CHAPTER 3

SECTORAL DIMENSIONS OF SUSTAINABLE DEVELOPMENT: ENERGY AND TRANSPORT

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3.1 Introduction

Energy use is an important source of environmental pollution. Reducing emissions per unit of energy consumed and reducing the energy intensity of economic growth are therefore important components of sustainable development. Faced with this challenge, informed observers range from very pessimistic, to positively optimistic. The resulting debate has been acrimonious, passionate and not always illuminating, as the recent controversies surrounding Lomborg's book *The Skeptical Environmentalist* demonstrate.[137] Environmental pessimists argue that pollution is inexorably linked to fossil energy consumption and that individually selfish countries see little benefit in reducing fossil energy intensity. Economic pessimists are prepared to accept that pollution could be reduced by intelligent tax policies, but that governments invariably choose very much less efficient policies that are likely to cost considerably more than the benefits. Thus, Nordhaus and Boyer[138] argue that the costs of the Kyoto Protocol are seven times the benefits, and almost eight times more than a cost-effective strategy. The high and unjustified level of cost in turn will lead to the policies being abandoned, rather than being replaced by more efficient alternatives.

Optimists take up from where the pessimistic economists leave off. They accept that policies are frequently poorly designed, but take encouragement from a number of positive trends. They accept that tax or price-guided solutions to addressing the external costs of environmental pollution are normally superior to quantity controls or standards, and that policy makers have a preference for controls and standards. They note that predictions of the costs of imposing standards often turn out to be too high, as unforeseen innovations allow these standards to be met at modest and acceptable cost. Faced with a challenging quantitative target, rather than a tax that can be passed on to final consumers, technologists redirect and concentrate their creative efforts to deliver surprising improvements, while managers make cost-effective investments or change production practices.

A second defence of a more optimistic assessment is that where current solutions appear inefficient and poorly directed, there is an incentive first to improve the estimates of costs and benefits, and then to encourage benefit-cost tests of proposed remedies. In the United Kingdom, measures to address emissions have shifted from a requirement to install BAT (best available technology) to BATNEEC (best available technology not entailing excessive cost). Excessive cost logically means costs that outweigh the benefits, creating a demand for a quantification of the benefits of emissions reduction. This trend has been reinforced by a parallel trend towards electricity and gas liberalization (often associated with privatization) and hence a replacement of energy policy based on physical planning with the need for market-friendly alternatives, such as taxes or tradeable permits. If taxes are to be set, or if quota prices feed through to final energy prices, then voting consumers will be able to judge the cost of meeting environmental objectives. That in turn is likely to force a reappraisal of whether the costs are justified, as well as stimulating developments to lower the cost of delivering those benefits. This should lead to a better balance between the costs of reductions and the benefits of improved environmental quality.

Optimists also expect that the cost of reducing emissions per unit of useful energy delivered may not be as high as feared, providing sufficient time is given for adapting the capital stock and developing new

[137] B. Lomborg, *The Skeptical Environmentalist* (Cambridge, Cambridge University Press, 2001); see the critique in *Scientific American*, January 2002, and the resulting debate partly reported on Lomborg's website (www.lomborg.org).

[138] W. Nordhaus and J. Boyer, "Requiem for Kyoto: an economic analysis", *Energy Journal*, special issue on "The costs of the Kyoto Protocol: a multi-model evaluation", 1999, pp. 93-130.

technologies. Long-run energy price elasticities are notoriously hard to estimate,[139] but in some sectors (e.g. transport) could be above unity (in absolute terms). Emissions price elasticities are necessarily higher than energy price elasticities, and for many pollutants are considerably higher. Large reductions may be possible for modest tax increases, and the environmental taxes should allow other distortionary taxes (ultimately on labour supply) to be beneficially reduced.

The optimists are optimistic because they believe that improving the social efficiency of energy use (reducing emissions to cost-justified levels) requires reasonably well-defined policies, and that ultimately the political process will be forced to make more rather than less efficient policy choices. Economic pessimists believe that the difficulties of reaching efficient multilateral agreements make this unlikely. Both, however, agree that well-designed policies can substantially reduce the costs of meeting any given level of environmental improvement. This paper will therefore concentrate on identifying what such policies would look like, and how they may be quantified and implemented. We start with a brief review of the evolution of energy policy, and the determinants of energy use at the economy and sectoral level. This leads to the link between energy use and environmental pollution. The last part addresses the design of policy to achieve efficient energy use, and the extent to which countries are moving towards such policies.

3.2 The evolution of energy policy

Traditionally, energy policy was primarily concerned with security of supply and accessibility at acceptable prices to the population. These concerns remain, and are reflected in requirements to carry fuel stocks, provide adequate gas storage, and adequate electricity capacity. Universal service obligations and concerns over fuel poverty continue to influence energy taxation and pricing in often perverse ways. Security concerns were given fresh impetus by the 1973 oil embargo, that also precipitated the next major concern – that of the finiteness of energy resources. The Club of Rome's doom-laden predictions of imminent scarcity seemed to be supported by the sharp increase in the oil price.[140] Natural resource economists appealed to Hotelling and argued that the scarcity rent of exhaustible resources would rise inexorably at the rate of interest, so that projections of future oil prices made in the 1970s reached alarming levels when projected to the end of the century. The United States embarked on a major research programme to develop alternative sources of energy, ranging from exploiting tar sands to exotic methods of developing electricity by photovoltaics, magneto-hydrodynamics or fusion reactors. Several countries launched major nuclear programmes with France proceeding furthest down this route.

The shift from oil as the marginal fuel for electricity generation back to coal and the rapid penetration of gas depressed demand for oil and softened prices. Oil prices halved in 1986 when Saudi Arabia reasserted its position as swing producer and controller of world oil prices. In OECD countries as a whole, the share of oil in total primary energy supply (TPES) fell from 53 per cent in 1973 to just under 41 per cent in 2000. About three fifths of oil is now used in transport (overwhelmingly road transport) with only a fifth used in industry and a fifth in all other sectors (where two thirds goes to residential use). In OECD Europe the pattern of oil consumption is similar but the oil share in TPES has fallen even more rapidly from 54.5 per cent in 1973 to 38.8 per cent in 2000.[141]

Falling oil prices, rapid gas development and the delayed resumption of economic growth after the oil shocks and international financial crises of the 1970s and early 1980s raised new concerns. If oil did not appear to be running out, reserves of gas appeared large and growing, coal appeared abundant and increasingly internationally traded, and concerns about the environment rose rapidly up the political agenda. Environmental pollution was not new, and most industrial countries suffered heavy and damaging pollution from smoke until various clean air laws were enacted. Controls on particulate emissions from power stations and the shift from coal to gas in the domestic sector led to dramatic environmental improvements in OECD countries, if not in the Soviet bloc. Concern shifted to acid rain, primarily from power stations, and smog, primarily from nitrogen oxides (NO_X) produced by road transport.

Transboundary pollutants, particularly sulphur dioxide (SO_2), were addressed in a series of international agreements and translated into national emission limits. As a result, sulphur dioxide emissions have been dramatically cut, partly by flue gas desulphurization, and partly by the shift from coal to gas in electricity generation. Similarly, increasingly stringent tailpipe emissions limits have dramatically reduced pollution from road transport, to the point that some of the worst affected areas such as Los Angeles now enjoy cleaner air despite massively greater traffic than in the early postwar years.

[139] T. Barker, P. Ekins and N. Johnstone (eds.), *Global Warming and Energy Demand* (London, Routledge, 1995).

[140] D.H. Meadows, D.L. Meadows, J. Randers and W. Behrens III, *Limits to Growth* (New York, Universe Books, 1972).

[141] OECD, *Energy Balances of OECD Countries 1999-2000* (Paris, OECD, 2002).

The health effects of air pollution have been carefully studied and quantified.[142] The challenge, which is increasingly accepted, is to encourage socially efficient levels of abatement. Whether this is best achieved by taxes or standards, or some combination, depends on the fuel, the use and the type of user. The implication is that abatement measures must pass a social cost-benefit test, which requires an estimate of the monetary value of the damage caused.[143] Although internalizing these pollution costs still presents an important challenge to the energy and transport sectors, and will be discussed below, concerns have shifted towards a more pervasive and difficult pollutant, carbon dioxide, CO_2. The potential of increased levels of carbon dioxide to cause global warming has moved from scientific theory to widely accepted fact, reflected in the Kyoto Protocol to reduce such emissions in the near term, and to contemplate more dramatic reductions over the next 50 years.

Carbon dioxide emissions are far more intractable than other air pollutants, as it is difficult and extremely expensive to prevent or reduce CO_2 emissions from fuel combustion. The only practical methods for reducing CO_2 emissions are to shift to less carbon-intensive energy sources (and renewables, hydro,[144] wind, and nuclear have essentially zero emissions) and/or to reduce energy consumption.

3.3 Sustainable development

The watchword for energy policy is now not just security but sustainability, aptly defined by the Brundtland Commission as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This concern with sustainability also reflects earlier worries about the exhaustion of fossil fuels; and for transport fuels, oil exhaustion is probably a more imminent concern than excessive global warming. Coal reserves dwarf oil and gas reserves, and in that sense oil and gas are potentially smaller contributors to likely future greenhouse gas emissions, although nonetheless significant.

Old-style energy policy shared many of the characteristics of Soviet planning, being quantity driven and not particularly susceptible to rational economic calculations. State owned electricity industries built plants under central guidance, domestic coal was protected by a complex web of taxes and contracts with the electricity industry, gas was denied to electricity generators (as a noble fuel too valuable for simply raising steam), and in some countries district heating schemes were built by *diktat* or with massive subsidies. All this started to change following Alfred Kahn's successful attack[145] on regulation in the airline industry and the liberalization of traditional utilities, first telecoms and then gas and electricity. Privatization in Europe, unbundling and increasing attempts to use competitive markets rather than regulation for setting prices unleashed dramatic changes in the energy sector and forced a reappraisal of energy policy.

This became clear in Britain soon after the electricity supply industry was restructured and privatized in 1989-1990. To ensure a satisfactory sale and to provide a smooth transition to an unregulated electricity wholesale market, the government put in place three-year contracts for the purchase of coal and the sale of electricity. As the end of these contracts approached, it became clear to an increasing number of observers (and finally to the government) that there would be a dramatic decrease in the price and quantity of British coal that would be purchased in future, partly because imported coal was cheaper, but mainly because the "dash for gas" was well underway. The government was criticized for not acting to protect the coal industry (i.e. the powerful miners) and for lacking any energy policy. Energy policy in Britain, as in most countries, is almost by definition politicized, for to leave the choice of fuel to an undistorted market is thought to indicate the lack of an energy policy. The government felt the need to defend its unprecedently non-interventionist stance after the collapse of the coal market in 1992 by arguing that: "the aim of the government's energy policy is to ensure secure, diverse and sustainable supplies of energy in the forms that people and businesses want, and at competitive prices".[146] "The government's energy policy therefore centres on the creation of competitive markets."[147]

Concerns over the possible tension between liberalization and sustainability (the new concern of energy policy) have been expressed in various

[142] For recent estimates, see the papers presented at the UNECE symposium, *The Measurement and Economic Valuation of the Health Effects of Air Pollution* (London), 19-20 February 2001 (www.unece.org/env/nebei/health_benefits_workshop.htm).

[143] 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.

[144] Large-scale hydro can, by inundating plant matter, lead to decomposition and the release of methane, a far more potent greenhouse gas than CO_2. Renewables absorb CO_2 from the air and release it again when burned and so produce no net emissions provided they are replaced and not mined.

[145] A. Kahn, *Letting Go: Deregulating the Process of Deregulation*, Institute of Public Utilities and Network Industries, Michigan State University (East Lansing), 1998.

[146] Department of Trade and Industry, *The Prospects for Coal: Conclusions of the Government's Coal Review*, Cm 2235, HMSO (London), 1993, p. 12.

[147] Ibid., p. 3.

International Energy Agency (IEA) reports[148] as well as by the European Commission. Thus, one of the criticisms levelled at electricity liberalization is that "if the internal market causes electricity and gas prices to fall, this in turn would probably lead to an increase in consumption" causing an increase in pollutant emissions and hindering attempts to honour commitments made in Kyoto.[149]

Economists and, increasingly, public bodies advocating more market-friendly policies and interventions, argue that there is no inevitable tension between liberalization and sustainability, providing that market prices are corrected by taxes to reflect all external costs, in this case those that cause social and environmental damage. Thus the British government, in its report *Sustainable Development: The UK Strategy* interpreted sustainability for transport as requiring that "users pay the full social and environmental cost of their transport decisions, so improving the overall efficiency of these transport decisions for the economy as a whole and bringing environmental benefits".[150] The same holds not just for transport, but for any decisions involving fuel.

If users must pay the full social cost of their decisions, society will be compensated for the environmental damage done, and can use the funds to make other environmental improvements, or to accumulate more physical and human capital, making the next generation richer and better able to address environmental issues. The benchmark that users should pay the full social and environmental cost is therefore central to the idea of a decentralized and non-coercive approach to dealing with environmental problems. It is completely compatible with liberalized energy markets, providing that the social costs are reflected in market prices, normally best done by corrective taxes.

At this point it is useful to distinguish between stock and flow pollutants. Flow pollutants cause damage while they are being produced, and the damage ceases when emissions stop. The larger part of the social and environmental cost of SO_2 and NO_X is the health damage caused by inhalation. Reducing emissions of these pollutants has an immediately beneficial effect on air quality as it affects health. Stock pollutants in contrast add to the stock of the pollutant, and it is the size of this stock rather than the rate of addition that causes the damage. Acid rain damages the eco-system by increasing the acidity of the environment, while CO_2 emissions add to the total stock of atmospheric CO_2 that is the main cause of global warming.

Flow pollutants are in principle easier to price than stock pollutants, as we only need to know their instantaneous rate of damage, normally through dose-response relationships, in ways illustrated below. In contrast, the damage done by stock pollutants endures over time, and will need an accounting of the damage done at each future period (that is likely to depend on future emissions as well and also on the discount rate). Future emissions are hard to predict and will likely depend on future technical progress, while the choice of a discount rate is also controversial.

The practical implications of this is that some energy-related pollutants lend themselves better than others to market solutions such as taxes (although standards may also be important where measuring emissions is difficult). Carbon dioxide is an interesting case for, on the face of it, it is the pollutant for which a tax solution is best fitted, as the damage done is directly proportional to the carbon content of the fuel to be burned, and does not depend on where or how that fuel is burned. Contrast that with NO_X, emissions of which depend on the temperature at which the fuel is burned, how it is burned, whether it is subject to tailpipe clean up, and where the damage caused depends on when and where it is released. Nevertheless, the correct or appropriate carbon tax to levy depends on reaching agreement across country borders, as well as on future CO_2 emissions. Not surprisingly, the range of estimates of the appropriate carbon tax is embarrassingly wide.

That suggests breaking the question of how to identify the right energy policy for sustainable development into a number of separate components. The first question to examine is what determines the demand for energy (and of different fuels), as other things being equal, a reduction in energy used will reduce the problem. If it appears that energy intensities can be significantly reduced, then the gains from intelligent policy are likely to be large. The second stage is whether and to what extent it is possible to reduce pollutants per unit of energy, since these are the ultimate source of the damage. Even if we cannot reduce energy use beyond a certain point, if it is possible to reduce the pollution per unit of energy, then it should be possible to go considerably further towards sustainable development.

Once the potential for improvement has been established, the next step is to encourage socially efficient choices (of energy and emissions abatement). That requires three conditions – first, that decision makers confront the right relative prices; second, that decision makers can identify and access the efficient

[148] IEA, *Energy Policies of IEA Countries, 1998 Review* (Paris), 1998.

[149] *Opinion of the Economic and Social Committee*, Official Journal of the European Communities, C 36 E, 8 February 2002, pp. 10-19.

[150] HMSO, *Sustainable Development: the UK Strategy,* Cm 2426 (London), 1994, pp. 6 and 169.

choice; and finally, that technical progress is directed to delivering the best future choices. Getting the prices right means correcting for the social costs of the choices, as well as avoiding tax-induced or other distortions. Ensuring that decision makers choose efficiently if prices are right is more complex. It requires that agents are well-informed, rational and have the right incentives to make efficient choices. Failures here may be identified by benchmarking companies (or other decision-making units in the public or domestic sector) against best practice, and may be explained by a lack of information or a lack of incentive. Agents may not be aware of the energy efficiency of the products they buy, or of the full costs of their operation. If they delegate decisions, their agents may not have sufficiently strong incentives for efficient choices, particularly where the benefits are hard to measure and occur with a lag.

A large part of the sustainability policy agenda is directed to providing information, benchmarking, auditing and stimulating research in promising directions. However, if the prices facing decision makers systematically diverge from their socially efficient level, much of this effort will be undermined, including the incentives to develop appropriate new technologies. The main thrust of this paper will therefore be on the rationality of the economic signals facing agents when making energy and pollution abatement decisions.

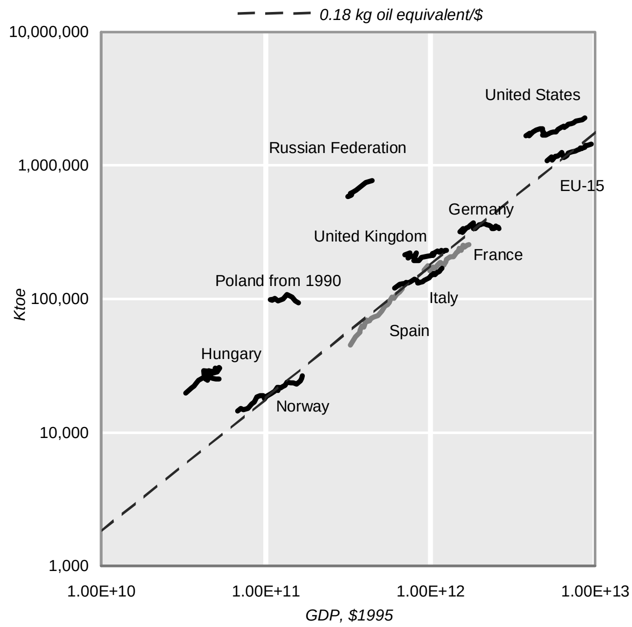
3.4 Energy use and growth

Chart 3.4.1 graphs the relationship between energy use – measured in thousands of tonnes of oil equivalent (ktoe) – and GDP at constant 1995 dollars, using World Bank data.[151] The approach taken in this paper is to concentrate on certain countries and groups of countries that span the range of UNECE countries (with the intentional exception of Japan). The main emphasis is on Europe, where we distinguish the EU countries as a group as well as some member states, Norway, several of the accession transition economies (Hungary, Poland, and sometimes also the Czech Republic), Russia and the United States. Each point in the graph is the energy use in a particular year for that country or group, and the graphs therefore show the evolution over time of the relationship between energy use and GDP. The graph is double logarithmic and the country slopes give the elasticity of energy use with GDP. The line of 0.18 kilogram (kg) oil equivalent per 1995 dollar (which is the average over the period for the EU) indicates a unit elastic relationship in

CHART 3.4.1

Energy use in relation to real GDP, 1972-1999

($1995)



Source: World Bank online database (www.worldbank.org/data/).

which a 1 per cent increase in GDP would lead to a 1 per cent increase in energy consumption.

It is clear that GDP is a main determinant of energy use, but it is also clear that some countries, particularly the transition economies and the United States, are notably more energy intensive than the EU countries. It is less obvious from the graph that in most countries energy intensity (toe/$) has been falling slowly (by 1.2 per cent per annum in the EU and 1.9 per cent per annum in the United States), while the variation in energy intensity across the EU as well as the United States has also been decreasing, indicating some convergence to a common energy intensity.

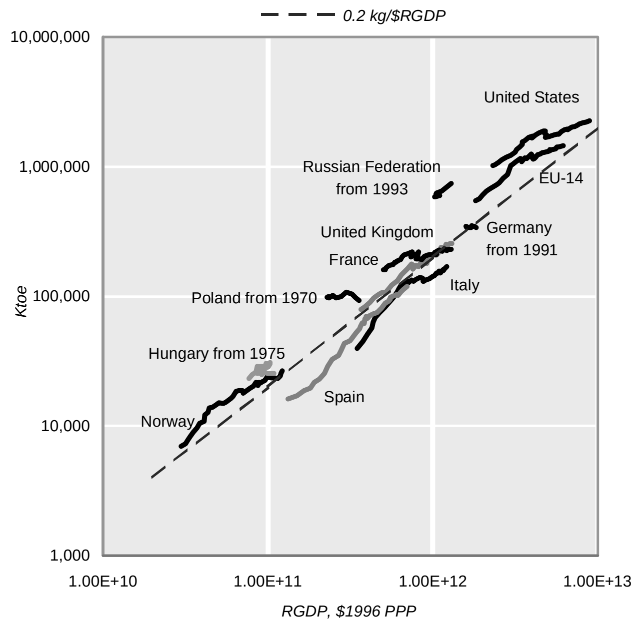
Chart 3.4.2 shows the relationship between energy use and real GDP (RGDP) at international prices or purchasing power parity (PPP).[152] This is arguably a better measure of relative standards of living, and corrects for the lower cost of non-tradeable goods in poorer countries (and some of the distortions caused by taxes and tariffs). This chart covers a longer period than chart 3.4.1 (from 1960 for most countries against 1972 in chart 3.4.1). For almost every country except Russia the ratio of RGDP to $GDP is roughly constant from 1972-1999, although it varies widely

[151] The data are available in electronic form in the World Bank's World Development Indicators Database, summaries of which are published annually in the *World Development Report*.

[152] Taken from Penn World Tables. The latest version can be accessed at (datacentre2.chass.utoronto.ca/pwt/).

CHART 3.4.2

Energy use in relation to real GDP at purchasing power parity, 1960-1999
($1996, PPP)



Source: World Bank online database (www.worldbank.org/data/).

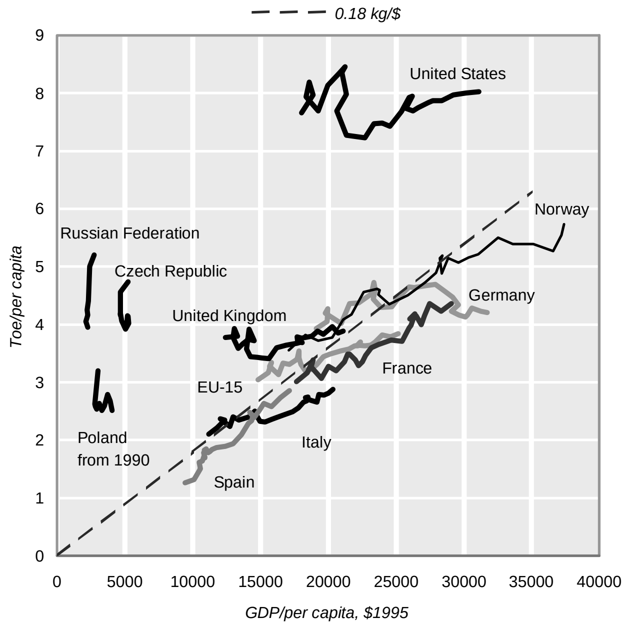
across countries.[153] The result is to move the transition economies closer to the unit elastic line drawn through the EU average intensity.

Charts 3.4.3 and 3.4.4 show energy use per capita in relation to the two measures of income per capita, this time on arithmetic scales. Again, the longer graphs in chart 3.4.4 reflect the longer time period covered (except for the central European countries). Lines of constant slope through the origin represent constant energy intensities (ktoe/$) and the graph for Russia (as in charts 3.4.1 and 3.4.2) shows decreasing energy use with a fall in income over time, in contrast to all other countries where income per capita typically increases. These two figures show the dramatic fall in energy use in the United States from 1978 to 1983 (due to the second oil shock and recession).

The difference between the two measures for the transition economies is clearly dramatic: at market exchange rates, Russia is 10 times as energy intensive as the EU, but only three times at PPP. Similarly, the energy intensities of the Czech and Slovak Republics and Romania are more than three times as high at market exchange rates than at PPP, and those of Hungary and

CHART 3.4.3

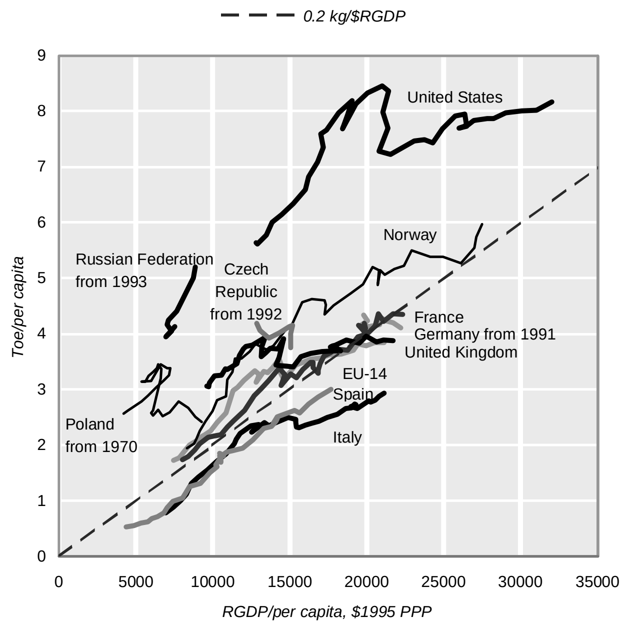
Energy use per head in relation to real GDP per head, 1972-1999



Source: World Bank online database (www.worldbank.org/data/).

CHART 3.4.4

Energy use per head in relation to real GDP per head at purchasing power parity, 1960-1999



Source: World Bank online database (www.worldbank.org/data/).

Poland are more than twice as high. This raises the obvious question of which measure is the better one for understanding energy demand and, more importantly, for estimating the potentials for reducing energy intensity. Eastern Europe was notorious for subsidizing

[153] For eastern European countries real (i.e. PPP) GDP is between two and four times $GDP (i.e. GDP at market exchange rates); the United States is defined as unity, while the EU countries range between 75 per cent and 123 per cent (Portugal).

energy (and other consumer goods, many of which were rationed), and collecting taxes directly from enterprises rather than from consumers or workers. Consumers' purchasing power was therefore greater than appeared at market exchange rates (which in any case were heavily distorted by the COMECON system of trade), and by that measure real income was higher than at market exchange rates.

The important question to which we turn next is whether the transition to a market economy, in which ultimately prices will be less distorted, will reduce the energy intensity, however measured. Over time (and the direction of movement may not always be apparent in the figures) the transition economies do seem to be moving towards the line of average energy intensity, supporting this hypothesis. As inefficient and resource-intensive heavy industry has been confronted with world market prices, so much of it has contracted, gone out of business or improved its efficiency. Nevertheless, the process of moving *effective* energy prices (that buyers actually pay) towards world market levels has been painfully slow in many countries, so this adjustment is likely to take some considerable time.

To summarize briefly on the relevance of measuring income levels at PPP, where there are larger differences than might be expected purely in terms of per capita income levels, the reason is likely to lie with highly distorted price structures, which in many cases are part of the reason for profligate and inefficient energy use. Using PPP exchange rates to deflate local energy prices may give a better impression of how expensive energy is to domestic consumers, but is not an adequate reason for subsidizing energy to those consumers, given that (most) energy is internationally tradeable, and therefore its price should be linked to the international price at the market exchange rate. For the rest of the discussion I shall therefore only use market exchange rates when making comparisons.

3.5 Sectoral energy use

In OECD Europe in 2000, 35 per cent of energy was consumed by industry, 20 per cent in transport, 25 per cent in the residential sector and 20 per cent in other sectors.[154] In the United States, the shares were more equal at 27, 26, 24 and 23 per cent. In both cases, the absolute amounts of energy (tonnes of oil equivalent) consumed in industry have remained remarkably stable since 1973, but transport use has grown rapidly (nearly doubling), and other sectors have increased by about 20 per cent. The share in industry has therefore fallen over time. What is perhaps rather surprising is that the energy intensity of industry is very similar to the economy as a whole (that is, total energy, including inputs into electricity consumed, per dollar of value added).[155]

TABLE 3.5.1

Index of industrial energy intensity, 1971-2000
(1995=100)

	1971	*1980*	*1990*	*1997*	*2000*	*Per cent change 1971-2000*
EU-15	..	136.40	105.00	98.70	94.60	-47
Austria	176.70	151.70	110.90	102.60	90.10	-49
Belgium	151.79	119.72	95.43	109.63	114.75	-24
Denmark	218.27	164.16	103.33	93.31	80.40	-63
Finland	112.84	100.79	113.19	97.71	81.62	-28
France	159.42	130.11	94.01	98.72	88.54	-44
Germany	161.03	154.50	111.45	95.40	90.57	-44
Greece	115.85	108.05	99.68	107.56	100.47	-13
Ireland	..	275.45	145.50	82.10	54.60	..
Italy	179.47	132.50	108.13	99.83	98.19	-45
Luxembourg	265.35	230.72	135.62	89.65	77.55	-71
Netherlands	118.08	128.75	113.73	96.45	96.49	-18
Portugal	111.71	102.45	105.95	100.07	108.70	-3
Spain	128.51	112.45	93.78	99.91	106.34	-17
Sweden	147.64	131.10	106.05	95.60	82.22	-44
United Kingdom	209.69	143.45	105.42	100.67	99.70	-52
Norway	249.76	202.41	125.02	89.69	102.51	-59
Bulgaria	..	..	..	..	..	..
Czech Republic	..	..	84.10	77.57	64.17	..
Hungary	..	179.83	144.31	87.28	57.51	..
Poland	..	..	124.12	85.83	58.39	..
Romania	..	..	..	..	..	..
Slovakia	..	..	164.31	88.90	93.33	..
Russian Federation	..	..	..	..	..	..
United States	220.65	176.48	112.05	90.28	80.11	-64

***Source*:** OECD, Energy Balances 2000 (Paris), 2000.

Note: The figure for EU-15 for 1971 is an estimated weighted average of the 15 individual countries.

Table 3.5.1 shows that industrial energy intensity has fallen by nearly 50 per cent in EU countries since 1971, and by 64 per cent in the United States, considerably faster than economy-wide energy intensities (shown in table 3.5.2), which fell by 28 per cent from 1972-1999 in the EU and by some 40 per cent in the United States. Estimating industrial energy intensities in transition economies is more difficult, particularly given the different system of national accounting and the distorted price structure, but there is some evidence that the sector energy intensities are also similar to the economy-wide intensities. That in turn

[154] This includes the fuel used for generating electricity, which is consumed by the end-use sectors. OECD, op. cit.

[155] Estimating sectoral energy intensities requires finding comparable coverage of sectors for both energy and value added, which is time consuming. The estimates here rely on World Bank data for the share of industry in GDP, and OECD energy balance data for energy consumption by sector, but the coverage may not be exactly the same.

TABLE 3.5.2

Energy intensity relative to average EU energy intensity, 1972-1999
(Market exchange rates, $1995, per cent)

	1972	1980	1990	1999	Per cent change 1972-1999
EU-15	1.19	1.07	0.92	0.85	-28
Austria	0.84	0.75	0.66	0.61	-27
Belgium	1.48	1.23	1.05	1.08	-27
Denmark	0.90	0.79	0.61	0.56	-38
Finland	1.44	1.44	1.20	1.19	-18
France	1.00	0.91	0.85	0.83	-17
Germany	1.18	1.10	0.87	0.72	-39
Greece	0.76	0.85	1.10	1.13	49
Ireland	1.52	1.28	1.10	0.82	-46
Italy	1.11	0.94	0.82	0.80	-27
Luxembourg	3.06	2.24	1.42	0.85	-72
Netherlands	1.35	1.20	0.99	0.87	-36
Portugal	0.72	0.80	0.93	1.06	48
Spain	0.78	0.93	0.92	0.98	26
Sweden	1.30	1.18	1.11	1.06	-18
United Kingdom	1.70	1.40	1.14	1.02	-40
Norway	1.20	1.08	0.98	0.89	-26
Bulgaria	..	13.56	10.73	8.74	..
Czech Republic	..	..	4.83	4.05	..
Hungary	3.39	3.59	3.15	2.72	-20
Poland	..	..	4.88	3.31	..
Romania	..	9.21	8.80	6.30	..
Slovakia	..	..	5.65	4.56	..
Russian Federation	..	..	..	10.18	..
United States	2.46	2.11	1.64	1.46	-41

Source: World Bank, *World Bank Development Indicators* (Washington, D.C.), various issues.

Note: Annual figures are relative to the energy intensity of the EU-15, averaged over the period 1972-1999.

implies that energy intensities are far higher than in market economies, reflecting the inefficient resource use associated with central planning and distorted prices.

The rapid growth in the use of energy in transport is primarily the result of the rapid growth in vehicle kilometres (km) travelled (VKT). In Britain, energy use per VKT has fallen from 104 grams (gm) oil equivalent/km in 1980 to 89 grams oil equivalent/km in 2000, or an increase in energy efficiency of 15 per cent.[156] Looking across countries, fuel efficiency varies – in large part because of variations in transport fuel taxes and hence prices. Thus, in the United States fuel consumption per kilometre is 40 per cent higher than in the EU, but transport fuel taxes and hence prices are significantly lower than in the EU.

3.6 The effect of price on energy use

The natural explanation for the considerable variation in energy intensity across countries and the relatively slow decrease in energy intensity with time is that prices vary more across countries than over time. In addition, energy use responds slowly to price changes, as the energy-using capital stock takes time to adjust to different energy prices – decades in the case of power stations and buildings, and maybe a decade for vehicles and machinery. Very simple cross-country econometrics suggests an economy-wide energy price elasticity of about -1.[157] More detailed studies of particular sectors suggest a similar aggregate figure, although the sector levels may be higher or lower. Estimates of gasoline price elasticities in transport are around -1 from cross-section studies, but range up to -2.3 for the long-run elasticity estimated from time series.[158] Industrial energy price elasticities may be lower (-0.3 to -0.5), but output elasticities are also below unity, suggesting a trend growth of energy efficiency even without price changes.[159] In all cases the short-run elasticities are much lower than in the long run, typically around -0.1 to -0.2.

Chart 3.6.1 illustrates the cross-country relationship between average energy price ($/toe, weighted by fuel share and sector) and average economy-wide energy intensity, for the OECD countries for the period 1993-1999, using data from OECD.[160] The constant elastic regression line is fitted for non-transition economies, and suggests that the energy intensity of transition economies is higher than expected given their energy prices. That is consistent with other factors (e.g. central planning) influencing energy use. Note that in chart 3.6.1 the assumption that the GDP elasticity of energy use is unity has been maintained. Once again, the cross-section price elasticity is -1.0 with a standard error of 0.14, consistent with the other evidence.

This economy-wide elasticity of about -1 is probably reflecting other policies as well as those associated with price changes, for when oil prices rose sharply countries often imposed additional incentives to reduce oil imports and energy consumption. Thus, prompted by the oil price shocks, the United States imposed corporate average fuel economy (CAFE)

156 Calculated from data for total vehicle kilometres and total energy use in Department for Transport, *Transport Statistics*, 2002 and earlier years. The rate of increase of efficiency from 1979-1981 is rapid, and then stabilizes until 1985 before continuing to improve, so the results are sensitive to the starting date chosen.

157 P. Hoeller and M. Wallin, *Energy Prices, Taxes and Carbon Dioxide Emissions*, IEA Working Paper, No. 106 (Paris), 1991; T. Barker, P. Ekins and N. Johnstone (eds.), *Global Warming and Energy Demand* (London, Routledge, 1995); A. Cooper, S. Livermore, V. Rossi, J. Walker and A. Wilson, "Economic implications of reducing carbon emissions: the Oxford Model", *Energy Journal*, special issue on "The costs of the Kyoto Protocol…", op. cit., pp. 335-366.

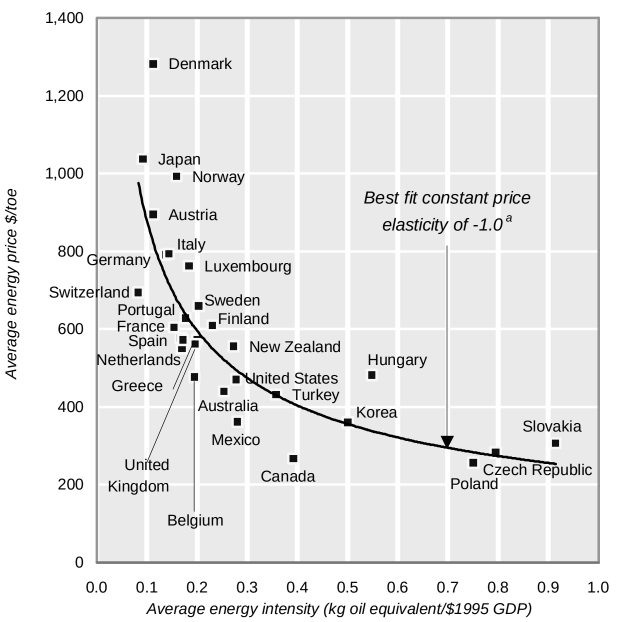
158 M. Franzén and T. Sterner, "Long-run demand elasticities for gasoline", in T. Barker et al. (eds.), *Global Warming…*, op. cit., chap. 4.

159 L. Vouyoukas, "Elasticities for OECD aggregate final energy demand", in T. Barker et al. (eds.), *Global Warming…*, op. cit., chap. 6.

160 Average prices and energy intensities are used as energy use responds slowly to price changes. OECD, op. cit.

CHART 3.6.1

Cross-section relation between average energy intensity and average energy price, 1993-1999



Source: World Bank online database (www.worldbank.org/data/).

a Standard error = 0.14; R^2 = 0.69 (excluding central and eastern Europe).

requirements on motor manufacturers to meet fleet average fuel efficiency standards. It could also be argued that these associated policies were primarily aimed at encouraging a more rapid adjustment of the capital stock to future expected prices, and is therefore one of the routes by which price changes feed through to final energy choices.

The implication is that energy prices and possibly other complementary policies can have powerful effects on total energy use (and even more powerful effects on the choice of fuels in individual sectors, such as heating, steam raising, electricity generation, and the choice between gasoline and diesel for vehicles). To put this into perspective, if the price elasticity is -1, and the GDP energy elasticity is 1 (i.e. energy intensity is invariant to income levels), and GDP grows at 3 per cent per annum, then energy use would not increase if prices rose at 3 per cent per annum in real terms (i.e. relative to all other prices). This would mean a price increase of 80 per cent over 20 years. Not surprisingly, most attempts to decouple energy use from GDP growth involve steady increases in real energy prices. For oil and eventually gas, such price rises are consistent with resource depletion (and were the default price forecast in the 1970s), but for coal and tar sands, stocks are too large for resource depletion alone to drive steady price increases. Some analysts have therefore argued that energy taxes should be steadily increased to depress the otherwise inexorable growth of energy use with economic growth. Extremists have gone further and argued that economic growth itself should be curtailed.

Simple energy taxes alone, however, do not make sense, as it is the harmful emissions that are the reason for action, not energy consumption per se. The time has come to switch attention from the determinants of energy use to those of the resulting environmental pollutants.

3.7 Policy to increase the efficiency of energy use

Sustainable energy use requires that market prices are corrected by taxes (or their equivalent) to reflect all external costs. How much the current generation bequeaths to the future can then be determined by the amount of capital accumulated, where capital includes not only physical capital, but also human, social, environmental and natural resource capital. The revenue from these corrective taxes can be used to purchase not just further reductions in these pollutants, but other services that may yield larger increases in welfare. If emissions of sulphur dioxide reduce life expectancy, then sulphur emission taxes may be able to buy more quality-adjusted years by transfers to the health service than being spent on increasingly expensive sulphur abatement. More generally, charging according to damage done, and allocating the revenues to where the greatest benefit occurs, is more efficient than forcing pre-specified levels of abatement.

The four main pollutants associated with fossil energy consumption are particulates (black smoke) from incomplete combustion, the acid rain precursors sulphur dioxide and nitrogen oxides, and green house gases, particularly carbon dioxide. We first discuss their relation to energy use, and the extent to which they can be or have been decoupled from energy use, and then discuss the design of appropriate ways of confronting energy users with their social costs.

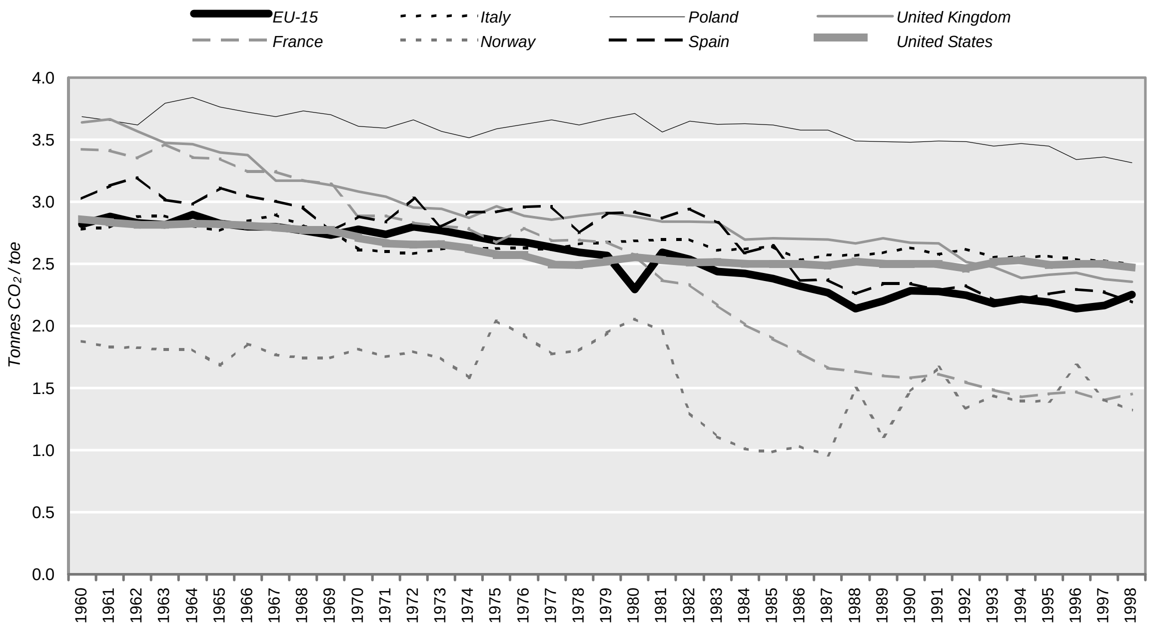
(i) Carbon dioxide emissions

Carbon dioxide (CO_2) is released in direct proportion to the carbon content of the fuel, and is the main cause of climate change (global warming). Fuels vary in the carbon content per unit of useful energy, measured for example by tonnes of carbon per tonne oil equivalent (tC/toe), or tonnes CO_2/toe as in chart 3.7.1.[161] Thus, bituminous coal has 1.1 tC/toe, gasoline 0.8 tC/toe, HFO 0.88 tC/toe and natural gas 0.64 tC/toe, while nuclear energy, renewables and hydroelectricity

[161] The ratio of tonnes CO_2 to tonnes C is 44:12 or 3.67:1.

CHART 3.7.1

Carbon dioxide content per tonne of oil equivalent, 1960-1999



Source: World Bank online database (www.worldbank.org/data/).

have zero values.[162] The wide range of values in chart 3.7.1 reflects at one extreme Norway's heavy dependence on hydroelectricity (also used for domestic heating) and at the other the heavily coal-dependent Poland. The rapid decrease in CO_2 intensity in the United Kingdom reflects the switch from coal and oil to natural gas and the development of nuclear energy. The larger fall in France reflects the more complete penetration of nuclear power in electricity generation that has moved France from near Poland's intensity to that of Norway.

Clearly then, CO_2 intensities can be reduced by fuel switching, particularly to non-carbon based electricity. Norway and France demonstrate, however, that the gains from switching are limited by the overwhelming dependence of transport on oil.

(ii) Emissions of other pollutants

Climate change *policy*, if not concern, is relatively recent, and the Kyoto Protocol has still not been signed by key countries such as the United States. In order to judge how effective environmental policy can be, it is useful to look at the dramatic successes of earlier policies towards other air pollutants. In each case, once the damage had been recognized, local action was taken. Where the damage spilled over national frontiers, a surprising degree of international agreement and action followed. Economists have criticized some of these agreements and legislation as inefficient, or unjustified on narrow social cost-benefit terms,[163] but judged purely in quantitative terms their impact has been impressive. The evidence below is taken mainly from British sources, but the same results could be found in most developed countries.

For most pollutants, policy acts at two levels. Typically the source of the problem is addressed by imposing emission limits, at the national and/or at the source level, for total emissions and/or emissions per kilometre travelled or per kilowatt-hours (kWh) generated. Early legislation concentrated more on controlling emissions, while later legislation addresses the resulting air quality standards. Thus in the EU, the Framework Directive 96/62/EC requires a preliminary assessment of air quality by certain dates for each pollutant, and hence is in a position to detect excessive levels.

(iii) Particulates

The first major environmental pollutant to attract attention and legislation was smoke from burning coal. Londoners in the twelfth century complained about the noxious fumes from burning sea coal, and the corrosive effects of sulphur dioxide, SO_2, dissolved in

[162] Taken from IEA, *CO_2 Emissions from Fuel Combustion 1971-2000* (Paris), 2002. Note that tC/tonne of fuel may be quite different, e.g. only 0.67 tC/tonne of bituminous coal.

[163] See e.g. D. Newbery, "Acid rain", *Economic Policy*, Vol. 11, October 1990, pp. 297-346; R. Crandall, H. Gruenspecht, T. Keeler and L. Lave, *Regulating the Automobile* (Washington, D.C., Brookings, 1986).

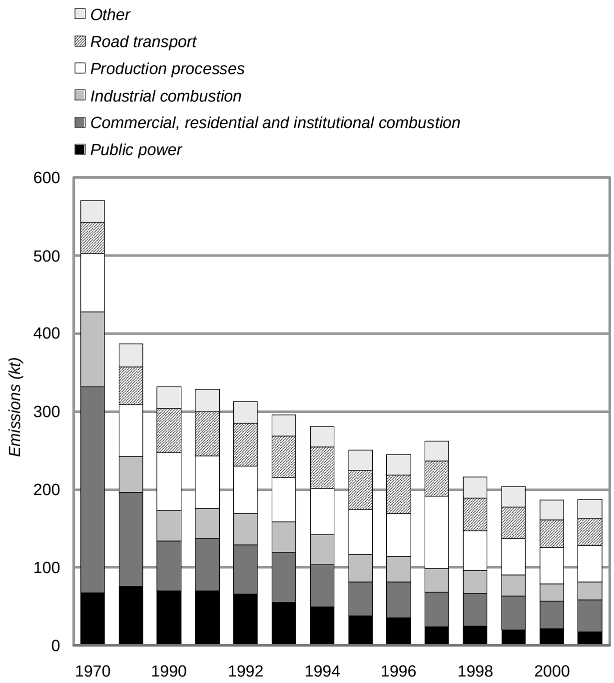
rain has been well understood for at least a century. In Britain, policies to address the harmful effects started with the Smoke Abatement Acts of 1853-1856, and via various other measures to the landmark Clean Air Act of 1956, followed by a second Clean Air Act in 1968. Concentrations of SO_2 in London fell from 900μg/m^3 in 1850 to 25μg/m^3 in 2000.[164] The proximate cause for this later legislation was the very obvious health hazards associated with the unregulated burning of coal, and in particular the large number of people, estimated at 4,000, who died in the great London smog of December 1952. The incomplete combustion of coal (and oil) produces fine suspended particulates that are damaging to health, and increase mortality and morbidity. The severity of the risk increases with the concentration of fine particulate matter, which is measured by the concentration of particles of less than 10 microns (PM_{10}).

The combined effect of legislation, which prompted the development of smokeless fuels to replace coal in designated areas, and the gradual replacement of open coal fires by central heating (now mainly gas-fired) in domestic use, dramatically reduced PM_{10} emissions, as shown in chart 3.7.2. Total emissions fell by 46 per cent in the decade 1970-1980, while emissions from the domestic sector (which are the most damaging as they come from low level sources in densely populated areas) fell by 58 per cent.[165] The rate of decrease continued, with domestic emissions falling 49 per cent in the decade 1980-1990 and a further 47 per cent from 1990-2000. Over the whole period 1970-2000 total emissions fell by 74 per cent. Domestic emissions now only account for 20 per cent of a much smaller total, compared with 42 per cent in 1970. Similarly, power station emissions have fallen dramatically, by 81 per cent per kilowatt-hours from 1970 and by 76 per cent in the period 1990-1999 (primarily as a result of the switch from coal to gas), while emissions per kilometre travelled by road transport have fallen 73 per cent since 1970 and by 57 per cent since 1990.

Records of emissions and concentrations in other countries typically cover shorter time periods.[166] Thus in Germany, if the data are to be believed,[167] total emissions fell from 2,059 kilotons (kt) (thousand

CHART 3.7.2

Emission of particulates in the United Kingdom, 1970-2000



Source: Department for Environment, Food and Rural Affairs, *Digest of Environmental Statistics*, March 2003.

tonnes) in 1990 to 864 kilotons in 1992, a drop of 58 per cent in just two years.

(iv) Sulphur dioxide

Sulphur dioxide, primarily from burning coal and oil, is a prime contributor to acid rain, and when released from high stacks can travel considerable distances as an aerosol, causing damage downwind and in other countries. The fact that the damage might be done to other countries and could not therefore be addressed by national action alone, was a prime factor leading to international agreements and protocols. Different countries responded to different facets of the pollution problem. The Scandinavian countries were troubled by the death and disappearance of fish from lakes and rivers. Germans worried about dying trees in their forests. Glasnost revealed the full extent of the environmental disasters in eastern Europe, and provided the focus for local hostility to the environmental insensitivity of central planning.

The debate on acid rain and on appropriate responses has been conducted in two different forums. The initial pressures came from the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP) that has 34 members from Europe and North America. Much of the pressure here was exerted by the Scandinavian countries and Canada, which are both large net importers of acid rain because

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[164] Lomborg, op. cit., p. 165 for sources, which for 1850 are derived from coal imports.

[165] Department of the Environment, *Digest of Environmental Statistics*, No. 17 (London, HMSO, 1995). Particulate emissions before 1980 are measured by black smoke, which correlates closely with PM_{10}.

[166] See (europa.eu.int/comm/environment/air) and the detailed studies on individual pollutants accessible from there.

[167] See (europa.eu.int/comm/environment/air/pdf/pp_pm.pdf), table, p. 65. Presumably the dramatic fall from 1990 to 1991 reflects the rapid restructuring of east Germany after reunification.

of their unfortunate downwind locations. In 1982, Norway and Sweden pressed for the signatories to reduce SO_2 emissions to 30 per cent below 1980 levels by 1993. This led to an informal "30 per cent Club" founded in Ottawa in March 1984, and, in July 1985, 21 countries, but not including the United States and the United Kingdom, signed a protocol at the third meeting of the UNECE LRTAP Convention in Helsinki.

Whereas the Scandinavians were initially primarily concerned with the acidification of lakes and streams and consequent loss of fish, west Germans were worried about the impact their own industry was having on the environment, concerns which were reflected in the growing political power of Green parties in the early 1980s. An emotive campaign in 1982 drew attention to the problem of *Waldsterben* or forest death, in which official estimates showed that over half the forest area had suffered damage, attributed to acid rain. For a variety of political reasons described in more detail in Berkhout et al.,[168] a Large Combustion Plant Ordinance (*Grossfeuer-ungsanlagen-Verordnung* or GFAVo) was enacted in June 1983, under which flue gas desulphurization equipment would be fitted to 37 GW[169] of coal-fired power stations, and a further 12 GW would be subject to early closure. Not surprisingly, industry protested that the costs of this programme, which were to be borne by electricity consumers, would harm west Germany's competitive position in international markets, and this led the government to press for similar standards being adopted by the whole of Europe. The European Commission proposed a Large Combustion Plant (LCP) Directive based on the GAFVo in December 1983, calling for a cut of 60 per cent in SO_2 emissions by 1995, to 40 per cent of their 1980 level. After much debate,[170] the United Kingdom finally agreed to reduce SO_2 emissions from existing large plants to 20 per cent below their 1980 level by 1993, to 40 per cent below by 1998 and to 60 per cent below by 2003; nitrogen oxides (on the same basis) would be cut by 15 per cent by 1993 and 30 per cent by 1998. The Directive also provides for stringent emission standards for new large combustion plants, which the United Kingdom accepted.[171] In November 1988, the United Kingdom Environment Minister signed a United Nations protocol in Sofia committing the United Kingdom and most leading industrial countries to freeze the level of nitrogen oxides at 1987 levels until 1994 and by 1996 to agree to further reductions based on critical levels. In due course the Second Sulphur Protocol was signed and has had a significant effect on efforts to reduce sulphur dioxide emissions.

Britain reduced SO_2 emissions by 82 per cent between 1970 and 2000, and although the decadal decrease was only 24 per cent until 1990, from then the impact of international agreements (and their translation into national limits) has been dramatic, with an overall decrease of 69 per cent from 1990-2000, and a 76 per cent decrease in SO_2/kWh in power production (which in 1990 accounted for just under 80 per cent of total emissions). Britain emitted only 76 per cent of the 1998 LCP ceiling by the deadline date, and in 1999 was emitting only 87 per cent of the substantially more stringent 2003 limit.

Detailed data on emissions from European countries is available from the European Monitoring and Evaluation Programme (EMEP). This was set up in 1978 to monitor the movement of pollutants, and to determine where the pollutants released from each source were deposited. For the EU, emissions fell 20 per cent between 1980 and 1990, and are forecast to fall by a further 60 per cent to 91 per cent between 1990 and 2010. The decline in other European countries (which account for as much as the EU) is similarly forecast at between 29 per cent and 86 per cent over the same period.[172] Among the transition economies SO_2 fell by more than 35 per cent in the CIS countries (but as energy use fell by 28 per cent, emissions per toe fell by 28 per cent), and by 25 per cent in central Europe, the Baltic states and south-eastern Europe, the latter as a result of lower emissions per toe.[173]

(v) Nitrogen oxides

Nitrogen oxides, NO_X, are produced from the air involved in combustion processes, rather than in pollutants contained in the fuel itself, as with SO_2. As with SO_2, country level data on NO_X emissions are available from the EMEP. In Europe as a whole in 1994, 57 per cent of total NO_X emissions came from transport, and 39 per cent from stationary combustion sources.[174] In the EU in 1995, 62 per cent of such emissions came from transport and 34 per cent from stationary sources. In the United States, the original

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168 F. Berkhout, S. Boehmer-Christiansen and J. Skea, "Deposits and repositories: electricity wastes in the UK and west Germany", *Energy Policy*, April 1989, pp. 109-115.

169 Gigawatts, 1 GW = 1 million kW.

170 Described in J. Skea, "UK policy on acid rain: European pressures and emission prospects", *Energy Policy*, June 1988, pp. 252-269.

171 Department of the Environment, *Our Common Future: A Perspective by the UK on the Report of the World Commission on Environment and Development* (London, HMSO, 1988).

172 See (europa.eu.int/comm/environment/air/pdf/pp_so2.pdf), p. 9.

173 EBRD, *Transition Report, 2001* (London), p. 93.

174 CORINAIR, *Summary Report No. 1 – Final Draft*, under contract to the European Environment Agency, 1995.

impetus to address the problem was the deteriorating air quality in urban areas such as Los Angeles and Washington, D.C., where photochemical smog led to high levels of ozone. This was traced to exhaust emissions of hydrocarbons and nitrogen oxides and California led the way in introducing successively tighter emission controls on vehicles. These have been adopted in other countries in their emission standards for vehicles (where international trade is a powerful mechanism for standardization). In Europe, acidification was again one of the major forces for policy change. (In terms of acidification, NO_X is counted as 70 per cent as damaging per tonne as SO_2.) As with SO_2, the approach was to impose limits on emissions from large combustion plants (and on emissions in grams per kilometre for vehicles). The EC Large Combustion Plants Directive 88/609/EC required that emissions in 1998 be 40 per cent below those of 1980.

Again the evidence from Britain is instructive, and covers a longer time period than for most other countries. Total emissions fell by 40 per cent between 1970 and 2000, but as they rose by 10 per cent between 1970 and 1990, the fall in the subsequent decade was a more dramatic 45 per cent. Emissions from road transport per kilometre travelled fell by 58 per cent between 1990 and 2000, and those from power stations (which accounted for 28 per cent of the total in 1990) fell by 60 per cent per kilowatt-hour over the same period. By 1998 Britain was producing only 55 per cent of the LCP target for that year. Thus, Britain demonstrates that once the problem is recognized as important, and is systematically addressed by standards (for vehicles) and emission limits (for large plants), dramatic reductions can be achieved. In the case of vehicles, as the proportion of vehicles meeting the more recent tighter limits increases, so emissions per kilometre and in total are forecast to continue falling.

3.8 Designing efficient energy pollution policies

At one level, CO_2 is conceptually the simplest pollutant, for the damage done does not depend on where the emission occurs, and is directly proportional to the carbon content of the fuel. A fuel tax per tonne of carbon is therefore the logical instrument, and one that has been adopted by a number of Scandinavian countries (none of which has an indigenous coal industry to protect). The obvious problem is that the benefits of reducing CO_2 emissions in one country are overwhelmingly captured by other countries, so the incentive for any one country to unilaterally tax CO_2 is minimal.

The second problem is that it is difficult to quantify the present discounted total global benefits to reducing emissions of CO_2 now. There are long lags between emissions and their impacts on global temperatures, and then on ecological, climatic and sea level changes. These impacts have very different effects on different countries, with the adverse impacts falling disproportionately on poorer tropical developing countries. Indeed, some calculations suggest that for modest global warming, some richer countries might even benefit, or at least lose only to a limited extent.[175] The damage done will depend on the direct costs of the damage and the cost of measures taken to avoid damage (better sea-level defences, etc.), both of which will depend on the future state of technology. Even the discount rate to use is controversial, as normal commercial discount rates evaluate damages a century hence of negligible present value. Thus, the present value of $1 million in 100 years time at a 5 per cent per annum discount rate is only $7,600. Lower discount rates can be defended if future income levels are substantially lower than at present, but most forecasts do not predict that outcome. Finally, the cost of reducing CO_2 emissions in the future depends on technical progress, which is also uncertain. That affects the optimum (cost-minimizing) path of CO_2 reductions, and hence the time path (and present level of) carbon taxes.

Uncertainty is no excuse for inaction (although it may be a cause for delaying irreversible and costly actions if information can be improved), and considerable effort is being deployed to determine the global optimum climate change policy and the implied level of taxes. In practical political terms it is most improbable that a uniform global level of carbon taxes can be agreed, but the Kyoto Protocol suggests a feasible and equivalent alternative. If global limits on CO_2 emissions can be agreed and quotas allocated to countries, and if these carbon quotas are freely tradeable, then in a competitive trading environment a global carbon permit price should emerge.[176] If energy users had to obtain these CO_2 permits in proportion to fuel purchased, then the external cost (at least of global warming) would be efficiently internalized.

The main objection to the presently formulated Kyoto Protocol is that it does not foster global (as opposed to regionally restricted) carbon trading, as most developing countries are exempt. Another major objection is that by itself the Protocol will only delay

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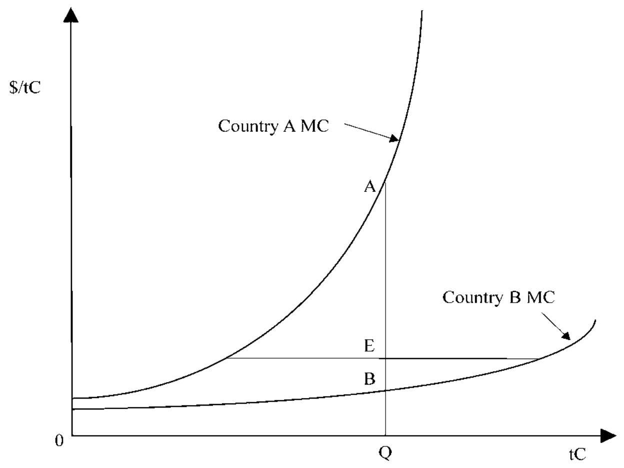
[175] J. McCarthy, O. Canziani, N. Leary, D. Dokken and K. White (eds.), *Climate Change 2001: Impacts, Adaptation and Vulnerability*, contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Cambridge, Cambridge University Press, 2001.

[176] The qualification is important, for if major CO_2 emitting countries such as the United States (with 24 per cent of the world total), Russia (with a likely large trade surplus of permits) or China were to use their market power, the internal and world prices would not be equilibrated.

CHART 3.8.1

The benefits of emissions trading



century-hence levels of atmospheric CO_2 by about six years, and so a whole sequence of future CO_2 restrictions will be needed. As a result the costs of compliance could be many times higher than the least costly global trading solution (eight times, according to an estimate of Nordhaus and Boyer).[177] It is easy to see why. Chart 3.8.1 shows the marginal cost (MC) of reducing CO_2 emissions by one tonne in two different countries, at the pre-trade levels of allowed emissions, OQ. The extra cost of reducing emissions in country A is QA, considerably higher than that in country B, QB. If country A could purchase a quota from country B, the cost saving would be (approximately) QA-QB, which could be many times the value QB (and also many times the equilibrium price with free trade between these two countries, QE).

Global trading in carbon permits combined with country quotas for every country (and monitoring for compliance) would create the right conditions for selecting the efficient choices from those available, but would not guarantee that the right technologies would be produced. RD&D (research, design and development) is a quasi-public good (even with good patent protection), and the learning spillovers from developing and producing new carbon-saving technologies are likely to be large. That is a prime argument for subsidizing low-carbon technologies, and an argument for international agreements to fund such research and set targets for their introduction, in order to stimulate their development and deployment. Fortunately, it seems somewhat easier to persuade individual governments to support local initiatives than economists, fearful of free-riding, might have expected. Support for low-carbon energy is even more important if developing countries lack economic incentives to reduce CO_2 emissions, for if these technologies become competitive against traded fossil fuel, then these countries will have an incentive to use these rather than carbon-intensive fuels.

If governments appear to be taking the development of low-carbon energy substitutes reasonably seriously, the same cannot yet be said for pricing carbon, at least in most countries. Britain, for example, has introduced a Climate Change Levy, which is a pure energy tax (with exemptions for renewables, good quality combined heat and power (CHP), but not for nuclear electricity). Households, whose energy is already subsidized though a reduction in VAT of 12.5 per cent, are exempt, although improving household energy efficiency is probably one of the least-costly ways of lowering overall energy use. A more logical approach would be for each government to levy the carbon tax needed to meet its Kyoto commitment (or, on an optimistic view, at the level of the future equilibrium price of traded carbon permits). If carbon permits become tradeable, then the government can replace the carbon tax by the requirement to buy carbon permits, ideally at the same rate as the tax.

Carbon dioxide emissions are not the only reason for taxing fuels, but if we inquire how energy is actually taxed, it is hard to relate taxes to potential damage, as the next section demonstrates.

3.9 The current pattern of energy taxes and subsidies

Different fuels are taxed at very different rates in almost all OECD countries, and the same fuel is taxed at very different rates across the OECD. Chart 3.9.1 gives the average mineral oil tax rates in 1997 across EU countries, defined as total tax revenue (excluding VAT) divided by the final consumption of oil products. To gain a rough sense of the tax rates, the pre-tax price of oil products in 1997 probably averaged about €100/tonne oil equivalent, so the taxes as a percentage of product prices were high (substantially greater than 100 per cent). In contrast, coal is normally untaxed (except in Denmark and Finland), as is gas for industry (with a few more exceptions).

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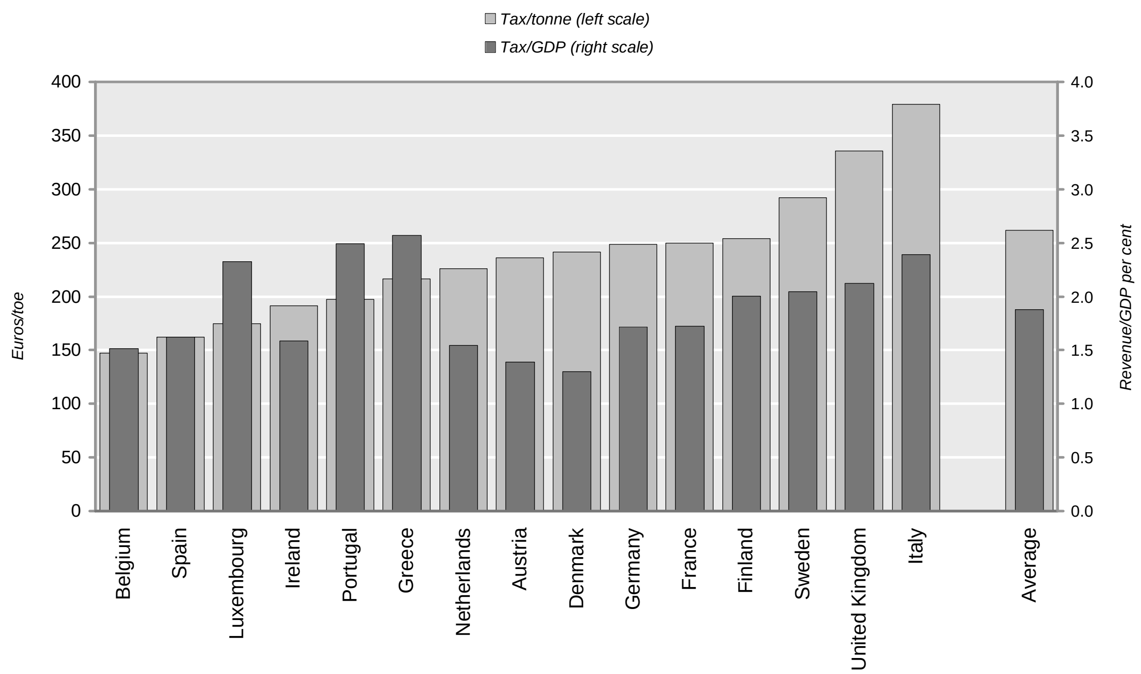
[177] W. Nordhaus and J. Boyer, op. cit. Nordhaus's model, however, suffers from serious methodological problems (T. Barker, review of *Managing the Global Commons: The Economics of Global Change*, by W. Nordhaus in *Energy and Environment*, Vol. 7, No. 1, pp. 85-88); and the costs of mitigation depend sensitively on how the tax revenues are recycled (and the size of the "double dividend"), how far carbon reductions lead to additional reductions of other pollutants, as well as the extent of trade. T. Barker and P. Ekins, "The costs of Kyoto for the US economy", Cambridge Department of Applied Economics, 2003, mimeo, compare the range of cost estimates presented in R. Watson (ed.), *Climate Change 2001: Synthesis Report*, contribution of Working Groups I, II and III to the Third Assessment Report of the IPCC (Cambridge, Cambridge University Press, 2001) for differing degrees of trading. The ratio of the costs of mitigation with no trade compared to global trading range from 2.3 to 22, with most estimates between 5-7. The ratio of the costs with trade limited to annex I countries to global trading cluster around 3. All these figures are affected by revenue recycling and ancillary benefits.

CHART 3.9.1

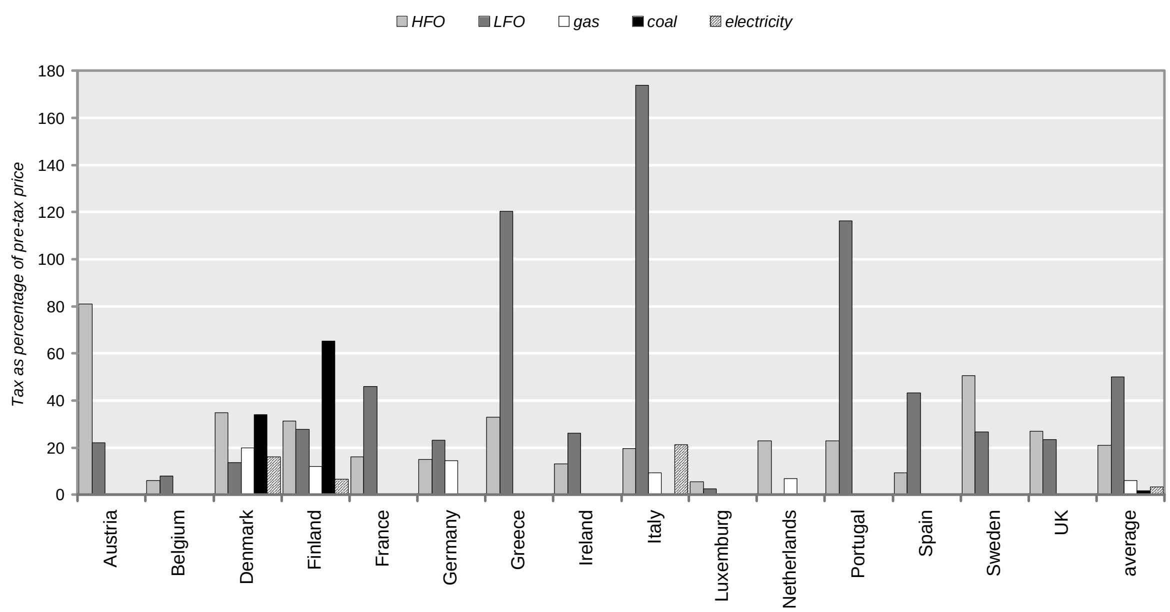
Average mineral oil tax rates, 1997



Source: European Commission, *Excise Tax Duty Tables*, July 2001, ranked by tax rate.

CHART 3.9.2

Tax rates on industrial fuels in the EU, excluding VAT, 1997



Source: International Energy Agency, *Energy Prices and Taxes* (Paris), ranked by tax on light fuel oil.

Hydrocarbon taxes are also fiscally important. On average they contribute 2 per cent of GDP to the budget (as shown on the right hand scale of chart 3.9.1), or about 5 per cent of tax revenue. The United Kingdom stands out as having heavy oil taxes, primarily but not solely arising from the heavy taxation of road fuels. The ratio of hydrocarbon taxes to total United Kingdom government revenue has risen from 4.5 per cent in 1989 to 6.7 per cent in 1999, and the real tax receipts grew at 6.2 per cent per annum over this decade. More to the point, hydrocarbon taxes account for a significant share of indirect taxes – 20 per cent of all indirect tax revenue (including VAT) in the United Kingdom, and 46 per cent of indirect taxes if VAT and import duties are excluded.

The variation of EU tax rates (as a percentage of the pre-tax price, and again excluding VAT) for different fuels for the industrial sector is shown in chart 3.9.2. Light fuel oil (LFO) stands out as heavily taxed in some countries, notably Italy, Portugal and Greece, presumably where there are difficulties in preventing tax evasion on the even more heavily taxed road diesel fuel, for which kerosene can readily be substituted. Heavy fuel oil (HFO) is relatively heavily taxed in Austria and Sweden, while Denmark appears to have the most uniform tax system across fuels, as the base is primarily carbon content.

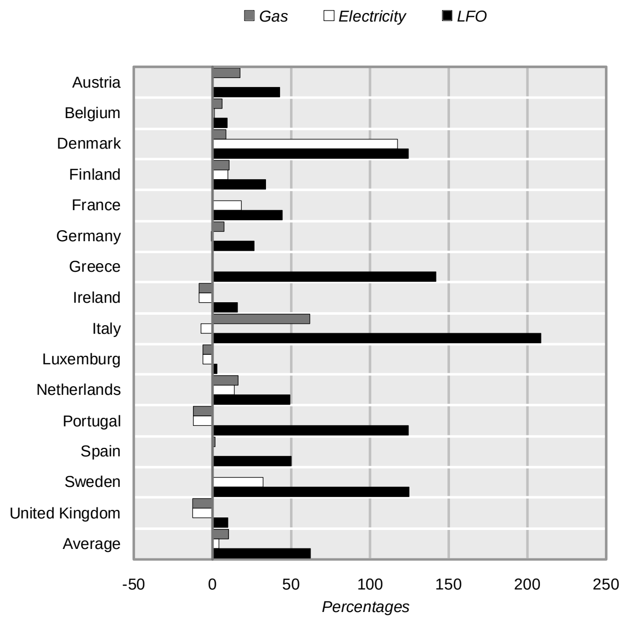
Chart 3.9.3 shows the taxes on fuel consumed in the EU domestic sector (excluding road fuel, which is shown in chart 3.9.2). LFO is primarily used for central heating, as is gas, but they are taxed at very different rates (except in Denmark), again probably to prevent road fuel tax evasion. The variation 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.

Chart 3.9.4 completes the picture by comparing taxes on road fuel across the EU. The tax *rates* were more than 250 per cent of the pre-tax price on average, and over 300 per cent for France and the United Kingdom. Taxes for the United States (which vary by state) are half the lowest EU taxes (in Portugal and Greece). Note that chart 3.9.4 is ordered by increasing rates of diesel tax rate, where the average *rate* is high at about 190 per cent (but again over 300 per cent in the United Kingdom). 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.

Describing and quantifying levels of fuel taxation in transition economies is more difficult, at least for non-accession countries and for all countries before 1990. Commodity taxation was primarily designed to adjust for price differences between COMECON trading partners, and to extract rents or provide transfers, rather than guide resource allocation. It is difficult collecting prices relative to the efficient level for most sectors, but as a guide, residential electricity prices were only half the long-run marginal cost (LRMC) for transition economies in 2000.[178] Similarly,

CHART 3.9.3

Effective tax rates on domestic fuel in the EU, net of standard VAT, 1997



Source: International Energy Agency, *Energy Prices and Taxes* (Paris).

the price of heating was significantly below the LRMC in most transition economies, and the relative pattern of industrial to domestic prices is highly distorted. The second problem which continues to affect most of these countries is that the proportion of energy bills actually paid in cash is frequently low – in 2000 only 15 per cent in Azerbaijan, 25 per cent in Uzbekistan, 35 per cent in Georgia, 45 per cent in Romania, although it had risen to 85 per cent in Russia from levels as low as 20 per cent.[179] Commercial losses (non-billed consumption) are also high. If consumers do not have to pay the quoted price, they are effectively further subsidized.

The special case of coal

Coal is nominally untaxed in the EU (and most other OECD countries) except in Denmark and Finland, neither of which mine coal. Coal production has until recently been heavily subsidized in most significant European 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 in the EU, and one of the most protected in Europe, as measured by the producer subsidy equivalent (PSE) per tonne.[180]

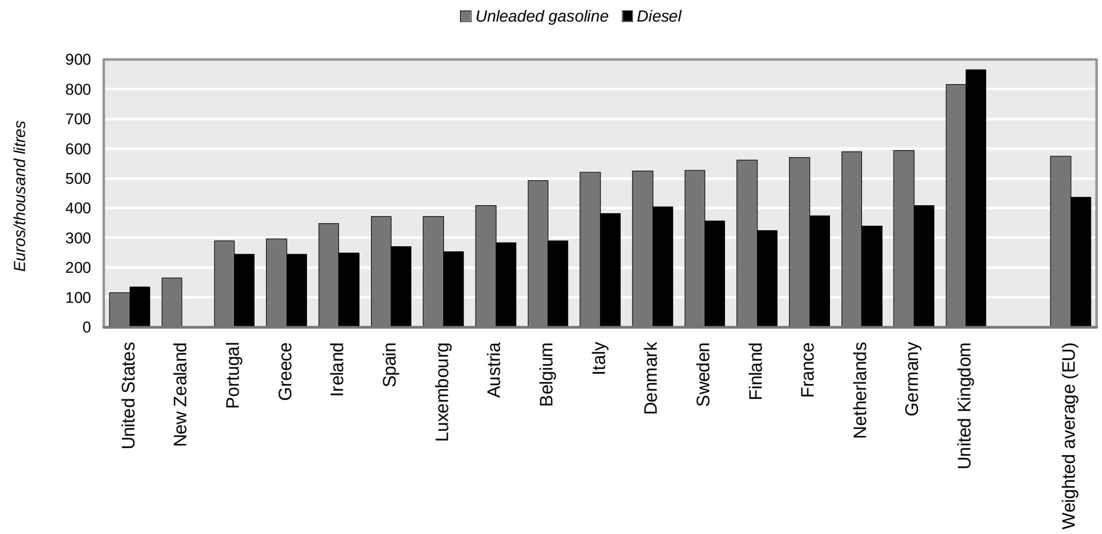
[178] EBRD, op. cit., p. 96.

[179] Ibid.

[180] IEA estimates Germany’s PSE at $105/tonne coal produced in 1992. IEA, *Energy Policies of IEA Countries; 1992 Review* (Paris), 1993, p. 38.

CHART 3.9.4

Road fuel taxes in the EU, 2001



Source: International Energy Agency, *Energy Prices and Taxes* (Paris), various issues.

Germany also paid the highest prices for coal for power generation, and had the highest industrial electricity price. The United Kingdom had the lowest PSE/tonne of the European coal producers ($18/tonne of coal in 1992) but one of the highest coal prices for electricity 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. I have estimated that the PSE raised the effective domestic price for coal producers by about 450 per cent above import parity in Spain (compared with the IEA's estimate of 100 per cent), about 250 per cent in Germany, and about 50 per cent in the United Kingdom.[181]

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 contracts have ended in the United Kingdom, 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. Coal escapes carbon taxes (except in Denmark). Clearly coal is still treated rather leniently compared with most other fuels.

[181] D. Newbery, "Removing coal subsidies: implications for European electricity markets", *Energy Policy*, Vol. 23, June 1995, pp. 523-533.

3.10 Explaining current fuel taxes

Looking at the considerable dispersion of tax rates for the same fuel in similar countries, and across similar fuels in the same country, it is hard to accept that fuel taxes have been set to internalize external costs, or to improve the efficiency of energy use. The simplest explanation is that gasoline and road diesel are mainly taxed as a means of charging for road use, as discussed below. That in turn often makes high taxes on kerosene necessary to prevent diversion to road use. Heavy oil is taxed to protect indigenous coal in some countries (e.g. the United Kingdom), and coal production (although not normally consumption) is frequently subsidized to protect coal-mining jobs. In cold climates the concept of "fuel poverty" influences domestic fuel taxation; in Britain fuel poverty is defined as spending more than 10 per cent of income on energy (a problem that in the mid-1990s affected perhaps 20 per cent of households). Thus Britain levies a lower VAT rate on domestic fuel use (5 per cent instead of the standard 17.5 per cent). In warmer southern climes, it is politically easier to tax domestic gas and electricity.

Finally, and especially in countries with poor tax compliance, fuel taxes are cheap and easy to collect and often attractive on those grounds. Where municipal authorities receive the income from domestic electricity and gas sales, prices are often raised (and the fuels therefore implicitly taxed) to pay for municipal services (as in Germany). Where competition and/or falling fuel prices have driven down wholesale electricity prices, some countries (Germany, the Netherlands) have imposed additional taxes to collect these rents (often in the guise of eco-taxes, to encourage a switch to green or renewable electricity). In other countries, notably the United Kingdom, energy taxes are politically so salient that they have been reduced while liberalization drove down wholesale prices.[182]

Nevertheless, EU countries are increasingly adapting energy taxes to address environmental concerns and defending them on those grounds. Several countries have introduced comprehensive "green" tax reforms, in which environmental taxes have been raised and the revenue normally used to reduce other taxes or support renewable energy. The IEA[183] gives more details, but briefly, Finland and Denmark introduced "carbon" taxes in 1990 and 1992, although with extensive rebates for industry and power. Norway effectively introduced a "carbon" tax in 1991, although confined to mineral oil and again with some rebates. Italy planned much the same in 1998, but oil price increases have delayed their introduction. Sweden rebalanced its energy taxes in 1991 to concentrate them on carbon and sulphur. Belgium increased energy taxes on private consumption, and Austria has imposed them on gas and electricity since 1996. The Netherlands introduced a general fuel tax and specific eco-taxes in 1995. France's attempts at restructuring environmental taxes were eventually ruled unconstitutional, while the Swiss rejected two proposals for green taxes in a referendum in 2000. Britain's Climate Change Levy has already been mentioned. As the IEA notes, "even if these levies are often labelled 'CO_2 taxes', the tax rates facing different polluters hardly reflect the carbon content of the fuels they are using".[184]

3.11 Designing an efficient set of fuel taxes

Energy taxes are primarily input taxes and, as such, fall on production as well as consumption. Standard tax theory[185] 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. However, externalities are prevalent, and there are good reasons for reflecting their social costs in corrective taxes. The simplest cases are where the damage done is proportional to the pollutant in the fuel. Carbon is the best example, with sulphur raising minor additional problems.

Countries that have signed the Kyoto Protocol have a choice between two equivalent efficient policies, either a carbon tax at the same rate on all fuels proportional to their carbon content, or a requirement to buy carbon permits to cover the carbon content of all fuel purchases (or use). The problem in setting the tax is that there are wide differences between various estimates of the appropriate level. The original EU energy tax was $10/barrel, of which half was to be on the carbon content of the fuel, the rest on the energy content. If it were all allocated to carbon it would amount to about $75/tonne carbon (tC). Maddison et al.[186] estimated the shadow prices of controlling the last unit of carbon dioxide released assuming optimal abatement and a marginal cost of $5.9/tC at constant 1993 dollars. This is only slightly less than the cost assuming "business as usual", calculated as $6.1/tC. ECMT[187] cites estimates ranging from $2-$10/tC, considerably below the EU's original proposed carbon tax discussed above. Tol et al.[188] review various estimates and argue for marginal damage costs below $50/tC. The United Kingdom's Department of the Environment, Transport and the Regions decided in early 2001 to take as their working assumption a central estimate of $80/tC, with a range of $40 to $160. It is worth noting that a carbon tax of $80/tC would amount to $75/tonne of coal, or 215 per cent of the EU import price of $35/tonne in 2000. The Danish carbon tax introduced in 1992 was at a rate of DKK100/tonne CO_2 or $38/tC, while Finland levied a carbon tax on all energy at about FMK500/tC or $70/tC, roughly twice as high.

Parry and Small[189] review the literature and select a central figure of $25/tC, with a range of $0.7-$100/tC. Even their modest list of citations suggests a range of almost 100:1, with preferred estimates differing perhaps by 10:1. Emissions trading of carbon would allow a better estimate of the marginal cost of

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182 The fossil fuel levy, originally set at 10 per cent of the pre-levy final price, is an interesting example of a tax designed to collect revenue to finance nuclear decommissioning. Because it was hypothecated to that purpose, it was not called a tax and hence not subject to the normal political bargaining.

183 IEA, *Energy Prices and Taxes, First Quarter 2002* (Paris), 2002.

184 Ibid., p. xxvi.

185 P. Diamond and J. Mirrlees, "Optimal taxes and public production I: production efficiency", *American Economic Review*, Vol. 61, 1971, pp. 8-27.

186 D. Maddison et al., *Blueprint 5, The True Costs of Road Transport* (London, Earthscan, 1996).

187 European Conference of Ministers of Transport (ECMT), *Efficient Transport for Europe: Policies for Internalization of External Costs* (Paris, OECD, 1998), p. 70.

188 R. Tol, S. Fankhauser, R. Richels and J. Smith, "How much damage will climate change do? Recent estimates", *World Economics*, Vol. 1, Issue 4, December 2000, pp. 179-206.

189 I. Parry and K. Small, "Does Britain or the United States have the right gasoline tax?" (Washington, D.C.), 2001, mimeo. See also Resources for the Future website (www.rff.org/~parry/Papers/01/gas_tax.pdf).

abatement, if not the marginal damage done by emissions. A tax of $25/tC would raise the cost of gas-fired electricity generation in new combined cycle gas turbine (CCGT) plants by $2.5/megawatt-hours (MWh), or 10 per cent of the average total cost, but by $6.5/MWh for coal-fired generation, or by 35 per cent or more of its avoidable cost. Such a tax would probably not be sufficient to make new nuclear power competitive against gas-fired generation at current gas prices, nor would it be likely to make most renewables competitive, although it would advance the date at which they are likely to be competitive. The same carbon tax applied to transport fuel would amount to less than €0.02/litre, small in comparison with the taxes shown in chart 3.9.4

(i) Sulphur taxes and sulphur trading

Sulphur in fuel produces SO_2 but unlike CO_2 it can be largely removed by scrubbing or by flue gas desulphurization. In addition, the sulphur content of otherwise equivalent fuels varies, and sulphur can be removed from some fuels at the production stage (in oil refineries, for example). The damage done also depends on the location and height of release and the direction and strength of the wind. These complicate the task of confronting users with the correct marginal social cost of the damage they cause, and so relatively cruder methods are needed. Under the various international agreements, each country is now limited in the amount it can release, and the logical policy to meet this limit is one of "cap and trade".

Under this policy, the government issues or auctions permits up to the cap, that is, the total amount allowed. Some part of this total may be allocated to existing polluters as "grandfathered" entitlements. Trading then determines the market-clearing price, and allocates them efficiently (provided, as seems to be the case, that transaction costs and market power are low). Energy users can then choose whether to buy low-sulphur fuel, install clean-up technologies, or buy permits. The evidence[190] suggests that the resulting costs of meeting the cap are lower than anticipated, and that the cost of abatement technology falls as it becomes subject to market forces and is no longer mandated (which before gave the suppliers substantial monopoly power).

The main objection to this approach is that there is no guarantee that the level of the cap is justified on a social cost-benefit test. I have noted that the limits were set to avoid exceeding environmentally determined critical loads, rather than addressing the larger damage to health.[191] If the environmental damage could be given a monetary value, then average damage costs per tonne SO_2 could be estimated for each country, and the permits replaced by a tax on the sulphur content of the fuel burned (with rebates for subsequent abatement, which would be easy to measure by the volume of sulphur removed from the combustion gases). Denmark offers the choice of taxing the sulphur content of fuel (at €2.7/kg) with rebates for sulphur not released as SO_2 (e.g. bound in the ash), or charging emissions at €1.35/kg SO_2. Norway and Sweden also impose sulphur taxes (or taxes on sulphur-containing fuels in proportion to their sulphur content) at rates between €2.5-€4/kg.

(ii) Particulates

Unburned carbon particles, or particulates, measured by PM_{10}, are the most damaging and socially costly combustion products, although SO_2 and NO_X also give rise to particulates with similar damaging effects. Large Combustion Plants are subject to emissions standards and can be taxed on their emissions, as in Denmark. Domestic emissions are now primarily controlled by prohibiting the more polluting fuels in certain areas (smokeless zones). The main problem is dealing with transport emissions, as their damage depends on when and where they are released. In most developed countries tailpipe emission standards on new vehicles have resulted in a dramatic reduction in the total levels of road transport emissions, despite the continuing increase in traffic. The cost of meeting these standards means the "the polluters pay", but not necessarily in proportion to the damage done, as increasingly tighter standards are only applied to new vehicles. This can have the perverse effect of discouraging users from replacing older more polluting vehicles by newer versions which, because they are cleaner, are more expensive. Britain addresses this problem for trucks by charging a lower annual licence fee on newer and cleaner vehicles. A sensible tax regime for this form of pollutant might therefore be to levy a tax equal to the average damage of older and more inefficient vehicles (or other sources), and give rebates on the annual licence fee for improved performance. Fines for excessive emissions can be used to target more accurately the emission charge on the small number of gross polluters.

The next question is to determine the correct level for the particulate tax. Newbery[192] argues for estimating the social costs of the health effects of

[190] A. Ellerman, *Analysis of the Bush Proposal to Reduce the SO_2 Cap*, MIT CEEPR Working Paper, WP-2002-002, February 2002 (web.mit.edu/ceepr/www/abstracts.htm#2002002).

[191] D. Newbery, "Acid rain", op. cit.

[192] D. Newbery, *Fair Payment from Road-users: A Review of the Evidence on Social and Environmental Costs*, report published by the Automobile Association, 1998.

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 National Health Service (in the United Kingdom or its counterpart in other countries) to achieve an extra year of quality life. The numbers used in the evaluation of transport should be consistent with numbers used elsewhere in health economics. This would enable the money raised in green taxes (which are mainly the costs of health damage) to be allocated to the National Health Service, which should be able to compensate for the quality life years lost through pollution by an equal saving of quality life years gained from improved health services.

Recent work presented in UNECE[193] suggests an encouraging convergence in estimates of the mortality effects of the more damaging pollutants. Severe urban pollution reduces life expectancy, and a *permanent* increase in air pollution of 10 :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 zero emission level. Road transport may be responsible for 4.4:g/m^3 of PM_{10} in Britain, reducing the loss of life expectancy per person exposed to 0.21 days per year of exposure.[194] 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 number of QALYs lost by one year's traffic particulate emissions is 34,000.[195]

The United Kingdom's Department for Transport assumes the value of a statistical life saved (VoSLS) in traffic accidents to be £1.44 million. The weighted average age of a traffic accident if all are equally exposed is 38, and life expectancy is then 40 years. We can therefore take a statistical life as 40 QALYs, making the value of a QALY £36,000. The United Kingdom's National Institute of Clinical Excellence was reported[196] as tentatively accepting a figure of £30,000 per QALY, suggesting a convergence on the valuation side. At £36,000/QALY, the cost of traffic pollution is £1.2 billion/year, negligible compared with road taxation of £27.5 billion in fiscal year 2000/01 (excluding all VAT). Most (89 per cent in Britain) of this cost is attributable to diesel vehicles, and would amount to 5.6p/litre of diesel (€100/tonne, or 0.9p/km), and 0.45p/litre of petrol (€10/tonne or 0.04p/km). Note that for pre-1993 vehicles the particulate tax should be 40-50 per cent higher than this average value, and for post-1997 vehicles 50-80 per cent lower (with diesel cars showing the greater improvement). These figures do not include the cost of morbidity (which is likely to be a modest fraction of mortality costs).

(iii) Nitrogen oxides

Similar principles can be used to determine standards for, and taxes on, NO_X emissions, as these share many of the same attributes as PM_{10} and SO_2. The United States has a regional cap and trade system for NO_X, which contributed to dramatically increased wholesale electricity prices in California in the summer and autumn of 2000. There the price of tradeable NO_X permits rose to unprecedented levels as the annual quota became inadequate, with permits trading at $80,000/ton at their peak, compared with $400/ton on the east coast.[197] If this approach is to be adopted the permit price itself needs to be capped at a sensible estimate of the marginal social damage done in adverse conditions (e.g. summer temperature inversions). While the United States SO_2 programme appears to have been a considerable success, the NO_X programme clearly needs modification, but it does not undermine the general claim that market-based systems have the potential to lower compliance costs considerably compared with command and control solutions.

3.12 Taxing transport fuels

Transport fuel prices in most EU countries are set at high levels as road user charges, not to reflect environmental externalities. I have set out the principles for designing a set of road user charges, and the likely levels of fuel tax required in the absence of road pricing,[198] estimating that an appropriate level for the United Kingdom in 2000 would be €0.60/litre for gasoline and €0.67/litre for diesel.[199] Chart 3.9.4

193 UNECE symposium, *The Measurement and Economic Valuation…*, op. cit.

194 D. Newbery, "Road user and congestion charges", in S. Cnossen (ed.), *The Economics and Ethics of Excise Taxation*, 2003, forthcoming.

195 Compare this with the estimate in BeTa, the Benefits Table Database listed on the EC DG Environment website, which assumes, without evidence, that the number of life years lost to the chronic effects of particles on mortality is five years.

196 *Times* (London), 10 August 2001.

197 R. Laurie, "Distributed generation: reaching the market just in time", *The Electricity Journal*, March 2001, pp. 87-94.

198 D. Newbery, "Pricing and congestion: economic principles relevant to pricing roads", *Oxford Review of Economic Policy*, Vol. 6, Issue 2, Summer 1990, pp. 22-38 and D. Newbery, *Fair Payment from Road-users*, op. cit.

199 D. Newbery, "Road user and congestion charges", op. cit.

shows that in the EU in 2001, only Denmark, Finland, France, Germany, Italy, the Netherlands and Sweden were levying gasoline taxes above €0.50/litre, while the United Kingdom was charging some 25 per cent more than was justified. The only OECD country charging the target level or above for diesel was the United Kingdom.

3.13 Concluding remarks

Energy prices have a considerable effect on energy consumption, but targeted taxes on environmental pollutants are considerably more effective at encouraging sustainable energy use. The wide range of energy intensities, and the even wider range of emissions per unit of activity (GDP, vehicle km, kWh) suggest that suitable taxes and standards can have powerful effects on environmental emissions. The transition economies have dramatically reduced energy use and emissions, although in most cases this was a result of the collapse of economic activity rather than improved efficiency. Nevertheless, as energy prices are gradually adjusted to world market levels, and new environmental standards accepted (often as part of EU accession agreements), incentives for efficiency improvements are being introduced.

Liberalization and privatization make market instruments (permit trading and eco-taxes) increasingly preferable to command and control solutions, and in turn create a constituency for measuring the damage caused by pollutants and relating taxes to that damage. International agreements for the control of transboundary acid rain pollutants have been surprisingly successful, given their very asymmetric cost distribution and the slender economic basis for the agreed levels. Combined with cap and trade markets, the marginal costs of abatement in each country should become clearer, and with it perhaps a move to trade across boundaries to equalize these prices, potentially offering large cost reductions. Full carbon trading might, according to some estimates, reduce compliance costs by a factor of eight.

The transport sector is the fastest growing source of CO_2 emissions, and also attracts the highest rates of tax. In some countries these high and growing transport fuel taxes are defended as necessary on environmental grounds, but a careful assessment casts doubt on this claim, except in North America (where such claims are in any case absent). Transport taxes in most European countries are higher than emissions taxes alone would suggest, although (with the exception of the United Kingdom) below the combination of road user charges and emissions taxes. Diesel fuel is normally and inefficiently less heavily taxed than gasoline. The energy uses that stand out as under-taxed in most countries are coal (with notable exceptions in countries that have introduced carbon taxes), and households, where distributional concerns obstruct incentives for improved energy efficiency.

Pessimists (and economists) continue to criticize the irrationality of energy tax policy, but optimists can point to the steady improvement in our understanding of the costs and benefits of reducing pollution, and the resulting improvement in the design of emissions policy.

DISCUSSANTS' COMMENTS

3.A Inge Mayeres

David Newbery's paper gives an excellent overview of the issues at stake. Given my research background, I shall concentrate my comments on transport policies. The structure will be as follows:

- First, I shall elaborate somewhat on the use of environmental measures in the transport sector;
- Second, environmental problems are not the only problems present in the transport sector. I shall briefly review the implications of this;
- Third, I shall argue that the design and evaluation of transport policies should take into account not only the transport sector, but also their impacts on the economy as a whole.

Environmental measures in the transport sector

The best solution would be a perfect emissions tax, with the tax rate depending on the level, location and time of emissions. The last two characteristics are important because the damage from emissions is site and time specific. For instance, the formation of tropospheric ozone from VOC and NO_X emissions depends strongly on sunlight, temperature and wind direction. Recent studies have also shown that emissions of particulate matter in large urban areas cause much greater damage than emissions in rural areas.

Recent technological advances in the measurement of vehicle emissions may justify the use of an emissions tax. But Fullerton and West[200] argue that this technology is still expensive and that it could also be tampered with by car owners. Therefore they investigated the extent to which the optimal Pigovian tax[201] can be mimicked by a tax on fuel and on car characteristics such as engine size, vintage or the presence of pollution control equipment. They find that such instruments do have such a potential. They show that 71 per cent of the welfare gain under the Pigovian tax can be obtained with a combined tax on size, fuel and vintage; 62 per cent is obtainable via the fuel tax alone. Note that they assume only one externality. I shall discuss the more realistic case of several externalities later on.

These results are in line with other studies. Mayeres and Proost[202] investigated related issues in a paper on the relative taxation of diesel and gasoline driven cars. Since fuel taxes do not distinguish users of the fuel (cars versus trucks, vehicles with different emission technology, private versus professional use, and so on) and since fuel "tourism" occurs, especially in small countries, there is a role for vehicle ownership taxes. These aspects are also analysed in De Borger[203] who derives optimal rules for the taxation of car ownership and car use in the presence of externalities. His analysis shows that if there are no restrictions on tax instruments, taxes on car ownership mainly raise revenue rather than correcting for external effects. However, when there are restrictions on tax instruments, the taxes on car ownership become crucial in responding to external cost differences between vehicle types. The tax differential between two vehicle types is then shown to be a complex function of the relationship between variable taxes and marginal external costs and of the various price elasticities that determine the budgetary implications of the tax adjustments.

Up to now I have abstracted from the fact that environmental damage can be time and location specific. Kolstad[204] examines the use of uniform or differentiated regulation when damage is variable. The optimal uniform regulation is shown to depend on the relative slopes of the marginal abatement cost curve and the marginal damage curve. Uniform regulation can lead to more or less emissions than a differentiated approach. He also analysed the inefficiencies associated with uniform regulation and showed that the least inefficiency is associated with perfectly elastic marginal cost and benefit functions and that the inefficiencies associated with uniform regulation increase as the marginal cost and benefit functions become more steeply sloped.

200 D. Fullerton and S. West, *Tax and Subsidy Combinations for the Control of Car Pollution*, NBER Working Paper, No. 7774 (Cambridge, MA), July 2000.

201 That is, a tax levied on the producer of an emission at a rate which would equalize the private costs (as calculated by the producer) and social costs of the activity.

202 I. Mayeres and S. Proost, "Should diesel cars in Europe be discouraged?", *Regional Science and Urban Economics*, Vol. 31, Issue 4, July 2001, pp. 453-470.

203 B. De Borger, "Discrete choice models and optimal two-part tariffs in the presence of externalities: optimal taxation of cars", *Regional Science and Urban Economics*, Vol. 31, Issue 4, July 2001, pp. 471-504.

204 C. Kolstad, "Uniformity versus differentiation in regulating externalities", *Journal of Environmental Economics and Management*, Vol. 14, 1987, pp. 386-399.

Environmental costs of transport versus other externalities of transport

Transport generates other externalities besides air pollution, congestion, accidents and noise being the principal ones. A good policy design requires that these aspects be considered together.

Table 3.A.1 shows the marginal external costs that can be expected from using a car in Brussels in 2005 under a business-as-usual scenario. Congestion is the most significant external cost, at least in peak periods. In off-peak periods, accidents are the most important costs of using non-diesel vehicles. The air pollution costs of diesel vehicles are higher than those of gasoline vehicles.

Proost and Van Dender[205] examine the welfare gains from adopting different types of regulation, including both pricing instruments and technology standards. This is done on the basis of a partial equilibrium model (TRENEN)[206] for approximately 20 transport markets, calibrated for Brussels in 2005.

The results are shown in table 3.A.2, which considers four types of measure: an improved technology standard, a higher fuel efficiency standard, a fuel tax and time varying cordon pricing. The welfare effects of these measures are compared with the welfare gain from full external cost pricing.

The results underline the fact that it is important to conduct an integrated analysis which considers all transport externalities simultaneously.

In this particular case study, imposing improved car emission technology does not yield any welfare gains. This is because the exercise starts from a baseline which incorporates current EU abatement standards for new vehicles, which already reduce emissions considerably. Policies to regulate emissions may have reached the point of strongly increasing marginal abatement costs. This explains why further emissions reductions via a higher technological standard reduce welfare, because the marginal costs of further reductions are quite high. Some caveats are in place. First of all, it should be noted that the study is carried out in a EU country, and that the results are not necessarily valid in countries with less stringent emission standards. Second, the authors point to a number of other caveats, concerning the number of measures included in the emission standard, the type of vehicle for which they are imposed, and the size of the city considered in their study. Finally, it might be that in other parts of the transport sector, such as inland navigation, there is still scope for obtaining benefits from better emission technology.

Imposing higher fuel efficiency standards on cars leads to a welfare loss, for similar reasons to those in the case of emission standards.

A fuel tax performs better. It gives some incentive for increasing the fuel efficiency of vehicles, but its main benefit is that it reduces traffic and therefore congestion. However, it is not differentiated according to time of travel so its welfare gain is less than that of a time varying cordon pricing scheme.

The time varying cordon pricing scheme can – in a somewhat rough manner – impose both a congestion charge and an emissions tax. It can achieve 52 per cent of the welfare gains of a perfect charging system, and is therefore relatively efficient.

The conclusion is that reducing emissions in the EU transport sector by means of standards that are stricter than those currently planned may not be a wise policy. This also holds for CO_2 reduction: one should be careful not to go too far in the transport sector. Greenhouse gases have to be reduced, but this should be done in a way that is least costly for society as a whole. As there is already a high fuel tax, and therefore implicitly a high greenhouse tax on car use,

TABLE 3.A.1

Marginal external costs of car use in Brussels, 2005
(Euros/vehicle kilometres)

	Gasoline car		*Diesel car*	
	Peak	*Off-peak*	*Peak*	*Off-peak*
Congestion	1.856	0.003	1.856	0.003
Air pollution	0.004	0.004	0.042	0.026
Accidents	0.033	0.033	0.033	0.033
Noise	0.002	0.008	0.002	0.008
Total	1.895	0.047	1.932	0.068

Source: S. Proost and K. Van Dender, "The welfare impacts of alternative policies to address atmospheric pollution in urban road transport", Regional Science and Urban Economics, Vol. 31, Issue 4, July 2001, pp. 383-411.

TABLE 3.A.2

The welfare effect of transport policy reforms, 2005
(Percentage)

	Percentage of welfare gain obtained under full external cost pricing
Improved emission technology standard	0.0
Higher fuel efficiency standard	-17.1
Fuel tax	5.3
Time varying cordon pricing	52.3

Source: As for table 3.B.1.

[205] S. Proost and K. Van Dender, "The welfare impacts of alternative policies to address atmospheric pollution in urban road transport", *Regional Science and Urban Economics*, Vol. 31, Issue 4, July 2001, pp. 383-411.

[206] An analytical model developed for the European Commission to optimize the European transport pricing policies under a variety of constraints.

fuel efficiency is already relatively high in the transport sector. There will be cheaper options in other sectors for reducing greenhouse gas emission reductions.

Of course there may still be some cheap options for emission reduction in the transport sector (for instance, inland navigation). Moreover, some transport volumes are too large because external congestion or accident costs have not yet been internalized by the transport users. A better transport policy will reduce these flows, thereby generating side benefits in the form of lower emissions.

Transport policy in a more general setting

Governments' objectives are not confined to controlling transport externalities. They also need to raise revenue in order to be able to provide public services. They have to use distortionary taxes for this. Moreover, they have equity objectives. In general these two objectives cannot be separated. Indeed, the very presence of a distortionary tax such as the labour income tax reflects equity concerns.

All this implies that transport instruments should not be viewed on their own, but as part of the global set of a government's policy instruments. The full welfare impact of transport policies can be assessed only if the rest of the economy is taken into account.[207]

The imposition of a higher tax in the transport sector may have impacts outside the sector. For instance, labour taxes distort the economy by subsidizing leisure. If, for example, one increases the tax on road use, this may further exacerbate the labour market distortion. This needs to be taken into account when choosing between transport instruments, and when setting their level.

The literature also highlights the point that in order to evaluate a given transport policy, such as an air pollution tax, one needs to consider how the extra revenue will be spent, which will depend on equity objectives. For instance, if only efficiency is important, a good policy would be to use the extra revenue to reduce the labour income tax rather than, for example, to increase social security transfers. However, when equity is more important, the opposite may be true.

Equity issues also play a role in determining the level of transport taxes: if the government wants to give a higher weight to low income groups, the level of tax will depend on the extent to which the services of transport are consumed by these income groups and on the extent to which they value the reduction in the externalities.

3.B Thomas Johansson

Thomas Johansson considered some of the constraints on policy choices implied by Professor Newbery's paper. According to Johansson, the main challenge of the future is to move away from dependence on conventional oil. The magnitude of this challenge is enormous, given the hitherto dominant security aspects of energy supply, and the fact that about one third of the world population does not yet have access to electricity. Furthermore, there are systematic boundaries to the evaluation of the problem: actually, we know very little about the health effects of emissions. Due to the stock character of the greenhouse effect, huge reductions in emissions are necessary, and these may not be achievable by tax correctives alone.

Such considerations might eventually involve more room for hydrogen-technology, or nuclear energy, while natural gas may provide an important bridge in the shift away from oil. However, technological improvements or new technologies are highly policy sensitive. Technological decisions are linked to market behaviour and performance, where a lot remains to be done to create real competition and induce private sector investment: currently, subsidies amount to some 10 per cent of energy sales worldwide.

Taxes can help to improve energy efficiency, but only to a very limited extent. Overall, there are many small opportunities and it is the task of policy to integrate them. Many of these involve moral hazard problems, such as the landlord-tenant problem, where the landlord decides whether or not to introduce improvements in energy efficiency but the tenant bears the costs of the decisions. Such situations call for appropriate policies to avoid inefficient solutions. Sometimes, market solutions, such as markets for energy use or emission certificates, can internalize the problem and bring about efficiency improvements.

Although government spending on R&D is declining everywhere, the most important challenge is to initiate an "innovation chain" of new technologies. This might involve subsidizing demonstration projects to reap the benefits from learning before making new technologies available to the private sector, which otherwise might be unwilling to bear the risk of investing in them.

The power generating sector has some very specific features. In particular the fact that electricity cannot be stored and must be consumed at the moment

[207] I. Mayeres, "The efficiency effects of transport policies in the presence of externalities and distortionary taxes", *Journal of Transport Economics and Policy*, Vol. 34, Part 2, May 2000, pp. 233-260 and *Equity and Transport Policy Reform*, ETE Working Paper Series, No. 2001-14, Centre for Economic Studies, K.U. Leuven, July 2001.

it is produced has serious implications for competition that tend to keep alternative technologies out of the market. To ensure a wider dissemination of new technologies certificate markets can make a difference. Other instrumental public policies in this respect are capacity building issues, such as training, and the creation, analysis and dissemination of knowledge.

3.C George Kowalski

George Kowalski noted that after the first oil price shock (in 1973) there was a decoupling of economic growth from energy consumption and CO_2 emissions in the developed market economies thanks to the combination of two processes: i) declining energy intensity per unit of output and ii) inter-fuel substitution away from carbon-intensive fuels. However, since the 1980s (i.e. after the second oil shock) the gains on these two accounts have steadily decelerated largely due to two factors:

- Real energy prices for end-users have declined persistently since the early 1980s, a development supported by tax policies;
- Expenditure on energy as a share of disposable income has been declining since the mid-1980s.

The Kyoto Protocol sets quite timid goals but even if these are achieved they will not result in a significant long-term environmental improvement. The main problem is to stabilize concentrations of CO_2 in the atmosphere. But this requires a 60 per cent reduction of CO_2 emissions in developed market economies between 2000 and 2050 (assuming the same rate of GDP growth as between 1971 and 1999). This, however, contrasts with the fact that at present 2 billion people in other parts of the world do not have access to commercial energy. They will do so, however, as their economic growth proceeds, and this will have an enormous impact on fuel consumption.

Policies should respond to these challenges in different time frames. Over the short to medium term a mix of the following policy instruments is required:

- Economic instruments: enforcement of the Kyoto mechanisms (including emissions trading, which could give rise to a large market) and the use of fiscal measures;
- Command and control measures, particularly efficiency standards and mandated levels of use of renewables.

The implementation of such policies would give transition economies (which still have an excessively high energy intensity) the opportunity to apply Kyoto mechanisms at a lower cost, and emissions trading would provide them with a source of financing to modernize their economies.

Over the long term, the main policy response should consist of strong investment in research and development, mainly in:

- More competitive renewables;
- Safer nuclear power, including a solution for the disposal of nuclear waste;
- Zero emission fossil fuels technologies through fuel cells and CO_2 sequestration and storage.

In the next 50 years fossil fuels will be in plentiful supply and will continue to be a major source of energy (even for hydrogen cells). Therefore it is necessary to develop ways to use them in a more environmental-friendly way.

3.D José Capel Ferrer

José Capel Ferrer commented on the sectoral dimension of sustainable development from the perspective of the transport sector, focusing mainly on motor vehicles.

He noted that the number of motor vehicles in the world is currently estimated at about 800 million, and that the number is expected to climb to 1.1 billion by 2020. A major part of this growth will take place in developing countries. These figures point to an area of utmost economic, social and environmental importance. It is also one in which the UNECE plays a special role and where it makes a practical contribution to sustainable development. Capel Ferrer explained that the UNECE Transport Division provides the secretariat to the World Forum for Harmonization of Vehicle Regulations (WP.29), which is the international regulatory and standard setting body for motor vehicles, working in the framework of the UNECE. It administers three major international agreements, including the 1958 Agreement and the 1998 global Agreement, in the framework of which it develops international regulations on the safety and environmental aspects of motor vehicles, including emissions.

The 1998 Agreement is too recent to have produced concrete results, but it is worth noting that all regulatory activities on vehicle emissions are now being carried out at the global level in the framework of this Agreement.

The 1958 Agreement, however, has already produced tangible results. Altogether 115 ECE regulations have been developed in its framework and are widely implemented, not only in the ECE region, but also in many other countries. A number of these regulations establish pollutant emissions and energy consumption requirements for all types of road vehicles, including private cars and commercial vehicles.

ECE regulations on vehicle emissions, through successive amendments to incorporate the best available technology, have greatly reduced the emission limits of the various pollutants, reducing them by a factor of more than 20.

In addition to reducing emissions by petrol and diesel vehicles, WP.29 has also developed regulations to provide for the safe use of two other fuels, liquid petroleum gas (LPG) and compressed natural gas (CNG), which appear to have environmental benefits compared with traditional ones. It has also regulated electric vehicles and it is expected that in future other fuels will be added to the list.

The substantial reduction in the emission limits of motor vehicles, and their mandatory introduction through regulation, was possible because the technology was available to provide efficient solutions at low cost. However, the issue of energy consumption and CO_2 emissions, as Professor Newbery rightly says in his paper, is more pervasive. Firstly, technological research has not been able so far to provide the means for achieving the same level of abatement as for other pollutants. Secondly, increased safety requirements and other types of equipment have led to heavier and therefore more energy consuming vehicles. As a result, regulation has so far not been of much help in substantially reducing energy consumption and CO_2 emissions.

Nevertheless, ECE continues to closely monitor new technological developments that may bring about significant reductions in energy consumption and CO_2 emissions. There are interesting possibilities for technical regulation in future, including of various types of hybrid vehicles and, in a more distant future, of fuel cell technology**.** The latter, when developed, may have the potential to solve most of the environmental problems created by vehicles, including fossil fuel consumption and CO_2 emissions. By using hydrogen as a fuel, vehicles equipped with fuel cells would only release steam from their exhaust pipes. In view of its potential, and in order to prepare the regulatory work required to introduce that technology, WP.29 has incorporated fuel cells into its work programme.

In the meantime, governments will have to apply a wide array of other measures to obtain additional environmental benefits. These include taxation, traffic demand and traffic management measures; measures to improve urban transport, including road pricing and the promotion of public transport; and measures to reduce travel needs and travel distances, including better land-use planning. Some of these measures will be developed in the framework of the UNECE's Transport, Environment and Health Pan-European Programme.