility, then personal travel is a relatively weak substitute for leisure if the expenditure elasticity for distance travelled is less than one (which, in developed countries, is normally the case). That provides a case for relatively higher taxes on travel, but there is an additional effect to consider. Congestion increases the costs of travel to work, and road prices that reduce congestion therefore increase labour supply and hence reduce the distortionary costs of labour taxation. They claim that there is an additional benefit from reducing congestion over and above the pure efficiency effect, justifying yet more gasoline taxation. However, if road capacity is optimally expanded to maintain an efficient level of congestion and if road users are already charged the long-run marginal cost of supply road space, then there is no additional charge.

Parry and Small (2002) estimate that the Ramsey component of the optimal gasoline tax would be 6–7 US cents per litre or € 100/’000 litres. The congestion feedback would be 0.3–2 cents per litre (the low figure being for the USA, the high figure for the UK, neither arguably applicable). Their estimates of the optimal gasoline tax (including accident and pollution externalities but with carbon tax at $5/tC and ignoring any optimal oil tariff) amount to US (2000) 95 cents/US gallon (€ 390/’000 litres) in the US and €530/’000 litres in the UK.

6 EMISSIONS TAXES AND THE “DOUBLE DIVIDEND”

If externalities are dealt with by tradable permits and if these are allocated free of charge to incumbent firms, as with the ETS, these firms will enjoy a rent transfer compared to the case in which the external costs are addressed by corrective taxation. Some economists have argued that imposing environmental taxes can deliver a “double-dividend” – double because they first improve efficiency by reducing pollution to optimal levels, and in addition allow the efficiency of the tax system to be improved by reducing more distortionary taxes.[31] The discussion of the Ramsey corrective case for additional fuel taxes considered above is different in that would apply even if the tax system were otherwise optimal, whereas proponents of the double dividend start from the claim that the existing tax system is sub-optimal.

There is considerable confusion created by the models used to demonstrate the existence of a double dividend. Note that any representative agent fiscal model misses the main point of distortionary taxation, which is to address issues of equity, so any argument deriving a marginal cost of public funds from such models is fatally flawed.[32] If the tax system is optimal, then the sole additional benefit from pollution taxes lies in the small

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[31] For discussions of the double-dividend hypothesis see e.g. Goulder (1995) and Smith (1998).

[32] If there is a single agent the optimal tax is lump sum.

overall reduction in taxes that the extra revenue raised allows (apart from the case of non-separability considered above).[33] If the tax system is not optimal, it needs to be shown why pollution tax revenue can be better targeted at reducing particularly distorting taxes while other tax revenue sources apparently cannot. Conceivably, the Government could be aware that a particular tax were inefficient (e.g. taxes on savings) but might be reluctant to reduce such a tax if it meant raising another tax, from which there would be bound to be vociferous losers. Perhaps public opinion would allow a virtuous pollution tax that could relax this constraint while they would be unwilling to accept another, less distortionary tax change.

In some cases there are potentially clear advantages in taxing emissions rather than allocating tradable permits, even in a certain world where the Weitzman uncertainty argument is irrelevant. The ETS scheme will raise the cost of marginal carbon-based electricity generation, and in a liberalised electricity market, raise the market-clearing price. If, as seems likely, the marginal generation is more carbon intensive than the average, there will be additional inframarginal rents to incumbents until entry of new capacity restores long-run equilibrium. If in addition generators receive permits that can be traded, they will be compensated for most of the extra costs and will enjoy all the extra revenue from higher prices as a windfall. The impact will fall on tradable energy-intensive industry (particularly aluminium) and final consumers. Provided new capacity is not allocated permits, output and investment decisions need not be distorted, but the Government will have foregone a sizeable quantity of revenue (£1.6 billion at the 2005 EUA price in the UK, or 0.34 of 1% of tax revenue) that could have been used to increase benefits or reduce taxes. The distributional impact is roughly the effect of a lump sum tax on all consumers financing a transfer to rather rich share-holders, and as such is unappealing, even if on a positive theory of instrument choice (see Aidt and Dutta, 2004) it is likely (and thus a costly constraint on feasible tax reforms).

7. THE CASE FOR HARMONIZATION

The standard case for harmonizing taxes within a customs area is to reduce internal trade distortions and enhance welfare, and possibly co-ordinate on a common effective external tariff (particularly relevant for oil). That becomes even more important with capital and labour mobility, as in the EU Single Market. If so, then the prime concern would be with differences in tax rates on inputs to production, and possibly for consumer products where consumers can arbitrage across frontiers (as with road fuels near country borders).

The CEC commissioned a paper on the impact of fuel taxation on technology choice for the Green Paper on Energy Security (EC, 2001a, Annex 2). The aim was to see whether fuel taxation distorted the choice of technology for new investment compared to no taxation (not compared to the appropriate level of carbon tax). The paper studied power generation, industrial steam raising, household space heating, and private cars, using tax and price data for 2000 and found surprisingly modest distortions. For domestic space heating Ireland and Spain are dissuaded from using gasoil instead of the more costly (pre-tax) natural gas, but otherwise

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[33] The formulae for optimal pollution taxes are affected by the presence of distortionary taxes in quite complex ways, as Atkinson and Stiglitz (1980, 14.5 and 16.2) demonstrate. In a similar vein, Bovenberg and de Mooij (1994) argue that distortionary taxes *reduce* the corrective tax compared to the simple Pigouvian formula. One interpretation is that imposing the Pigouvian tax without recognising its interactions with the rest of the tax system would *reduce* welfare (compared to the correct tax), the apparent opposite of a double dividend (but see Fullerton, 1997).

natural gas dominates pre and post-tax. Belgium, France, Germany and Sweden encourage diesel-powered cars instead of the preferred gasoline powered cars at 18,000 km/yr, though excises have no effect on the least-cost choice at 13,000 km/yr.

Even where fuel excises do not affect the choice of technique, their differing level affects the cost of production and hence potentially distorts trade within the EU. Very different diesel prices may favour foreign compared to domestic haulage (as argued in the UK) and may fail to properly charge for road use costs when vehicles transit without refuelling. There are other solutions to these problems, such as vignettes, but there are also strong pressures from the Commission to harmonize road fuel taxes to avoid more bureaucratic and intrusive alternatives.

Apart from road haulage, where fuel excises (and other vehicle excise duties) are a significant fraction of production costs, and a few energy-intensive industries (metallurgy, fishing, some chemical processes), energy taxes are a relatively small fraction of the final price, and are unlikely to lead to major trade distortions. In many cases, even at current natural gas and carbon prices, natural gas is so obviously the preferred choice where feasible (which rules out transport), that high oil and low coal taxes have relatively minor effects. That could cease to be true if natural gas prices were to rise and coal were to become the preferred fuel for power and steam raising. At that point the lack of intelligent taxation could have adverse effects, though the strict environmental constraints placed on coal burning in large combustion plants and the ETS may offset this risk. Moreover, natural gas is arguably the one fuel where a security premium (perhaps via the requirement to hold adequate natural gas in store) might well be justified, suggesting some benefits from a more rational approach to energy taxation.

This leads to the final argument for harmonizing taxes. If there is a logical set of energy taxes, and if these hold fairly uniformly across the EU (as they do for carbon taxes, and might approximately at least for road user charging), then most countries should have similar tax rates. The main reason why this might not be the case is that the Diamond-Mirrlees argument of not taxing inputs assumes that it is no more costly to collect value added than input taxes. Energy taxes are particularly cheap to collect, so it may well be that in less tax-compliant countries they remain an advantageous instrument compared to VAT and/or income taxes (Newbery, 1997). If different EU countries face different collection and compliance costs, they may well be advised to choose different energy tax structures, quite apart from the political opprobrium attached to changing the existing form of tax collection. EU energy taxes score quite well on the “silence of the plucked goose” test.

8. IMPLICATIONS FOR THE ELECTRICITY SECTOR

Coal was heavily protected in the EU until relatively recently, but in most countries is now priced at import parity, although in some countries (e.g. Denmark, Sweden) attracts a carbon tax. Heavy Fuel Oil (HFO) has been taxed at very different rates across the EU and is an important electricity fuel, as figure 2 above showed. Light fuel oil is potentially important for peaking plant (open-cycle gas turbines), and is very heavily taxed. IEA *Energy Price and Tax* data of gas tax rates very spotty. In 2001, 45% of electricity was generated from fossil fuels in the EU, 28% from coal, 5% from oil, and 13% from gas.

The effects of differential fuel taxes into electricity generation is potentially very distorting, although trend towards a single electricity market mandated by the EU Electricity Directives has put considerable pressure on member states to harmonise their electricity fuel policy, notably for coal. EU emissions standards and the ETS create further pressures for harmonisation. Perhaps as a result, some of the potential distortions now appear less serious, as the previous section suggested, while the move towards tradable permits for the more important power plant emissions should further erode these differential effects. Targets for and subsidies to renewables are best treated as mechanisms for funding the public good aspect of learning-by-doing, rather than potentially distorting (negative) taxes. Outside the EU, electricity is only traded to a limited extent between countries, and so one might argue that tax harmonisation of electricity fuels is less critical than for traded goods. Aluminium, however, is highly electricity-intensive and internationally traded, and will be affected by differential tax treatment of carbon across countries (less so by fuel taxes, as most aluminium is hydro-based, although fuel taxes will affect the marginal cost of electricity in the increasingly integrated EU electricity market).

9. CONCLUSIONS

Most energy taxes are excise taxes that fall on producers. Standard arguments imply that taxes should be concentrated on final consumption, raising the question addressed here of why energy should be taxed? Three justifications for energy excise taxes have been advanced and have merit within the EU and also for the US – as an optimal import tariff, where each trading bloc has considerable market power, as a carbon tax or equivalent permit charge to reflect global warming, and as a second-best method of charging vehicles for road use. For the EU and the US, the combination of the optimal tariff and carbon tax suggest oil taxes of between 36 to 171 €/TOE with a median value of 79 €/TOE (or 26 US cents/US gallon of gasoline). If road fuel taxes are intended to cover road costs, the gasoline tax (including the optimal tariff and carbon tax) might be as high as 565 €/’000 litres (2002 prices, or $2/US gall.)

The fourth justification for using energy excise taxes is to correct failures elsewhere in the tax system (primarily failures due to income tax evasion), although the “double dividend” argument is suspect. The related argument that energy taxes on consumption (i.e. differential rates of VAT on energy as in the UK) can improve the redistributional impact of the tax system also relies on the inadequacy of the income tax and/or benefit system. That is not to deny that politicians often defend distortionary energy taxes on distributional grounds, but the public finance case is usually weak. The opposite argument that because some fuels are price inelastic they should be heavily taxed on revenue raising grounds is equally invalid, given full coverage of direct and indirect taxes, although it has some appeal if tax evasion is a serious problem (Dixit and Newbery, 1985).

Global warming argues for a carbon tax, but political expediency and the need to decentralise the public good of reduced GHG emissions favours emission trading schemes rather than fuel taxes. These are also attractive for SO_2 and NO_x, where the damage caused depends on the extent of clean-up and possibly on location and time, so the permit markets can be made regional and time-limited. Emissions charges or taxes rather than fuel taxes are in any case potentially better targeted on the harm done. The inefficiencies caused by emission price volatility can be reduced by allowing inter-temporal trades, although the loss of tax revenue has fiscal opportunity costs (Bovenberg and Goulder, 2002).

Fiscally the most important energy taxes are those on road transport fuels. They can be defended as a second-best mechanism for charging for road use and environmental damage. The European Commission adopted its Transport White Paper on the future of the common transport policy on 18 July 2001, which sets out a new charging policy:

> The principles for infrastructure charging will be aligned and fuel taxation for commercial use harmonized. The integration of external costs must also encourage the use of modes with a lower environmental impact and facilitate investment in new infrastructure. The current Community rules need to be replaced by a modern framework for charging infrastructure use.

Until more efficient charging methods are evolved, fuel taxes will continue to play an important part in charging for road use. The two main arguments for harmonizing commercial road fuel taxes are that it will discourage tax arbitrage between countries and encourage the adoption of sensible road tax policies. It seems likely that the efficient levels of road user charges are more similar across the EU than the present pattern of diesel taxes (whose unweighted coefficient of variation, CV, was 22% in 2001). The same arguments apply with somewhat less force to gasoline taxation (CV 15%), as this falls primarily on final consumption. The main distortionary effect of differential gasoline and diesel taxes is the inappropriate choice of diesel for passenger vehicles. This can be discouraged by increased vehicle excise duties on diesel cars.

The other striking feature about energy taxation is the low taxation on coal relative to a sensible carbon tax policy, and the very variable taxes on LFO and HFO. Natural gas is also relatively under-taxed compared to its main substitutes in power generation, which, given the heavy import dependence on insecure supply sources, is somewhat surprising. Protecting domestic customers from high energy taxes is politically understandable in colder countries where fuel poverty continues to be a serious problem, although targeted subsidies are preferable and feasible. Ensuring efficient relative prices of power generation fuels is a logical counterpart to pressures to integrate the single European electricity market. The ETS, by creating an EU wide market for CO_2 will go some way to addressing these failures, and ought to prompt a more systematic rethink of at least European energy taxation.

There is always likely to be political resistance to energy tax reform, either from voters or finance ministers. The UK collects substantial excess revenues from energy taxes compared to the EU proposals, and the Chancellor of the Exchequer has indicated that they are justified for financing social expenditures on health and education. Countries that have to raise their transport fuel prices risk arousing the organised opposition of transport operators with the support of the motoring public, as was demonstrated dramatically in Britain and France in 2000. Nevertheless, as energy markets become more integrated, and permit trading becomes more common for addressing pollution problems, pressures for harmonization will continue and may lead to steady, if slower than desired, convergence.

References

Aidt, T. S. and J. Dutta (2004), ‘Transitional politics: emerging incentive-based instruments in environmental regulation’, *Journal of Environmental Economics and Management*, **47**, 458-79

Atkinson, J. and N. Manning (1995), ‘A survey of international energy elasticities’, ch 3, 47-105 in T. Barker, P. Ekins and N. Johnstone (eds.) *Global Warming and Energy Demand*, London and New York: Routledge

Atkinson, A.B. and J.E. Stiglitz (1980) *Public Economics,* London: McGraw Hill

Austvik, O.G. (1997)’Petroleum taxation and the prices of oil and gas’. In Aakvaag, T. and F. Mueller (eds.) *European Energy Supply at the Turn of the Century. Natural Gas and Electricity*, Ebenhausen: Stiftung Wissenshaft und Politik.

André, M., D. Hassel and F-J. Weber (1998) *Development of short driving cycles*, INRETS Report LEN9809, May.

BeTa (n.d.) *Benefits Table database: Estimates of the marginal external costs of air pollution in Europe*, EC Commission DG Environment available at http://europa.eu.int/comm/environment/enveco/air/betaec02a.pdf

Bovenberg, A.L. and R.A. de Mooij, (1994) ‘Environmental levies and distortionary taxation’ *American Economic Review*, **84**, 1085-1089

Bovenberg, A. L. and L.H. Goulder, (2002) ‘Environmental Taxation and Regulation’ in A. Auerbach and M. Feldstein (eds.) *Handbook of public economics*. Volume 3. Amsterdam; London and New York: Elsevier Science, North-Holland, 1471-1545

Clarkson, R. and K. Deyes, (2001) *Estimating the Social Cost of Carbon Emissions,* Environment Protection Economics Division, Department of Environment, Food and Rural Affairs: London, Aug.

Corlett, W. J., and Hague, D. C. (1953), ‘Complementarity and the excess burden of taxation’, *Review of Economic Studies*, 21: 21–30.

Deaton, A. (1987), ‘Econometric issues for tax design in developing countries’, in D. M. Newbery and N. Stern (eds), *The Theory of Taxation for Developing Countries*, New York: Oxford University Press.

Deaton, A. and Stern, N. (1986), ‘Optimally uniform commodity taxes, taste differences and lump-sum grants’, *Economics Letters*, 20: 263–6.

Delucchi, M. (1997) *The annualized social cost of motor-vehicle use in the U.S., 1990-91: summary of theory, methods, data and results*, Davis, CA: Institute for Transportation Studies

DEFRA (2004), *Digest of Environmental Statistics*. Department for Environment, Food, and Rural Affairs at http://www.defra.gov.uk/environment/statistics/des/index.htm.

Department of Health (1998) *Quantification of the effects of air pollution on health in the United Kingdom*, COMEAP, London: HMSO

Dixit, A.K. and Newbery, D.M. (1985) ‘Setting the Price of Oil in a Distorted Economy’, *Economic Journal* (1985) Supplement, 71-82.

Dubroeucq, F. and A.D. Ellerman (2004) 'Sources of emission reductions: evidence for US SO2 emissions 1985 – 2002' Cambridge CMI EP 43 at http://www.econ.cam.ac.uk/electricity/publications/wp/index.htm

Diamond, P.A. and J.A. Mirrlees (1971) `Optimal taxes and public production I: production efficiency', *American Economic Review*, **61**, 8-27

EC (2001a) *Towards a European Strategy for the security of energy supply*, Green paper COM(2000) 769 final, Luxembourg: European Communities

EC (2001b) *Excise Duty Tables*, Brussels, EC DG Taxation and Customs Union Tax Policy, available at: http:/europa.eu.int/comm/taxation_customs/publications/info_doc_

EPA (1996) *National Air Quality and Emissions Trends Report*, Document number 454/R-97-013), US Environmental Protection Agency

EPA (2004) *NO_x Budget Trading Program 2003 Progress and Compliance Report*, US Environmental Protection Agency available at http://www.epa.gov/airmarkets/cmprpt/nox03/noxreport03.pdf

Eurostat (2004) *Structures of the Taxation Systems in the European Union*, Luxembourg Eurostat Series C

Farzin Y.H. and O. Tahvonen, (1996) ‘Global carbon cycle and the optimal time path of a carbon tax’, *Oxford Economic Papers*, **48**, 515-36.

Franzén, M. and T. Sterner (1995), ‘Long-run demand elasticities for gasoline’, Ch 4, 106-120 in T. Barker, P. Ekins and N. Johnstone (eds.) *Global Warming and Energy Demand*, London and New York: Routledge

Fullerton, D. (1997) ‘Environmental levies and distortionary taxation: comment’, *American Economic Review*, **87**, 245-51

Gately, D. and H.G. Huntington (2002) ‘The asymmetric effects of changes in price and income on energy and oil demand’, *Energy Journal*, 23 (1), 19-56

Goodwin, P. J Dargay and M Hanly (2004) ‘Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review’ *Transport Reviews* **24**(3) 275-92.

Goulder, L.H. (1995) ‘Environmental taxation and the “double dividend”: a reader’s guide’, *International Tax and Public Finance*, **2**(2), 157-83

Graham, D. and S. Glaister (2002), ‘The demand for automobile fuel: A survey of elasticities’, *Journal of Transport Economics and Policy*, 36(1), 1-25.

Hoel, M. and L. Karp (2001) ‘Taxes and quotas for a stock pollutant with multiplicative uncertainty’ *Journal of Public Economics*, **83**, 91-114

IEA (1992) *Energy Prices and Taxes, Second Quarter, 1992*, OECD, Paris.

IEA (2004) *Energy Prices and Taxes, First Quarter, 2004*, OECD, Paris.

Karp, L. and Newbery, D.M. (1991a) `Optimal tariffs on exhaustible resources', *Journal of International Economics*, **30**, 285-299.

Karp, L. and Newbery, D.M. (1991b) `OPEC and the U.S. Oil Import Tariff', *Economic Journal Supplement*, **101**, 303-13.

Karp, L. and Newbery, D.M. (1992) `Dynamically Consistent Oil Import Tariffs', *Canadian Journal of Economics*, Feb 1992, 25(1), 101-21.

Karp, L. and Newbery, D.M. (1993) `Intertemporal Consistency Issues in Depletable Resources', ch 19, pp 881-931, in *Handbook of Natural Resource and Energy Economics*, Vol III, eds A V Kneese and J L Sweeney, Amsterdam: North-Holland.

Kemp, M.C. and N.V. Long (1980), ‘Optimal tariffs and exhaustible resources’, essay 18 in M.C. Kemp and N.V. Long (eds.) *Exhaustible resources, optimality and trade*, Amsterdam: North-Holland

Laurie, R.A. (2001), ‘Distributed generation: reaching the market just in time’, *The Electricity Journal*, Mar 87-94.

Maddison, D (1998) `Valuing changes in life expectancy in England and Wales caused by ambient concentrations of particulate matter', mimeo, CSERGE, University College, London

Maskin, E. and Newbery, D.M. (1990) ‘Disadvantageous Oil Tariffs and Dynamic Consistency’, *American Economic Review*, 80 (1), March, 143-56.

McCubbin, D.R. and M.A. Delucchi (1996) *The social cost of the health effects of motor-vehicle air pollution*, report 11 in series: *The annualized social cost of motor-vehicle use in the U.S., based on 1990-91 data*, Davis, CA: Institute for Transportation Studies

Mayeres, I. (1999), 'The distributional impacts of policies for the control of transport externalities: an applied general equilibrium model', Fondazione Eni Enrico Mattei (Global Network of Environmental Economists), Working Paper 8.99. Available at www.feem.it/web/activ/_wp.html.

Mirrlees, J. A. (1979), 'The theory of optimal taxation', in K. J. Arrow and M. D. Intrilligator (eds), *Handbook of Mathematical Economics*, Amsterdam: North Holland.

Newbery, D.M. (1976) 'A paradox in tax theory: Optimal tariffs on exhaustible resources', SEER Technical Paper, Economics Department, Stanford University

Newbery, D.M. (1988) `Road User Charges in Britain', *Economic Journal* (Conference), 161-176.

Newbery, D.M. (1989) `Cost recovery from optimally designed roads', *Economica*, vol 56, 165-85.

Newbery, D.M. (1990) `Pricing and Congestion: Economic Principles Relevant to Pricing Roads', *Oxford Review of Economic Policy'*, Vol 6 (2), 22-38

Newbery, D.M. (1992) `Should carbon taxes be additional to other transport fuel taxes?' *Energy Journal*, vol 13 No 2, 49-60.

Newbery, D.M. (1995) `Removing coal subsidies: Implications for European electricity markets', *Energy Policy*, **23**(6), 523-33.

Newbery, D. M. (1997) `Optimal Tax Rates and Tax Design during Systemic Reform', *Journal of Public Economics*, 63, 177-206

Newbery, D.M. (1998) *Fair payment from road-users: A review of the evidence on social and environmental costs*, Report published by Automobile Association, February.

Newbery, D.M. (2004) 'Road User Charges', in S. Cnossen (ed.) *Taxes on Pleasure* OUP, forthcoming

Newbery, D.M. and G Santos, (1999) `Road Taxes, Road User Charges and Earmarking', *Fiscal Studies*, **20**(2), 103-32

Parry, I. W. H., and Small, K. A. (2002), 'Does Britain or the United States have the right gasoline tax?', Resources for the Future, Discussion Paper 02-12. Available at www.rff.org/disc_papers/2002.htm forthcoming in *American Economic Review*

Pesaran, M.H, R.P. Smith and T. Akiyama, (1998) *Energy Demand in Asian Developing Economies*, 1998, Oxford: Oxford University Press

Rowat, C. (2000) *Additive externality games*, PhD, Cambridge University. http//www.econ.cam.ac.uk/phd/CIR20/master3.pdf

Smith, S (1998) 'Environmental and public finance aspects of the taxation of energy', *Oxford Review of Economic Policy*, **14**(4), 64-83.

Stern, N. (1987), 'The theory of optimal commodity and income taxation: an introduction', in D. M. Newbery and N. Stern (eds), *The Theory of Taxation for Developing Countries*, New York: Oxford University Press.

Tahvonen, O. (1997) 'Fossil fuels, stock externalities, and the backstop technology', *Canadian Journal of Economics*, **XXX** (4), 855-74

Ulph, A. and D. Ulph (1994) 'The optimal time path of a carbon tax', *Oxford Economic Papers*, **46**, 857-68

Weitzman, M.L. (1974) 'Prices vs. Quantities', *Rev. Econ. Stud.* **41** (4), 477-91

Wirl, F. (2003) 'Tragedy of the commons in a stochastic dynamic game of a stock externality', University of Vienna Working Paper 45

Appendix: Deriving the optimum Nash-Cournot import tariff

Let $V^j(p + \tau^j)$ be the money value of utility for a consumer in country j facing a domestic price of oil $p + \tau^j$. If the country produces an amount y of oil, then the total welfare of the country is $W^j = V^j(p + \tau^j) + p.y + \tau^j q^j$. By Roy's identify, $q^j = V^j_p$ where the subscript indicates the derivative with respect to p.

The optimum tariff at date t can be found from the first order condition

$$\frac{\partial W}{\partial \tau} = (V_p + y)\frac{\partial p}{\partial \tau} - \tau V_{pp}\left(1 + \frac{\partial p}{\partial \tau}\right) = 0, \qquad \text{(A1)}$$

suppressing references to time and country. On the assumption that producers (including producers within the country) have already made their output decisions at the moment tariffs are chosen, total supply at date t, $X(t)$, is inelastic, but supply must equal total demand, Q:

$$X = -\sum_j V^j_p \,. \qquad \text{(A2)}$$

This can be differentiated with respect to τ^i (noting that X is independent of τ^i) to give

$$\frac{\partial p}{\partial \tau^i} = \frac{-V^i_{pp}}{\sum_j V^j_{pp}} \,. \qquad \text{(A3)}$$

This can then be used in (A1) to solve for τ^i:

$$\tau^i = \frac{y^i + V^i_p}{-\sum_{j\neq i} V^j_{pp}} = \frac{y^i - q^i}{\sum_{j\neq i} \partial q^j / \partial p} \,. \qquad \text{(A4)}$$

For the linear case in which $V^i = ½\alpha^i\beta(p^* - p - \tau^i)^2$, consumption demand is given by $q^i = \alpha^i \beta(p^* - p - \tau^i)$, where α^i is the share in untaxed output, $Q = \beta(p^* - p)$, the formula for the tariff is

$$\tau^i = (\alpha^i - y/Q)(p^* - p) \,.$$