Pricing Carbon for Electricity Generation:

National and International Dimensions

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NATIONAL AND INTERNATIONAL DIMENSIONS

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Abstract

In this paper, which forms a chapter in the forthcoming Book "***Delivering a Low Carbon Electricity System: Technologies, Economics and Policy***"[2], Grubb and Newbery examine how carbon for electricity generation should be priced. They begin by suggesting that it is not clear what the correct price of carbon is, but that it spans the whole range of economically plausible prices. They then go on to discuss the theoretical merits of taxes versus quotas, concluding that theoretically a stable tax would best reflect the true social cost of emissions, which should not change with market conditions. They then go to evaluate the EU Emissions Trading Scheme where allowances for the emission of CO_2 are traded (EUAs). The price signals offered by the scheme in its first trading period have been very unsatisfactory with high variability and the price trending down towards very low levels as it has become clear that governments were much too generous in their initial allocation of quotas. What is needed is a stable investment environment for low carbon generation investments. They discuss a number of policy options to achieve this: long period commitments on quotas; allowing unconstrained banking and borrowing of EUAs over multiple periods; long term price declarations to be used in allocation auctions; government issued contracts for differences on the future carbon price; or simply to issue low-carbon electricity contracts. The authors conclude with a discussion of the scope for international agreements on carbon emissions reduction. They conclude that imperfect though it is the EU ETS is a good place to start to link up emerging trading regimes, and that quota systems have more of a chance of commanding international agreement at least initially. However any international climate change agreement will be difficult to establish.

JEL Classification: Q54, Q58, Q55
Keywords: Carbon price, electricity, taxes vs quotas, emissions trading

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1 Introduction

The UK *Energy Review* states that "The only way in which the international community will limit the rise in carbon emissions is if governments, industry and individuals take into account the costs associated with the emissions for which they are responsible. … A carbon price is essential for making lower carbon emissions a business imperative. … Establishing a price for carbon is best done internationally because climate change is a global problem requiring collective action." (DTI, 2006, p27). "Policy to reduce emissions should be based on three essential elements: carbon pricing, technology policy, and removal of barriers to behavioural change." (The *Stern Review*, Stern, 2006). The UK Government's approach to climate change is thus based on sound economics. Chapter 2, in discussing the 'Social Cost of Carbon', has by implication discussed the level of carbon pricing that could be sought. This chapter addresses the *instruments* that might deliver such carbon pricing and the challenges in seeking to internationalise such instruments. Other chapters address instruments for energy efficiency, and for innovation.

2 The social cost of carbon, carbon pricing and power sector mitigation

From an economic perspective, the most fundamental single step in climate policy is to establish a price for carbon. This should be informed by (but is not the same thing as) the social cost of carbon – the present discounted value of the additional social costs (or the marginal social damage) that an extra tonne of carbon released now would impose on the current and future society. As described in chapter 2, the *Stern Review* uses the PAGE2002 model to calculate the likely damage caused by emitting an extra tonne of carbon and then to determine the resulting social cost of this damage, the social cost of carbon, SCC. We emphasise again that this measure of damage is not just a prediction of the economic impact of climate change, but an ethical valuation of its significance to society. As chapter 2 stressed, estimating the SCC is a multi-stage process.

The first two stages are to estimate the effect of greenhouse gases (GHGs) on temperature, and then the effects of this temperature rise on climate (regionally, seasonally, probability of extreme events, sea-level rises, etc.). After these two climate-science driven steps, integrated assessment models (like PAGE) attempt to estimate the regional impacts of this climate change on well-being. If our economic modelling were as good as the climate science, we would then have a quantified description of the various economic effects, but over the long periods of time involved it would be foolish to pretend to any accuracy.

In addition to the cascade of uncertainties set out in Chapter 2, the result does depend on the rate of technical progress (which influences economic and emission growth rates, the capacity to adapt to climate change, and the cost of mitigation). A typical prediction of the rate of technical progress is to assume that it will continue as in the past century (when it has been historically most unusually high). We have little other idea of the nature of future technology and hence the future standards of living, but the rate of technical progress will be a key determinant.

The final step is to value these impacts when and where they occur and discount them to an equivalent present global aggregate. The valuation is one of the most controversial steps in the calculation. The PAGE model (and many other models) uses equity weighting, as discussed in chapter 2. The preferred weights are inversely proportional to per capita consumption (often proxied by GDP/head at purchasing power parity, $PPP). This has the ethically agreeable implication that if each country's value of a statistical life is proportional to GDP/head, then climate damage that involves loss of life or life expectancy when weighted with these equity weights treats a year of life lost in Bangladesh as equal to that in the US or UK. Another way to appreciate the force of Stern's assumption is that the social cost of reducing the consumption of a person in a rich country by 10% is valued equal to the social benefit of increasing the consumption of a person in a poor country by 10% now. Thus as Western Europe has 25 times the per capita consumption of Sub Saharan Africa (at Purchasing Power Parity exchange rates), incurring a cost of $25 in Western Europe to deliver a benefit of more than $1 in SSA would deliver a net social gain on this calculus. The implications of this for the choice of policy instruments are discussed below.

The *Stern Review* adopts this approach, and also assumes a single view on the pure rate of time preference (PRTP, taken as 0.1% p.a.). Given these, and updating the IPCC 's 2001 *Third Assessment Report* to take account of stronger feedbacks and higher climate sensitivity, the *Stern Review* estimates the SCC as **$312/tC** (tonne of carbon, = **$85/tonne CO_2**, $2006 prices) if we remain on the Business as Usual (BAU) path (Stern, 2006, pxvi, p287), although this estimate is given with considerable hesitation: "We would therefore point to numbers for the 'business as usual' social cost of carbon well above (perhaps a factor of three times) the Tol mean of **$29/t$CO_2$** and the 'lower central' estimate of around $13/t$CO_2$ in the recent study for DEFRA (Watkiss et al. (2005))… Nevertheless, we are keenly aware of the sensitivity of estimates to the assumptions that are made. Closer examination of this issue – and a narrowing of the range of estimates, if possible – is a high priority for research." (Stern, 2006, p287).[1]

The PAGE estimates presented in chapter 2 suggest a mean SCC of $(2000) **43/tC** ($11.7/tCO2), for a range of possible baseline scenarios (Hope, 2007a), with a 5-95% range of **$10 to $130/tC** ($2.7 to 35.5/tCO2).[2] The central figure increases to **$90/tC** ($24.5/tCO2) (5-

[1] Box 13.1 of the *Stern Review* summarises other estimates of the SCC, citing a study by Downing et al (2005) for DEFRA, which observed that estimates in the literature range from £0-1000/tC, and suggested a lower benchmark of £35/tC ($12.5/t$CO_2$) (all at 2000 prices). Tol's (2005) survey found a median value of $14/tC ($3.8/tCO_2)and the 95th percentile at $350/tC ($95.5/tCO_2), comparable to that of the *Stern Review* (Stern, 2006, p288).

[2] As explained in chapter 1, the baseline scenarios assume no effective climate change mitigation, although different possible evolutions of emissions, so that eventually damaging climate change will

95% range **$10–220/tC** ($2.7-60/tCO2)) under updated estimates of climate sensitivity and other adjustments described in chapter 2. These estimates assume equity weights centred on the inverse of per capita consumption but with a range either side, and an average *consumption rate of interest* of 2 +/- 1%. If the rate of pure time preference is reduced (as in the *Stern Review*) to 0.1% - equivalent to setting a consumption rate of interest of about 1.5% - the model computes a mean SCC of **$330/tC** ($90/tCO2) (5-95% range **$65 – 870/tC** ($17.7-237.3/tCO2)**)**, essentially the same as the *Stern Review*. Ignoring equity weighting altogether, but taking a consumption rate of interest of 3+/-1%, the SCC is **$51/tC** ($13.9/tCO2) (5-95% range **$10 to $150/tC** ($2.7 to 40.9/tCO2)). As such it is comparable to those derived from other models using the same consumption rate of interest.

These estimates of the SCC and of the cost of climate change more generally, and the assumptions from which they flow, have attracted a great deal of economic discussion, as discussed in chapter 2. High values of the SCC can be defended either by assuming that we are willing to express significant social concern for distant future generations (low rate of pure time preference), or by assuming that the implied actions now, which are costly but not that costly (1-2% of GDP) should be considered as an insurance premium for a possibly very low (but essentially unknown) chance of very serious future damage. By definition, unpredictable events are impossible to model with any confidence, and the high SCC is warning us to take adequate steps now to reduce the risks of extreme, if unlikely, future disaster.

The SCC could be interpreted as the correct *price* to set for emissions of carbon if the world were to collectively agree to the associated system of equity weights and rate of pure time preference. Even then, as chapter 2 indicated, the SCC depends on whose consumption is taken as numeraire. As reported, the numeraire (as in the Stern Review) is world average GDP/head at $PPP, but the SCC would be much higher if EU GDP/head were the numeraire, and very much lower if Sub-Saharan African GDP/head were used instead. The world average makes sense if there were a world government allocating resources for the benefit of all, but we are a long way from that state. The PAGE SCC without equity weighting is somewhat more than half the equity weighted value, and might represent a consensus view in which each country worries about the cash value of its own damage, but collectively recognises the public good nature of mitigation. This is more likely if the costs of mitigation are proportional to GDP (as is likely in the electricity sector), since future damage is also likely to be proportional to GDP, and if anything larger in poorer countries, encouraging their co-operation. On the insurance argument, though, the main point is that the *price* of carbon should be high to induce sufficient mitigation, regardless of the fine balancing of current cost for expected future gain.

To maximise global efficiency – and if international transfers (or allocations of carbon allowances) can address equity issues - the carbon price should be the same everywhere.

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be unavoidable. In contrast, if we were to model a successful climate change mitigation strategy, then disaster would be averted and the SCC could be considerably lower.

Clearly in practice, any such global price of carbon would have emerge from negotiations, and would have to be a market price, not an equity weighted social value of the kind used in (typically national) social cost-benefit analysis (e.g. as in HMT 2003). Given all the considerations noted above, it is hard to predict what price might emerge from such negotiations, and the range of potentially defensible outcomes is clearly very wide.

In terms of its implications for electricity policy, the most significant thing is that *the range of potentially defensible SCCs spans almost the entire range of possible relevance to the economics of power generation.* Chapter 3 summarised the implicit additional cost of the main low carbon power sources available to the UK. The results are consistent with the IPCC conclusions that many large-scale options (e.g. nuclear, CCS, offshore wind and most biomass) would become economic at carbon prices in the range \$20-50/tCO2 (\$75-185/tC), if and as they were to be deployed at scale. The Stern Review's estimate of SCC is comfortably above the upper end. The Tol mean is towards the low part of this range. The PAGE results in Chapter 2 easily span the range and the 5-95% estimates go far beyond at both ends. In other words, plausibly defensible estimates of the SCC, applied as carbon prices, could imply anything ranging from a marginal additional cost insufficient to help most low carbon power sources, to a huge carbon charge sufficient for such sources to unambiguously dominate power investment.

Given that investment decisions need to be made, and that neither further analysis nor global negotiations are likely to resolve the uncertainties quickly, a need for forward-looking judgement is inescapable. In this context, Figure 1 frames the cost-benefit economics of carbon pricing decisions. As prices increase roughly over the range indicated, there may be quite a rapid increase in the degree of abatement in response, particularly as investment decisions start to switch away from coal towards low-carbon sources. Above a certain price however, most zero-carbon sources may be exhausted (or may be facing hard constraints on siting or rates of expansion), so additional abatement may be very limited, at costs that could anyway only be justified if the SCC were at the higher levels of estimation. In the context of such uncertainties, in other words, a rational mitigation goal would be for a price/quantity outcome somewhere around the 'point of inflexion' in the supply curve - in the circle indicated in the Figure that could minimise 'the cost of being wrong'. The circle itself spans a significant range. Where to aim is not just a matter of making a best estimate applicable – it also needs to consider the role the UK wishes to take in the global process (discussed below), and the dynamic implications of the related decisions.

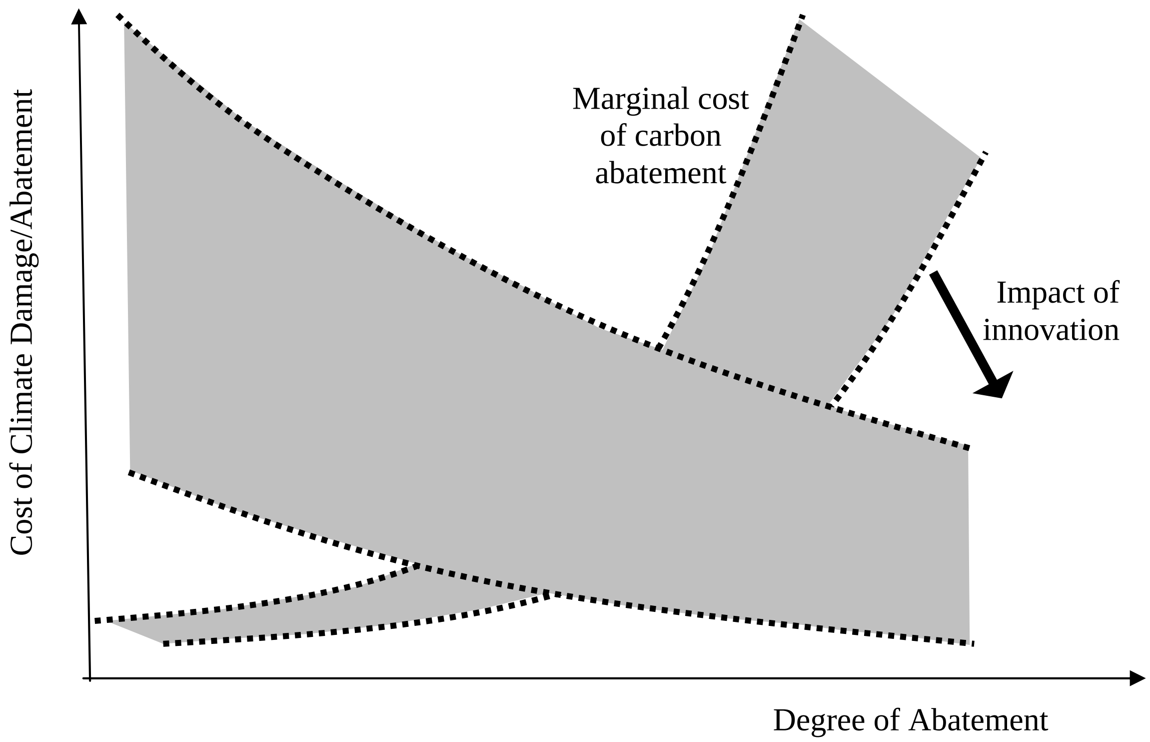

Figure 1: Plausible abatement marginal cost and benefit schedules[3]

3 Taxes or quotas?

3.1 Theoretical fundamentals

A price for carbon can be established directly either using a carbon tax, or by setting a quantity limit and letting companies trade the resulting emission allowances. The EU approach is to issue EU Emission Allowances (EUA), each for 1 tonne of CO_2, while in the past various countries, starting particularly in Scandinavia in the early 1990s, have imposed carbon taxes on fuels (with exemptions for internationally exposed industries). If there is complete information and no uncertainty, the efficient level could be achieved either by issuing the correct number of quotas or setting the pollution tax at the marginal damage cost at the efficient level. This equality of outcome breaks down under uncertainty or with asymmetric information. Weitzman (1974) started a lengthy debate by observing that in the presence of uncertainty, quotas are only superior to taxes if the marginal benefit from abatement schedule (i.e. the marginal damage of emissions) is steeper than the marginal cost

[3] The Figure illustrates schematically the cost-benefit tradeoff in the face of uncertainty and convexity. The ‘cost of climate damage’ declines as the degree of abatement (x-axis) increases, but is highly uncertain (as indicated by the wide vertical range - that is in fact still very much narrower than suggested by the discussion of Impacts earlier in this paper). The cost of abatement may be modest for small cuts, but both the cost and the uncertainty rises steeply for much more aggressive cutbacks. The dotted circle indicates that a rational tradeoff would be to pursue abatement to a level just before these costs start to rise sharply, whilst innovation policies seek to generate new options to bring down the cost of deeper emission cuts.

of abatement schedule as in Figure 2. The figure shows that if the taxes and allowances are set on the basis of the expected marginal costs and benefits, but the correct marginal costs are higher than expected, then the deadweight or efficiency loss from incorrectly setting a permit at level *Q* rather than *Q** is considerably higher than incorrectly setting the tax or charge at *t* rather than *t**.[4]

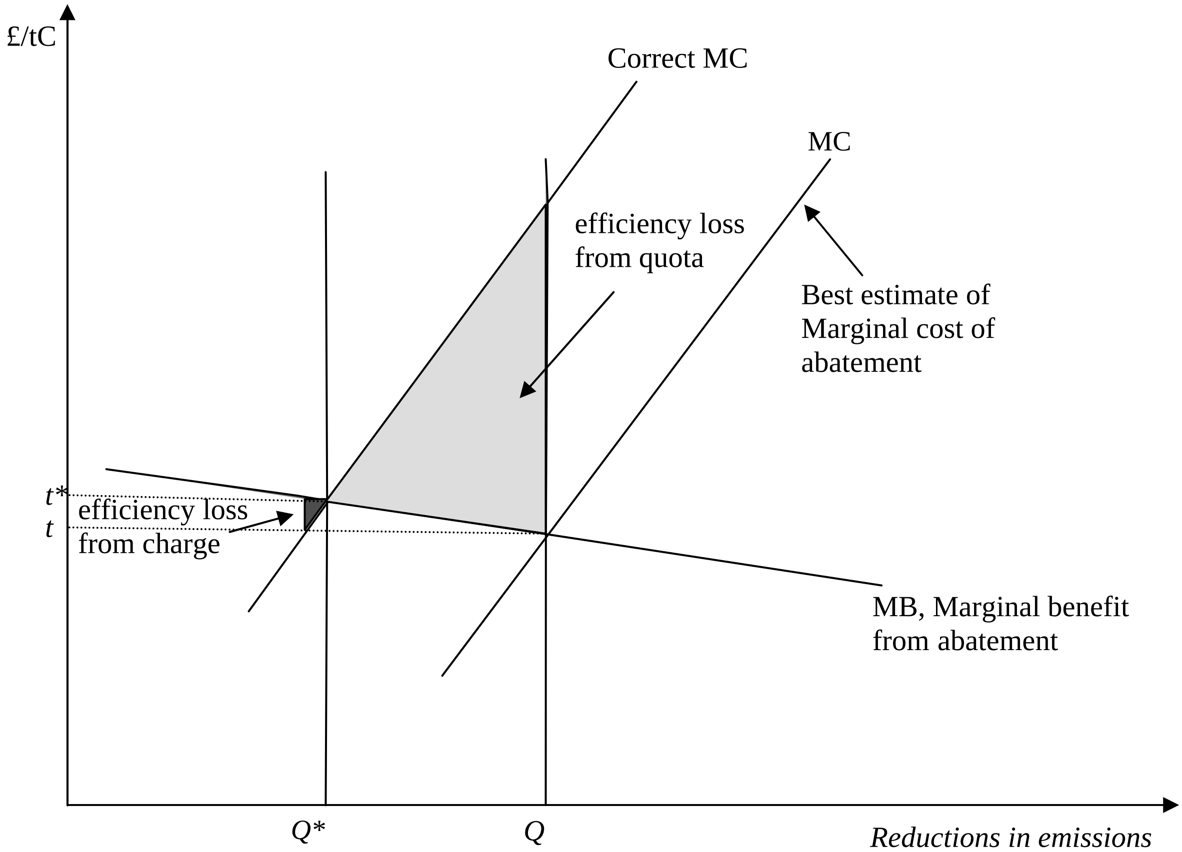

Figure 2: Relative efficiency of prices vs. quantities

As already noted, GHG emissions contribute to an atmospheric stock with a very slow rate of decay. The damage contributed by emissions today is effectively the same as those tomorrow, and so the marginal benefit of abatement is essentially flat at each moment, while the marginal cost of abatement rises rapidly beyond a certain point. The scale of the hazard of global warming is very uncertain, as are the future costs of reducing carbon intensity. All these are arguments for a stable global carbon price or tax. As more information about the damage of global warming arrives, so the optimal tax can be adjusted (just as the allowed level of emissions would have to be adjusted). The desirable stability of the carbon price is

[4] Weitzman shows that the comparative advantage of prices over quantities is given by the formula ½ *Variance of MC x* (*slope of MC - slope of MB*)/(*slope of MC*)^2, and is independent of the uncertainty in the position of the marginal benefit schedule, provided that policies are based on unbiased best estimates of the schedules. If that schedule is flat then the formula simplifies to ½ *Variance of MC* /(*slope of MC*).

not absolute, but only applies over (possibly quite long) periods of time in which no significant new information arrives, as discussed below. In contrast, tradable quotas can give rise to volatile prices over quite short periods of time, as illustrated for the EU ETS in the next section.

Hoel and Karp (2001) explore this question more carefully in a calibrated linear-quadratic dynamic model of global warming and confirm Weitzman's insight robustly. Pizer (2002) demonstrates the same result based on simulating a stochastic computable general equilibrium model, while as noted, the PAGE model discussed in chapter 2 demonstrates the apparent insensitivity of the SCC (including the carbon price with no equity weighting) to the level of emissions on a business-as-usual path. These simple economic arguments suggest that there is a stronger case for a fixed, stable carbon price (via taxes or some other mechanism) than for fixed or stable quota allocations, as long as the dominant determinants of emissions are to do with price more than regulatory structure, and that the carbon price would be significant relative to other economic forces.

These generic economic considerations need to be tested against specific applications. It is unclear the extent to which the likely characteristics of the cost and benefit schedules (Fig.1) may in themselves affect the Weitzman argument. The assumption that short-run mitigation has very little impact on long-run damages may not be true concerning some new power sector investments, such as the choice between a coal vs. nuclear or renewable plant that may last many decades. Moreover, whilst the *Stern Review* acknowledges the Weitzman argument for the short term, it also argues that increasing long-term risks make it desirable to aim at an equilibrium GHG concentration below 550ppm (CO_2 equivalent). This is equivalent to specifying a stock of GHGs, or a quantity limit on the amount of fossil fuel that can be burned over the next 100-200 years. The argument for choosing this quantity target, loosely stated, is that mitigation costs are too high to aim at lower levels (e.g. 450ppm), while overshooting 550ppm runs serious risk of irreversible and catastrophically expensive future outcomes. If so, then setting a quantity limit on the amount of carbon released appears prudent. Which is correct? The *Stern Review* leaves this open, noting that "***Establishing a carbon price, through tax, trading or regulation, is an essential foundation for climate-change policy.***" (Stern, 2006, xviii, emphasis in original).

The two views can be reconciled by noting that the carbon price should be moderately stable over reasonable time periods (1-15 years if no new information about the costs of climate change arrives) but over longer periods of time the price will need to be adjusted to balance cumulative carbon emissions with absorptive capacity. Hepburn et. al. (2006) discuss the relation between a longer-run target quantity and the need to stabilise the carbon price in the short to medium run.

The *Stern Review* proposes 550ppm as a ceiling, but does not thereby conclude that the annual (or even decadal) emissions should necessarily be quantity-controlled. Indeed, the *Review* points out that there are many trajectories consistent with meeting the eventual 550ppm target, and that some will clearly be more expensive than others. Unfortunately, without knowing the rate at which cost-effective low-carbon technologies will diffuse and improved technologies be developed, it is hard to choose between possible paths. Faced with such uncertainty, and given that the SCC may be relatively insensitive to the choice of path, it makes more sense for the market, guided by the carbon price, to determine the least cost path to the target.

3.2 International and whole economy approaches

A carbon tax is an efficient instrument to the extent that energy price is a major determinant of the relevant decisions. Grubb (2007) argues that about half CO_2 emissions in industrialised countries arise from sectors which are economically 'well behaved' in this sense. These comprise principally power generation and heavy industry, sectors in which coal is the principal source of emissions and the price of energy – and relative fuel prices – is the dominant determinant of emissions. However, buildings account for around a third of CO_2 emissions (including the embodied emissions through their power consumption), and there is overwhelming empirical evidence that emissions from buildings and the appliances within them are determined far more by building codes and appliance standard regulation, than by energy prices. This is due to a mix of contractual failure (the 'tenant-landlord' split), informational failures (consumer ignorance about the energy/emission characteristics of their purchases) and behavioural economic issues particularly concerning economically trivial expenditures. These observations do not make price in these sectors irrelevant, but it does imply than an efficient response has to involve a range of measures in addition to carbon pricing.

Even in the economically 'well-behaved' sectors, there could be difficulties in determining the true 'additionality' of carbon taxes. Thus most countries levy heavy excise taxes on road fuel which can be thought of as part of a system of road user charging, and could claim quite reasonably that some part of this fuel excise were a carbon tax and could be reduced to offset the agreed carbon tax (Newbery, 2006). Moreover, even under the clear carbon incentives of the EU ETS, its carbon effectiveness in some countries remains blunted by regulatory structures that prevent the pass-through of marginal carbon prices to final electricity prices (Sijm, 2006).

This points to fundamental difficulties in trying to define international mitigation policy through an agreement on carbon taxation. Such an agreement would not give an incentive for governments to fix market problems that increase emissions – indeed, by making carbon a source of revenue it could arguably do the opposite - and the real additionality of any such agreement could be almost impossible to define relative to existing tax and subsidy structures. Moreover, it touches on one of the most sensitive of all areas of domestic policy, namely sovereign authority to define the level and incidence of taxation. A stark illustration is the fate of the EU carbon tax. Despite the context of a successful completed Treaty of Maastricht, establishing the goal of a single market underpinned by the dilution of sovereign decision-making powers, the original EC proposal for a unified EU carbon tax was debated for five years after its proposal in 1990 before finally being buried in favour of far looser structure of guidance and partial convergence in relation to existing petroleum taxes. Globally, there is simply no supranational authority to which countries would be willing to entrust power to set tax levels, and override national sovereignty to choose other or complementary instruments. Hence the focus of the Kyoto Protocol squarely on agreeing quantified goals for emission reductions, leaving the choice of implementation to national decision-making. Allowance for trading between countries increases flexibility and encourage internationally efficient reductions, but without necessarily determining the same carbon price across all sectors of all participating economies. We discuss the challenges of international coordination further at the end of this chapter.

3.3 Tax vs. trading in domestic policy

The choice of tax vs. trading has more practical scope in terms of sovereign choice over the selection of domestic instruments. At this level there are additional differences between taxes and quotas that are important, although opposed. Pollution taxes raise revenue and allow other taxes to be reduced, thus reducing deadweight costs. The so-called “double dividend” is discussed in Newbery (2005) and need not detain us here. Quotas could be auctioned to produce revenue, so this is not necessarily a critical difference. The more important difference is that quotas are normally allocated freely – not only to countries, but within countries to eligible firms under grandfather clauses - in order to buy off opposition to their introduction. Again, this difference is not decisive, because countries could decide on a carbon price or tax, with each retaining their own tax proceeds (which has obvious attractions), subject to the problem of additionality mentioned above for the case of transport fuel excise taxes. One such example is the UK Climate Change Levy, which was imposed on industry but compensated for by a reduction in the National Insurance Tax (a tax on labour) paid by those liable for the tax.

Nor is it immediately obvious whether quotas or taxes offer countries greater opportunities to renege on any international climate change agreement, as that will depend on the reliability of GHG monitoring and the sanctions available to other countries to punish any deviations. If under the WTO countries can impose border taxes to compensate for “unfair subsidies” (i.e. a failure to properly charge for GHG emissions) and if these emissions can be observed, then tax floors may work. If countries use quota allocations to preferentially favour trade-exposed sectors, and are able to understate emissions from other sectors, then the agreement may come under greater pressure.

For some sectors, like household energy consumption, a carbon tax would appear intrinsically simpler in part just because of the transactional complications of trading instruments (notwithstanding the need to address other issues surrounding buildings-related energy use). In sectors like power generation, Weiztman-like arguments and the need for investment security favour a tax-like instrument. Such an application to industrial energy use, however, might exacerbate concerns about international competitiveness impacts. Indeed, an important final complication is that taxes, because they combine the function of a price incentive with large revenue transfers, are not only politically difficult but tend to be adapted heavily to reflect pre-existing circumstances. A study of Norway, Finland, Sweden and Denmark (Anderson, 2004) notes that, despite the strong common view in favour of carbon taxes since the early 1990s, the actual pattern of "carbon" taxes to emerge varies radically between this group of relatively closely-aligned four Scandinavian countries, in terms of level, coverage, derogations etc.

In the EU, considerations of sovereignty, legal and institutional structures, and the inherent political difficulties of more visible large-scale revenue transfers embodied in a carbon tax combined to make the EU ETS the only practical way to establish an EU-wide carbon price across the core power and industrial sectors.[5] Establishing a single carbon price across almost half the EU's total emissions itself, in principle, offers big efficiency gains that should not lightly be cast aside. Moreover, in principle this need not stop each country auctioning off quotas (collecting the same revenue as a tax at the market-clearing price on that level of emissions). In practice the European ETS requires 90% of these quotas (during the Kyoto first period of 2008-12) to be allocated or "grand-fathered". If quotas are issued and valid for a long time period and can be banked and borrowed (as with the US sulphur cap-and-trade system) the inter-temporal carbon price should be arbitraged, but this would not necessarily ensure that it remained constant even in present value over time (as the volatility of futures prices of storable commodities demonstrates). Nevertheless, the absence of a supranational tax authority – and the establishment of the EU ETS – are not arguments against stabilising the price of carbon.

All this suggests that efficient climate policy may need a combination of price and non-price measures, set within the content of an international agreement that gives incentives for governments to address the full set of inefficiencies in domestic price and regulatory structures that determine emissions. We return to this point below after considering the way the current EU Emissions Trading System works and how it may be improved.

4 The European Emissions Trading Scheme

The European Union has agreed the European Emissions Trading Scheme (ETS) as its principle means of reducing emissions of the main greenhouse gas, carbon dioxide, CO_2. Each year from 2005 until the end of 2007 each country allocates at least 95% of its overall allowances to eligible firms (at least 90% for Phase II, 2008-12), who are then free to trade them within the EU. The resulting price of an EU Emission Allowance (EUA) for 1 tonne of CO_2 is determined by EU-wide demand and supply of EUAs. At the end of each calendar year covered industries, of which the largest is the electricity supply industry, must deliver EUAs equal in total to their recorded emissions in that year. EUAs can be held until the end of 2007, at which point a new scheme starts and the old EUAs become worthless.

Figure 3 shows prices in the EU ETS for both first and second period delivery. Prices rose initially, as the European Commission sought to strengthen allocation plans, and stayed

[5] One might observe that allocating free EUAs for 95% of the power sector generated huge rent transfers from electricity consumers to generators, as they were able to include the EUA price in the variable cost of generation (as illustrated below), whereas a carbon tax would have allowed governments to reduce other taxes and so compensated consumers. Of course, auctioning the quotas would have had the same effect. Arguably the ETS was successfully launched as politicians (and consumer action groups) failed to appreciate the impact on electricity prices and the large rent transfers, while the electricity companies did.

relatively high until Spring 2006 when detailed verified information about supply and demand of EUAs became public.[6] The price of first period EUAs, which expire on 31 Dec 2007 and cannot be carried forward to the second period, has subsequently crashed as supply now appears high relative to demand, although the price in the second period remains moderately stable around €15/tonne CO_2. The market for EUAs has clearly been volatile. Moreover, the price of EUAs can be expected to feed through to the wholesale price of electricity in a competitive market, although where final prices are regulated, the price could be held down to offset the windfall profits earned on the allocated EUAs.

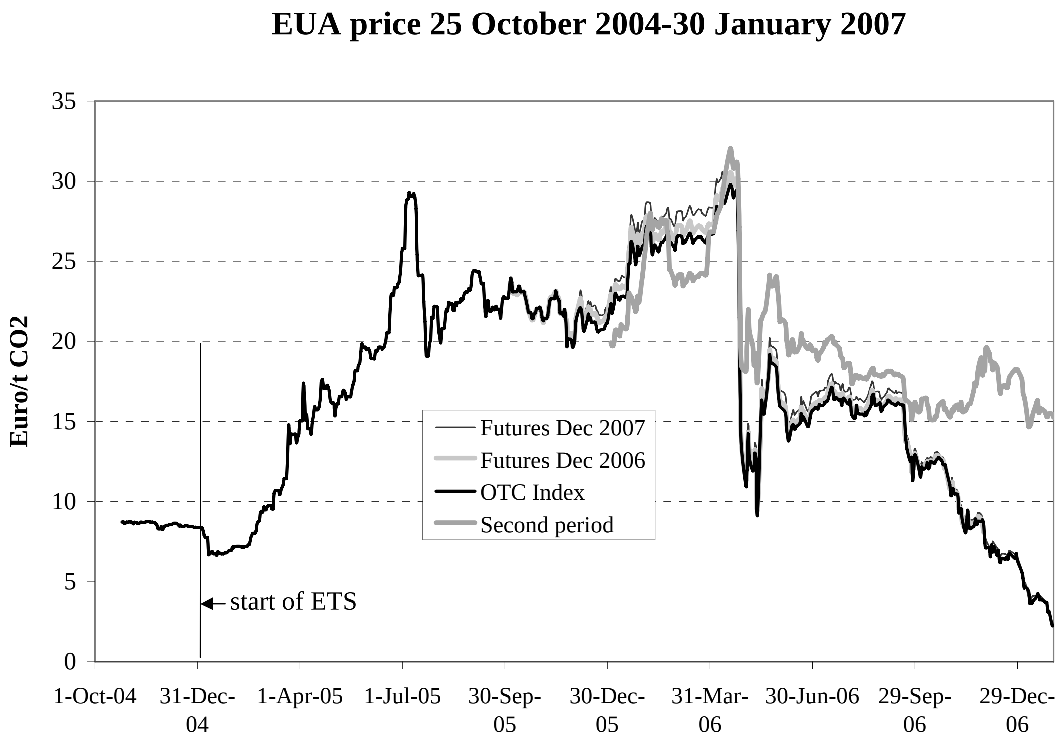

Figure 3: Price of CO_2 in €/tonne
Source: EEX

Some evidence that the EUA price does indeed feed through to the wholesale price is provided by figure 4, which shows the forward base year French and German electricity contract prices traded on the EEX, and the cost of the EUAs required for gas-fired or coal-fired generation.

The May 2006 fall in the futures price of French baseload electricity (all generated by nuclear power) drops by an amount better explained by the EUA gas cost than the EUA coal cost, even though the price in France is clearly set by the price in Germany (which has dominantly coal-fired base load electricity). We can probe the link between electricity, gas and carbon

[6] The European Commission published verified emissions data for 11,500 plants on 15 May 2006, suggesting that there was an excess of EUAs, either because of over-allocation of out-performance in emissions reduction, and this naturally caused prices to fall.

prices by examining the "clean spark spread" – that is, the price of electricity less the cost of gas needed in a combined cycle gas turbine (CCGT) of 50% efficiency and net of the cost of the EUAs required in such a plant. It measures the return to the capital cost of the plant (and any other non-fuel costs), and should tend towards the return needed to reward new investment, at least so long as CCGT remains an attractive investment choice).

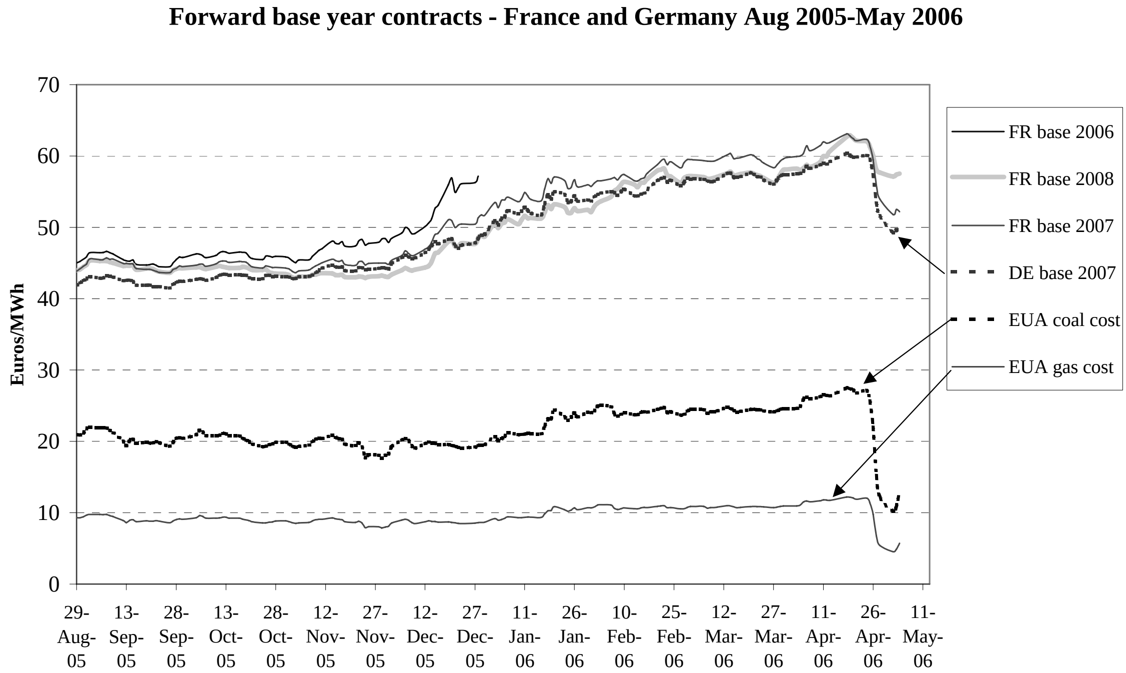

Figure 4: Response of forward electricity price to change in EUA price

Figure 5 graphs the clean spark spread in Britain, Germany and the Netherlands. The visual interpretation is that after an initial period of adjustment the gross profit margin has returned to where it had been, suggesting that most if not all of the EUA opportunity cost has been passed through into the wholesale price. Various authors have undertaken more careful econometric estimates of the extent to which EUA prices are passed through into electricity prices (IEA, 2007). Honkatukia et al (2006) estimated that 75-90% of EUA price changes were passed through to the Finnish Nord Pool day-ahead prices, even though the Nordic market is dominated by nuclear and hydro electricity (but linked to the rest of Europe). In a sophisticated boot-strapping econometric exercise Sijm, Neuhoff and Chen (2006) examined the impact of EUA price changes on the cost of generating from coal in Germany, finding complete pass-through for peak prices and 60-70% for off-peak prices (when interconnectors are less constrained and imports introduce competition from other fuels). In the Netherlands they found that 60-80% of the EUA price changes are passed through for peak hours for gas generation, and 70-80% passed through in off-peak hours for coal generation.[7]

Several consequences follow from this unsurprising conclusion. The first is that the free allocation of EUAs to power generators constituted a large windfall gain, as they we compensated for the increase in carbon cost of generation but could sell the electricity at the price inclusive of the carbon cost. For example, in Germany the second phase allocation of EUAs to the power sector will be 205 million p.a. which at a price of 20€/tonne CO_2 amounts to a windfall gain of over €4 billion p.a. (and that is for just one of the 25 countries). There is therefore a strong case for not allocating the electricity supply industry (ESI) more than a very small number of EUAs in future periods. The second conclusion is less obvious, and provides an additional argument for stabilising the price of EUAs, rather than allowing the price to be determined by supply and demand.

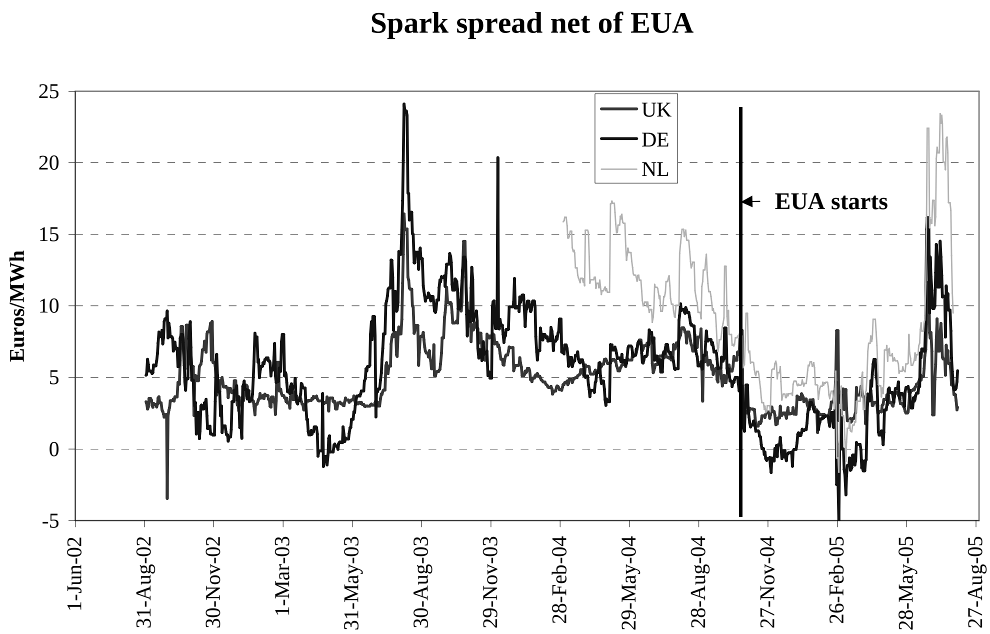

Figure 5: Gross profit of CCGT after paying for fuel and carbon
Source: Platts

4.1 The impact of the ETS on the gas market

Under the current organisation of the ETS, the price of EUAs is determined by supply and demand, and both depend on the extent to which the ESI can substitute less carbon-intensive fuels like gas for more carbon-intensive fuels like coal though changes in the merit order. This

[7] The impact of EUA price changes are roughly twice as high for coal as it is more carbon intensive. As Dutch electricity prices are above neighbouring countries, there may be less scope for passing cost increases through fully. Explaining spot electricity prices is particularly difficult as they are affected by contract cover, market power, the extent of the market, i.e. whether interconnectors are constrained, and the supply-demand balance, so the match between theory and evidence is impressive.

is nicely illustrated in Figure 6, which shows the daily evolution of generation in Britain over a short period of time in which the UK gas price increased sharply.

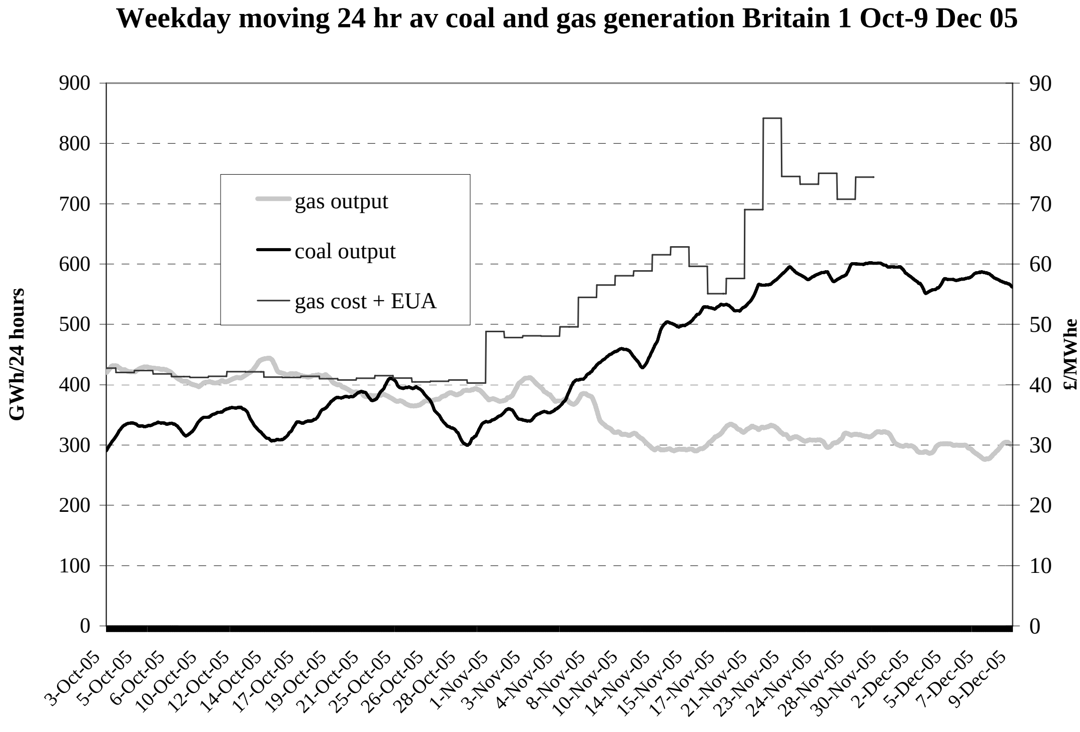

Figure 6: The impact of gas and carbon costs on the British merit order

As the cost of running gas-fired plant increased relative to coal, so the share of coal-fired generation increased sharply, increasing total emissions from the ESI as coal is more carbon-intensive than gas. Thus as the price of gas increases, the price of EUAs increases, as the demand from coal-fired generation will increase the demand for EUAs. This will raise the cost of burning coal instead of gas and reduce the extent to which electricity producers will switch from coal to gas in response to a gas price rise. The effect of fixing the *quantity* of EUAs, rather than their *price*, is that the elasticity of demand for gas will decrease (i.e. gas demand will become less sensitive to the price of gas because of the indirect effects on substitutes feeding through the EUA price change).

While the international market for coal is reasonably competitive, the same is not true for gas, particularly in Europe, which is heavily dependent on importing Russian gas from the monopoly supplier, Gazprom. In addition, gas producers and suppliers in the EU have more market power than the suppliers of other fuels, and are frequently vertically integrated into electricity generation. Ruhrgas, the dominant German gas company since its controversial merger with E.On, has a dominant position is gas supply through its control of its gas pipeline network, and an incentive to raise the price of gas to raise electricity prices and hence the profits of its merged partner, E.On (Henriksson, 2005). The market power of gas suppliers depends on the elasticity of demand for gas – if the elasticity is high so that demand falls sharply when prices increase, the dominant gas suppliers will have little market power. But if the elasticity is low or reduced because of the ETS, then gas suppliers will have more market power, and greater incentive to raise gas prices. There are therefore grounds for concern that the particular way climate change policy works in the EU through pricing a fixed supply of EUAs may amplify the existing market power in the gas market. The obvious solution is to cut the link between the demand for EUAs and their price by fixing or stabilising the price of the EUAs.

5 Stabilising the price of carbon and hybrid instruments

To recap, there are good economic arguments for fixing the price of carbon rather than fixing the total level of emissions in each period and allowing the market to determine the price. There are good political economy arguments for launching climate change policies through issuing tradable permits, as in the ETS (and most other market-oriented pollution abatement schemes). Various authors have argued that it may be possible to combine the best of both worlds through various hybrid approaches that are neither the two extremes of Weitzman's (1974) Prices *or* Quantities.[8] Thus Pizer (2002) argues for an initial allocation of permits, followed by the issuing of additional permits at a fixed price. In the case of the ETS this could be done either by the European Commission (or some body) being prepared to buy and sell any number of EUAs at the fixed price, or by replacing the ETS by a fixed carbon tax per tonne of carbon burned. The former is likely to be politically more attractive than the latter, and can be made cash positive or neutral to the EC by suitable reductions in the allocations of EUAs each year.

A similar proposal termed the "safety valve" is discussed by Jacoby and Ellerman (2004), while Hepburn (2006) surveys the range of hybrid instruments, including price ceilings and floors, and penalties for failing to deliver permits (which effectively cap the price at the penalty level – the method used in Britain for Renewable Obligation Certificates). These alternative approaches to reducing or eliminating price volatility differ in the financial risks they place on the agency entrusted to stabilise the price. While there is little risk in capping the price (and penalties would generate extra income), the main problem is in providing a floor, as buying permits to support the price could be costly. Of course, if sufficiently few permits are issued in the first place, with the balance sold at a fixed price, this risk can be made arbitrarily small, but that is not the present design of the ETS, and any change to the ETS would require the agreement of the member states. Such design issues are perhaps best left to the post-2012 period.

There remains one important issue that cannot be avoided. The social cost of carbon depends on ethical judgements as noted above, as well as economic and climate change forecasts, and is highly uncertain (as demonstrated by the width of the 5-95% confidence bands around the mean value). The Kyoto agreements and the ETS allocations were the outcome of a political

[8] as Weitzman himself recognised when he added that "The issue of prices vs. quantities has to be a 'second best' problem by its very nature simply because there is no good *a priori* reason for limiting attention to just these two particular signals". (Weitzman, 1974, p481).

bargaining process, albeit one influenced by ethics (particularly the contentious issue of the values of lives saved), as well as climate science. Any carbon price would likely have to be negotiated, perhaps better informed than before (as a result of the remarkable impact of and debates provoked by the *Stern Review*, and the ever greater confidence attached to the climate science). It seems most unlikely that any negotiation would agree anything like the Stern central value of \$312/tC (\$85.1/tCO2), which would quadruple the price of burning coal, compared to figures around \$70-180/tC (\$19.1-49.1/tCO2) at which EUAs have traded. On the other hand the ETS range sits comfortably with the PAGE equity weighted estimates of chapter 2. What then should be the target carbon price (or floor) that the EU should aim at, if we accept the desirability of stabilising the price, recognising the considerable uncertainty (and disagreements) about the right value?

One possible answer is to aim at the highest politically sustainable level, recognising that any political compromise is likely to fall short of the true SCC, but put in place an escalator that increases its value in real terms by, say, 2-3% p.a. (which is what should happen anyway, as chapter 2 argued). This model of an escalating charge has been followed for setting the road fuel duty in Britain in the 1990s. It was also adopted as a way of adjusting the price of water towards a level that more closely reflected long-run marginal cost after privatisation in 1989. Prices were adjusted each year in line with the retail price index, *less* an efficiency factor, *X*, but *plus* a capital adjustment factor, *K*, hence *RPI-X+K*. The lower the agreed value, the more important this should be stated as a floor, with possible upward revisions as new data or more political consensus (or a broader coverage of countries) indicates. If such a commitment could be made credible, it would do much to reduce investment risk. If any ceiling were set not too far above the floor, then the floor might be raised in response to sustained upward pressure on the ceiling, as with crawling peg exchange rates. If the price settled at the floor, then the fraction of EUAs to be auctioned rather than allocated should be increased (and more held back to support the floor).

6 Carbon price-investment security for the longer term

The current allocations under the Kyoto Protocol & EU ETS end in 2012, injecting considerable uncertainty into subsequent commitments and prices. The DTI's *Energy Review* is very clear about the need for longer-term carbon price signals:

"the Government is committed to there being a continuing carbon price signal which investors take into account when making decisions. This is particularly important given the scale of new investment required in UK electricity generation capacity. The EU ETS is here to stay beyond 2012 and will remain the key mechanism for providing this signal. The Government will continue to work with its international partners to strengthen the EU ETS to make it more effective. We will keep open the option of further measures to reinforce the operation of the EU ETS in the UK should this be necessary to provide greater certainty to investors." (*Energy Review* p157).

The *Energy Review* is, however, silent on how greater certainty could be provided. This section sets out *why* current instruments will not deliver an adequate investment response, and discusses the options for addressing this.[9]

6.1 Economic fundamentals: why the market may fail

Uncertainty is not new: investors face it all the time. There are, however, three things that make the low carbon electricity issue fundamentally different:

- The risk associated with carbon price is largely *policy and political* – risk that private investors find particularly hard to judge and manage, and where alternate strategies include investing in lobbying, or just waiting for policy uncertainty to be resolved.
- The timescales of investment are very long, and there is a marked disjuncture between the time horizons of most corporate or equity investors (seeking typically 10-15% rate of return for more speculative projects, though considerably lower for low-risk mainstream utility investments), and those of government (discount rates that reflect ethical bases for consistent intergenerational decision-making, as in the Stern report (of about 1.4%), and the UK Government *Green Book* rate of 3.5% - see Chapter 2). In itself this would not necessarily matter (other investments are also long-lived but do not need special treatment), but it is the combination of long timescales *and* policy risk that is damaging,
- While fossil-fuel generation is at the margin and setting the electricity price, conventional generators will be largely hedged against both fuel and carbon price risk, as these will determine the price of electricity. Investors take comfort from the link between the marginal (fuel plus carbon) cost of generation and the electricity price, and are thus able to shift much of the input cost risk through to consumers, at least if they have a balanced portfolio of plant. Companies that specialise in renewables or nuclear power are exposed to an electricity price driven by the volatile marginal fuel cost and a possibly volatile carbon price, and so face more risk (Roques et al., 2006). Thus *even with a fixed and guaranteed carbon price, the structure of electricity markets places the risk associated with uncertainties in the electricity price on low carbon investors.* Again such risks are not necessarily indicative of market failure, but they may amplify the underlying problem of policy risk.

Other market actors. Consumers should be keen to hold shares in generation companies whose costs are independent of fuel and carbon prices, in order to hedge the electricity price risks they face. Equivalently, suppliers (or even final consumers, as in Finland for nuclear power) may be willing to sign contracts for low-carbon electricity to hedge their exposure to electricity price risk. It has been suggested that insurance companies should be willing to finance low carbon generation with electricity bonds (linked to the long-term purchase price contracted for the output of the power station) and issue these as part of a pension portfolio, offering insurance against the future cost of electricity. However, this would require pension funds to actively

[9] The House of Commons (2006) report *New Nuclear? Examining the Issues* discusses the importance of and mechanisms for long-term carbon pricing at paras 179 et seq.

decide to make risky and possibly very illiquid investment decisions in new technologies - opening them to charges of failing in their fiduciary duties to pensioners.

The most fundamental conclusion is that without more stable long-term signals, investors will defer difficult decisions, and are more likely to adopt the lowest-risk - to them - and most flexible investments. Fundamentally, this favours investment in combined cycle gas turbines (CCGTs): low cost, quick to build, and with the fuel and carbon risks passed on to customers. Sustained over the coming decades, such investments would not provide either a secure, or a very low carbon, electricity system, albeit one that may be preferable to investing in more expensive plant burning cheap coal.

The *Stern Review* is even more explicit than the *Energy Review* about the need for a credible long-term carbon price: “In order to influence behaviour and investment decisions, investors and consumers must believe that the carbon price will be maintained into the future. This is particularly important for investments in long-lived capital stock.” (Stern, 2006, pxix). The *Review* is more specific about the design of instruments to achieve this goal, and its chapter 15 considers these issues in depth, drawing out strong implications for the future design of the ETS, although without explicitly stating the need to stabilise the resulting carbon price (Stern, 2006, box 15.3, p 337).

6.2 Policy options for longer term investment security.

This chapter has argued that it is desirable to stabilise the price of carbon (around a steadily rising path) rather than limiting the annual level of emissions, and this objective also achieves the other desirable goal of delivering the desired low-carbon investments at least cost. There are several ways to establish longer term, low-carbon incentives that could be considered in principle.

6.2.1 Long period commitments.

If Phase III EU ETS allocations could be agreed soon, and specified in a single period with a timescale covering investment time horizons, this would solve the problem. Neither is credible; it is debatable even whether the latter (much longer time periods of allocation) is desirable, since it would lock in an allocation for potentially a couple of decades whilst both science and politics of the issue are likely to develop far more rapidly.

6.2.2 Allowing unconstrained banking and borrowing of EUAs over multiple periods

Allowing extensive banking into, and borrowing from, future periods in principle would allow an intertemporal market to emerge with incentives and expectations feeding back to present prices. The most obvious way to bring some longer-term security is then to try and agree several rounds of quantity constraints in advance. A related approach is proposed for UK domestic policy on national emissions in the draft UK Climate Change Bill, which proposes 5-year budget periods defining allowed national emissions, which must be ‘set at least three periods (i.e. for fifteen years) ahead' (HMG, 2007). In itself such aggregate domestic quantity limits may be difficult for industry to translate to a future price, and in practice would leave the actual price in the power and industry sectors still contingent upon the EU ETS, not on the domestic targets.

The same approach could in principle be taken for the EU ETS itself; with full banking and borrowing, this in turn would be very similar to simply setting a longer commitment period, with the same fundamental trade-off. The difficulties of allocation and burden sharing several periods ahead would be daunting at an EU level – and greater still at a global level.[10]

Pizer et al (2002) set out in detail a fundamentally different approach to the problem. They show how defining appropriate long term *price-based rules* for allocations in a sequential emissions trading system could be used to chart a long-term price path for quantity-based systems. The biggest difficulty lies in translating such theory into practice. It requires credibility of a governmental commitment to both a long term target price, and to sticking with the rules for translating that into allocations over many rounds. Thus it does not necessarily solve the fundamental problem of the reluctance of markets to speculate – and invest – around political risk. It may not remove the volatility associated with the arrival of important new information (of the kind that caused the EUA price drop in May 2006, noted above) and additional measures, such as floors or caps, may be needed. It is governments that define the policy environment, and that are the best placed to bear the risks of changes in future policy directions, and should therefore seek ways of bearing or under-writing those risks for investors.

6.2.3 Long term price declaration

A simpler but less robust route would be for governments to set out, perhaps in legislation, planned carbon prices further ahead than the specific instruments and allocations agreed at EU or international level. The issue again is one of credibility. This would be significantly enhanced if implementation of the EU ETS included mechanisms (such as minimum price auctions) that would enable direct implementation of a price floor – though this remains only a partial solution to the credibility problem. If governments are really serious about any price declaration, the obvious question is whether and how they should transmit that conviction to the private sector in legal form - through contracts that bind successor governments, as follows.

[10] Indeed in the Kyoto negotiations, the original US proposal did suggest negotiations on two commitment periods simultaneously with banking and borrowing between them – a prospect that was rapidly dropped as the extreme difficulty of agreeing even on one became apparent (Grubb, 1999).

6.2.4 Contract-for-difference (CfD) on the future carbon price (carbon contracts).

The fourth option would be for governments to issue a contract-for-difference (CfD) with investors on the future carbon price. [11] This could be a simple CfD in which the contract states a strike price of e.g. 15 €/tonne CO_2 (or 55 €/tC), and these are either sold or issued in proportion to declared net capacity of new zero-carbon generation. The holder would then be entitled to receive the strike price *less* the actual carbon price implicit in any UK-wide carbon instrument that applies to fossil generation (and if this price were above the strike price then the holder would be obligated to pay the amount by which the price were above the strike price).[12]

An alternative would be to issue or sell a one-sided CfD with a floor price, say 10 €/tonne CO_2, with the issuer obligated to pay any shortfall below this floor price, but the holder would benefit from any upside. Another variant on this that has been explored by Ismer and Neuhoff (2006) is to issue put options on the carbon price. These CfDs could be exercised either at particular dates (perhaps averaged over the previous year) or (particularly in the case of put options) over an extended period. Such instruments would provide a powerful commitment signal by the Government (or the European Commission) to the continuation of the ETS or its successor, and would also help stabilise the future (and hence, with banking, the present) carbon price.

6.2.5 Low-carbon electricity contracts

A way which is less direct from a carbon standpoint, but more direct in terms of electricity investment incentives, would be to sell a long-term CfD on the price of electricity from low or zero-carbon generation. This would also provide a hedge against fuel price uncertainty. An obvious objection to this is that if there is a demand for such instruments, the market should offer them, and, as with government-financed strategic gas storage, such market interventions might distort the normal market and worse, displace comparable, more efficiently designed instruments. The defence would be that there is a missing market for carbon and no obvious source of private supply, as the prime risk is political. If so, then the direct approach already described seems best suited to address that market failure. Nevertheless, the Government may wish to consider such contracts as part of its commitment to alleviating pensioner fuel poverty, where such a contract may allow the future cost of dealing with such poverty lower as it ought them be possible to finance the capital-intensive generation at lower rates of interest (i.e. more indexed debt).

There are of course other options, some of which require cruder, direct intervention, such as direct government investment or subsidy for preferred low carbon electricity sources. These

[11] See for example House of Commons (2006) at paras 179 et seq.

[12] This would require the Government to be quite explicit about the equivalent carbon value of any instrument that might replace the ETS, particularly if this took the form of a carbon tax (*not* an energy tax like the Climate Change Levy). If there were no such instrument that specifically charged electricity generators in proportion to the CO_2 emitted, then the price would be deemed to be zero.

face well-known and tested objections, and run counter to the entire thrust of UK energy policy over recent decades towards liberalisation and a declining direct role for the state in investment decisions, and so are unlikely to be contemplated and are not considered here. There is however one related set of issues that cannot be dodged, which is the need for appropriate investment in the UK electricity network in ways that would support low carbon generation sources, and associated questions around the mandate and powers of OFGEM.

6.3 Preliminary conclusion.

These options all have pros and cons. The first – although it seems to attract the most attention – risks ending up with an uneasy compromise that does not in fact deliver either objective: for example a 10-year fixed allocation for post 2012, finally agreed in e.g. 2011, could be too long to give flexibility but still too short to help big investments. To the extent that option (b) still relies on future legislative decisions, rather than individual contractual commitments, it does not resolve perceptions of political risk. Option (c) also requires the market to have a high degree of faith in governmental promises and institutions.

Options (d) and (e) address this problem, by setting the commitment in individual contracts – the same status as any other government contractual obligation that can be matched by compensation clauses. Neither is equivalent to a "whole economy" (or even whole sector) carbon price, but for the investing counter-parties they do ensure that the political risk is borne by the government, not the investors. By the same token, they may face the most resistance from governments reluctant to bind themselves to such future liabilities in the event of a weak carbon price. However, because the investment risk in this respect intrinsically arises because of uncertainty about future policy, *there is a compelling case that governments should bear these risks directly* in respect of long-term, low carbon investments.

All the options raise issues of implementation, which are quite complex in the case of the two "contracts" ideas that seek to give contractual force to long-term price goals. These consequently must rigorously define either additionality of carbon savings from individual projects (for d), or qualifying generating sources (for e). Defining the problem as being specifically to do with electricity investment may suggest that the electricity contracts route provides a more direct solution. However, it would be helpful to map the relative characteristics and questions around the two 'contract' options side by side, since many aspects might be shared, and might yet throw up fundamental difficulties.

As always the difficulties of securing agreement on such measures decreases the larger and more diverse the set of countries that need to reach agreement. Options (a) and (b) would clearly require international agreement amongst all those countries involved in the carbon pricing / trading scheme. In practice, option (c) would as well, if it is to have much credibility. Thus a further, and potentially decisive, feature of the two contract options is that any government, if it chose to do so, could establish long-term contracts-for-difference for any facility sited in its territory. This would be a compelling a statement of its own confidence in future carbon prices, or at least, its willingness to bear the risk of protecting domestic low carbon investments against the possibility of failure of the international effort around more general carbon pricing instruments.

Such commitments would consequently lower the cost of delivering future lower-carbon technologies. The main downside is the risk of other countries free-riding, which suggests the importance of international sticks and carrots for climate change commitment, to which we finally turn.

7 Evolution towards a global climate change agreement?

A tonne of GHG released anywhere has the same global impact regardless of its country of origin, but the damage of climate change varies across countries, and may be more serious in the tropics (at least as a share of GDP). Every country has an interest in solving this global problem, but not all are equally able or willing to contribute. The international problem is to devise policies that will make humanity better off, and which limit the incentives to opt out of such agreements; the latter probably implies, at minimum, structures which ultimately make each country better off participating than not.

Similarly, all countries will benefit from the development of cheaper low-carbon technologies that lower the total cost of addressing climate change, but their development will be costly. Chapter 12 discusses briefly the prospect for international co-operation to help to share this cost to encourage the most cost-effective research and deployment strategies to be followed, with those best placed to develop each technology encouraged to take the lead.

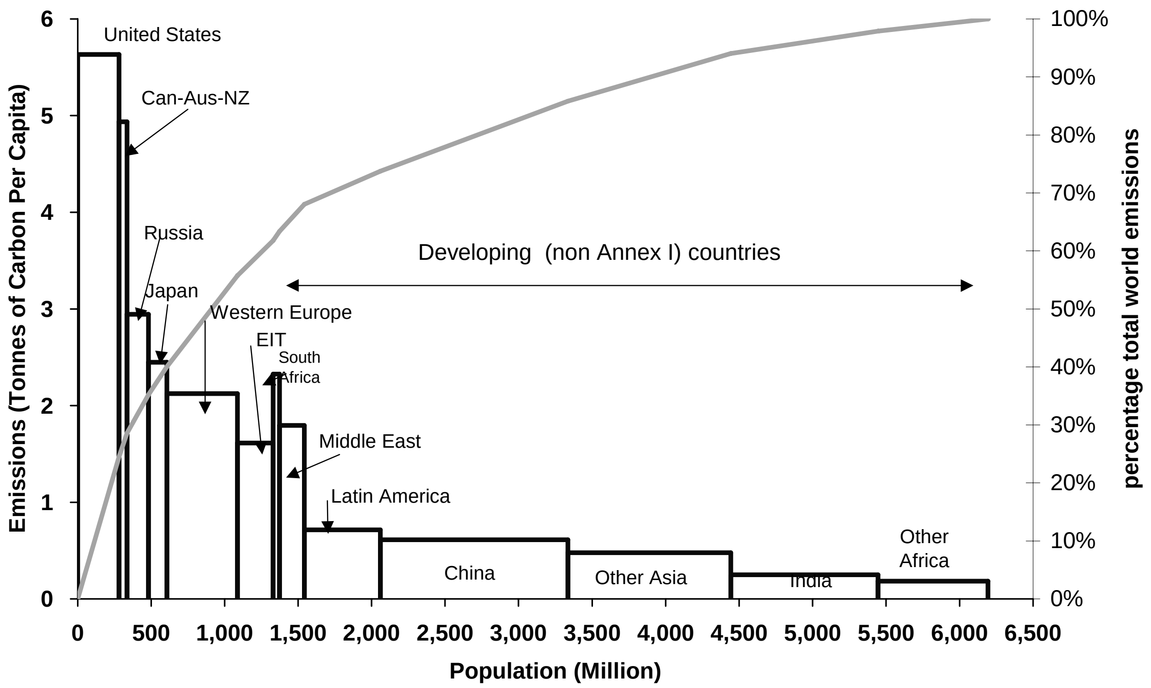

Figure 7: CO_2 Emissions per head against population (areas represent emissions)

The objective of international negotiation is to maximise the extent (measured by GHG emissions) of international co-operation. Figure 7 shows emissions per head on the *y*-axis and population on the *x*-axis, so that the area of each rectangle is total emissions, with countries ranked by emissions per head (as well as showing the division between the industrialised countries, as defined in Annex I of the UNFCCC, and those classed as developing countries). China accounts for 16% of the world total emissions and the combination of the US, EU and China would account for over half of total emissions. If China were to be added to the Annex I countries the coverage would be 78% of the total. The larger the share of global emissions covered by the co-operating nations, the lower the individual cost of achieving a given level of mitigation, and this provides an incentive for each country to encourage as many of the high emitters as possible to join the agreement. The first and probably most important step is ensure that public opinion and policy makers in the larger emitting countries are made aware of the consequences of climate change, and the costs to their country and to others of failing to reach international agreement to address them. The next step is to select policy instruments that are politically feasible, sustainable, and effective.

7.1 International collaboration on carbon-based instruments

On the face of it seems easier to negotiate over target emission reductions, and indeed that was the format for the Kyoto Protocol. The difficulty lies in the joint problem of agreeing the base allocation and the amount of reductions from that to be made. Developing countries argue on strong moral grounds that equal per capita entitlements are the only fair long-term basis, but the rich countries will never agree to the implied large carbon trade flows that this implies. To put this in context, at a carbon price of 50€/tC (13.6€/tCO2)and global emissions of 6Gt of carbon per year,[13] the value of carbon allowances would be € 300 billion p.a. Quite small surpluses or deficits would lead to large transfers.

This highlights a tension between different objectives. At one extreme, there is significant resistance in some countries (notably in north America) to *any* significant international financial transfer associated with climate change mitigation. At the opposite extreme, developing countries may seek to use international emissions trading as a vehicle for redressing wider perceived economic imbalances. It seems unclear why rich countries would agree to much bigger transfers through such an indirect route than, for example, in the context of the G8+ negotiations on debt relief. Nevertheless two arguments suggest a need for compromise between these extremes. The first is simply that international transfers are inherent in an efficient trading-based solution to climate change: global efficiency requires richer countries to be able to spend money to reduce emissions wherever it is cheapest to do so. Second, the general principles agreed in the UNFCCC – and articulated more fully in the Stern report – clearly imply that effective, equitable and efficient solutions require rich countries to assist poorer countries to abate.

[13] Gt – Gigatonnes, and 1 Gt = 1,000 million tonnes.

Willingness to spend to these ends is already established: around 1 billion tonnes CO_2 emission reductions from developing country projects under Kyoto's Clean Development Mechanism were sold on international carbon markets during 2005 and 2006 (combined), at total expenditure exceeding US$5bn, mostly driven by compliance with the EU ETS (much of it in forward transactions, see PointCarbon 2007). The total projected demand of the EU-15 and Japan to meet their Kyoto obligations is about twice this, a little over 1Gt CO_2 each over the Kyoto period. Their willingness to secure this is not in doubt (though governments may well be able to purchase more cheaply than the private-sector dominated trades in 2005-6) – which is not true for Canada.[14]

Various principles can be considered in negotiating the initial allocations that underpin such transfers. An equal proportional reduction from current levels has the advantage that the largest emitters make the largest initial contribution to solving the problem, but they are also the largest contributors to the problem in the first place. As countries become richer their economic structure shifts away from energy-intensive manufacturing to less energy-intensive services, so their rate of growth of emissions under business as usual (BAU) is likely to be lower than for poorer countries poised to expand manufacturing, power and transport sectors rapidly. The reductions might be better related to future predicted BAU levels than based on emissions at some past date (like the UNFCCC/Kyoto choice of 1990), but the methodology for predicting future BAU levels will itself be the subject of argument and will in practice be constrained by the requirement that any likely international trade surpluses in carbon are modest in scale.

In theory, the alternative approach to an economically efficient solution would be to agree a carbon tax rate to apply to all GHG emissions, with each country keeping the revenue. This has both the pros and cons of avoiding international transfers. The simplest way to levy this would be as an excise tax on the carbon content of all fossil fuel, greatly simplifying the problem of identifying and taxing CO_2 emissions for each source (although other GHGs will also have to be dealt with). For the reasons set out in section 2(b) above, this is unlikely to be effective or feasible as the *principal* focus of an international agreement, but it could still be considered for certain sectors with 'well-behaved' market conditions and minimal problems of defining tax additionality. The power sector, and other energy-intensive manufacturing sectors, could qualify. Because many of the latter produce internationally traded goods (and indeed electricity is increasingly traded internationally), such an approach would logically need to be complemented with a border tax on the carbon content of imported goods if they

[14] Projections place the total EU deficit at about 1.1Gt CO_2, and Japan at about 1.3Gt CO_2, after taking account of all policies and official governmental procurement plans in place at present. Canada would require about 0.5Gt CO_2 in total to comply with its Kyoto target, but the present government has indicated it is unwilling to purchase international emission reductions. Since the government cannot raise a Parliamentary majority to withdraw from the Kyoto Treaty and clearly has no intention of taking the drastic measures that would now be required to deliver the Kyoto target domestically, its current posture would place Canada in a position of almost unprecedented willful non-compliance with international law to which it has succeeded and ratified.

came from non-compliant countries. In principle this could be compatible with WTO rules, in part on the grounds that countries not charging for the carbon damage would be providing unfair subsidies to their carbon-intensive exports (for detailed discussion see Brewer, 2003; 2004).

How do these alternatives compare as choices for international design? First, an explicit carbon tax may make border taxes simpler than tradable permits whose price fluctuates, although it would be possible to levy a carbon import tax equal to the deemed carbon content of best available technology multiplied by either the current carbon permit price or its average over some previous period. In addition, it would be much harder (or impossible) to justify border tax adjustments for the *marginal* (opportunity) costs in a trading scheme, as opposed to a full tax incurred from a carbon tax (Hepburn et al, 2006).

Second, the textbook assumption that taxes and permits are equally efficient may not hold: on the one hand, international quota exchanges may offer the potential and temptation for large countries to exercise market power; whilst any tax agreement would be layered upon highly imperfect underlying energy market structures, including subsidies and areas of contractual failure.

Third, as discussed in section 2, the evidence of political economy is that taxes are hard to adopt and almost always distorted compared to the ideal (though distortions in emissions trading systems are also possible, Neuhoff et al 2006).

Fourth, as noted some degree of international transfers may be essential to capture the low cost options in developing countries. A tax-based agreement would thus need to be complemented by some explicit, probably centralised international funding mechanism.

Finally, taxes generate revenue that can be used for, inter alia, supporting the development and deployment of low-C technologies (and reducing other more distorting taxes).

For that reason, though, taxes will be opposed by those on whom the taxes fall (i.e. everyone), while quotas can be granted in proportion to base use, and can compensate (or, as with the electricity supply industry in the EU ETS, overcompensate) emitters for the extra carbon charge. In theory emitters could be given tax credits equal to the grand-fathered permit allocations (Pezzy 2003), and permit allocations could be progressively reduced with an increasing fraction being auctioned, so the differences in the redistributive properties of taxes and quotas can be exaggerated. From a political economy perspective, though, it is clearly much easier to introduce grandfathered tradable permits (as evidenced by the overwhelming preference for cap-and-trade systems to date).

A hybrid scheme might be allow each country to allocate permits as they join the “carbon abatement club” in any way they choose. The share freely allocated should decline over time on agreed schedules, with an increasing fraction auctioned. Once a sufficiently large part of the world is participating with sufficiently high level of auctioning, it may be much easier to switch to an equivalent tax, and thereafter allowances would be traded in for the tax (i.e. fossil fuel sellers could either pay the carbon tax or surrender the appropriate number of allowances). This hybrid should also work internationally in that those liable to a tax in any country could discharge the liability with a permit from an eligible country (one in which the permit price were as high as the internationally agreed tax).

A major problem is that for some countries the implied tax on coal and even oil would be a high fraction of its cost, and probably much higher in some developing countries than in much richer countries. Thus the local cost of coal in India and China may be considerably below its price in rich countries, and so the carbon tax would be a higher proportion. If coal is $60/mt imported into Europe, a carbon tax at the rate of $40/mt of coal would give an import tax *rate* of 67% (although the tax would be levied per tC and as a share of the final delivered price the rate would be lower). If the domestic price of coal in India were only $30/mt then the relative tax rate would be twice as high at 133%.[15]

India is a test case, as most Indian states find it impossible to raise electricity prices to cost-reflective levels, and would likely find it even more politically difficult to pass through carbon taxes. Of course, the same argument would apply to permits if their price were allowed to be reflected in marginal electricity prices as in most of the EU countries, but with regulated prices, free allocations would allow final electricity prices to be held down. Subsidies paid by carbon taxes could have a similar effect. If the local carbon tax were set using purchasing power exchange rates rather than market exchange rates the result would lead to lower $ taxes for the same perceived carbon price, and this might allow an acceptable compromise. The broad conclusion, however, is that an international response based explicitly around carbon pricing is only likely to be achieved from a process that starts with emission cap-and-trade and evolves towards greater auctioning over time.

7.2 International collaboration on longer term instruments and enforcement

Could international collaboration be extended to any of the options for longer-term carbon instruments discussed in the previous section? For the first option (long period caps) the challenge is synonymous with that already discussed. For the second (pre-commitments on the use of banking and borrowing to secure target prices) the difficulties would be multiplied many times, and clearly raise questions about the capacity of governments around the world to credibly commit their country to such a complex long-term carbon price management system. Declaring a long-term price objective is perhaps politically the most plausible, but carries the lowest credibility in terms of investment security. The complexity of international agreement on either of two contract-based options is also daunting, except to the extent that they address a more focused issue, namely relating to the specifics of power sector investments.

It is not entirely clear how much international agreement in respect of instruments for long term investment security matters, however. If *some* countries successful implement credible longer term incentives, business will be comparing two regimes: one with a clear long-term incentive, in which low carbon investments have been to a large degree "de-risked"

[15] The carbon tax needed to amount to $40/tonne of coal might be $60/tC, depending on the carbon content of the coal.

through unilateral government commitments; the other with a short-term carbon control instrument only, with the likelihood that additional obligations will be agreed in the future but no security at all about their terms and nature. It is not at all obvious that business would be prefer the latter: business itself might drive the pressure to underpin short-term commitments with longer-term certainty globally.

Finally, from an economic perspective, the greatest obstacles to securing any international agreement concern participation (willingness to accept a commitment) and enforcement (delivery of that commitment once written into an agreement). On the *incentives*, one issue is a potential linkage to the question of whether or not countries 'weight' a social cost of carbon, discussed in chapter 2. To the extent that SCC forms an operational part of policies (or commitments), if the degree of weight that countries attach to global SCC is linked to the breadth of participation, then large emitting countries in particular have an incentive to participate because of the impact this would have on implementation in other countries.

The counter-argument is that leadership is essential in fashioning any international treaty, and that if all countries start with a low implied SCC-weighting on the grounds of low international participation, then the international system may never make progress. For leadership to be effective, other countries would need to be reassured that the leaders have effectively committed their future abatement (or tax) policies, lest they believe that any additional abatement by new members would be countered by reduced abatement of the leaders. Ismer and Neuhoff (2006) show that put options or one-sided contracts for differences on the price of carbon can commit a government to maintaining a minimum future price for carbon both internally (to its own low-carbon investors) and externally, to signal commitment to other countries. An explicit price element in a Treaty may thus, paradoxically, assist with the challenge of ensuring compliance.

8 Conclusions

Addressing climate change efficiently requires that GHG emissions are properly priced, that relevant markets are not seriously distorted, and that low-carbon technologies are developed efficiently (see chapter 13 - that deals with technology support). These objectives require various interventions and international co-operation; the reach of carbon pricing in particular must expand to encompass all major emitters. These are daunting challenges. Table 1 summarises key characteristics of the different instrument choices as discussed in this chapter: not surprisingly, as in many complex policy choices, there are trade-offs to be made between competing objectives.

Given the immense political difficulty of establishing any carbon pricing system, the advent of the EU ETS – which ensures a uniform price of carbon across the major industrial emitting sectors for 27 countries – is a very big step forward. It nevertheless remains a highly imperfect and incomplete solution, for the reasons set out. Global efficiency requires a uniform carbon price across countries and over time (with a gentle increase in the price at a rate of perhaps 2-3% p.a.). The EU ETS alone scores badly on both counts. International linkages through the CDM offer only a partial contribution to the global objective, particularly in the absence of US participation, and hinge upon cross-border financial flows that might become unacceptable in scale if they are to seriously address e.g. the growth in Asian developing country emissions. Quota systems also yield unstable prices unless there are caps and floors, banking, and/or an agency charged with trading to stabilise the price. The current system of 5-year periods embodied in the Kyoto Protocol and the EU ETS offer flexibility to adapt, but at the cost of exacerbating the temporal problem as its reliance on sequential negotiations yields inherent uncertainty about its future evolution.

Taxes do much better on the temporal dimension, but face the difficulties associated with imperfect markets, political resistance, and (particularly in the transport sector) establishing additionality of the instrument. Taxes may also be (even) harder to globalise.

A gradual transition from cap-and-trade schemes to carbon taxation, through increasing levels of auctioning over time, holds attractions that justify serious further work on the political-economic aspects. There are interesting hybrid schemes, such as auction releases with a commitment to a floor and ceiling price that evolve in response to success or otherwise in limiting the cumulative emissions of GHGs, which could address some of these concerns, but as ever the main problem is designing a means of reaching international agreement to underpin a collective commitment to reducing these cumulative emissions. The *Stern Review* has signalled the seriousness of the task, and by placing high values on the social cost of carbon and the benefit-cost ratio of mitigation has endeavoured to convince the world that the problem is serious but worth collective action.

Finally, achieving an international climate change agreement with sufficient coverage will be an evolutionary process, combining a quest for instruments that command consensus support with an attempt to achieve efficiency in mitigating climate change. The first typically involve quantity instruments and targets to achieve satisfactory burden sharing, while the second require markets to equilibrate prices across time and space. Designing the appropriate sequence of national and international instruments to achieve this is challenging.

In this sense the power sector, with its relative international homogeneity of production processes and international market for equipment, is probably better placed than many others to achieve these two objectives through careful design to achieve efficient, sustainable and credible instruments. As indicated in the Introductory chapter (Chapter 1), power generation remains the single biggest source of CO_2 emissions globally, and is a prime driver of projected global emissions growth. If constructing a global regime to cover all sources proves too difficult, an agreement that builds out from and improves the EU ETS and other emerging trading initiatives, to establish a carbon price across the world's electricity systems, along the principles we have discussed, would still be a huge step forward.

Table 1: Characteristics of different economic instruments at national and international levels

	Tax	Tradable Quotas	Price contracts[1]	Quota offsets[2]
Political feasibility	*	***	**	***
Single-period efficiency	***	**	n/a	**
Outcome certainty[4]	*	***	*	**
Price stability	***	*	***	*
Long term stability	**	*	***	*
Flexibility for learning[3]	**	***	*	**

Characteristics as an international instrument

	Tax Varied	Tax Harmonised	No or Indirect linkage[4]	Inter-changeable	Long term global contracts	International offsets (CDM/JI)
Ease of extending jurisdictions	**	*	***	**	*	***
Global single-period efficiency	**	***	*(*)[5]	***	n/a	**
International transfers	Not intrinsic: separate institutions would be needed		Possible through indirect linkages	Intrinsic determined by allocation	n/a	Intrinsic but constrained by additionality requirements[6]

Notes.

1. Contracts-for-difference on future prices of carbon and/or (for low carbon sources) electricity prices
2. Quota offsets in which projects earn 'emission reduction credits' that can be used in a quota scheme to comply with quotas, or (in principle) offset against tax. Offset schemes in principle could also be directly state funded.
3. Flexibility to adapt over time. Quota and tax schemes also intrinsically generate different kinds of learning: quota schemes reveal the costs of given environmental goals; tax schemes in principle generate learning about the abatement response, though this is less easy to observe and separate from other factors that price observation in an emissions trading scheme.

4. Emissions trading schemes in different countries could be entirely isolated from each other, share an agreed platform in terms of contributing to negotiated national targets, or linked indirectly through common recognition of some types of international offsets.
5. Global efficiency depends upon the degree of indirect linkage
6. Additionality requirements are the requirement to demonstrate that emission credits reflect new and additional emission savings

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