THE ALLOCATION OF CARBON PERMITS WITHIN ONE COUNTRY: A GENERAL EQUILIBRIUM ANALYSIS OF THE UNITED KINGDOM.

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Abstract

As part of the Kyoto agreement on limiting carbon emissions, from 2008 onwards an international market in auctionable carbon permits will be established. This raises the issue of whether trading should be simply between governments or between companies, or in the latter case how such permits should be allocated.

Our paper uses the British section of a CGE model of the European energy sectors to evaluate the economics of various methods of allocating permits within a country, as discussed in Lord Marshall's recent report to the British government. The option of allocation entirely by auction is similar to the setting of a carbon tax, and the recycling of revenues to reduce or offset other economic distortions could produce a potential net benefit to incomes and employment. 'Grandfathering' some of the permits free to large firms, according to their base year carbon emissions, would mean loss of the benefits of recycling auction revenues. This might be exacerbated if it created windfall profits repatriated by foreign shareholders. The third major alternative is to review the allocation regularly, awarding permits to all firms according to a 'benchmark' allocation, based on 'best practice' as estimated by outside experts. This would be similar in practice to recycling the revenue as an output subsidy to the industry, though it could be complicated to implement. Such a system could allow much of the potential 'double dividend' to be realised, though it might still be preferable to auction permits, with the revenues used to offset taxes across a wider spread of industry.

Introduction.

The growth of concern worldwide over the effects of various pollutants, and the high potential costs of control by quantitative means[2], has lead to increased interest in recent years in economic instruments for controlling certain pollutants[3]. There is a considerable literature on both the theory and practice of such instruments: for example on the development of various trading schemes for sulphur emissions in the USA from the 1970s onwards, under the aegis of the Environmental Protection Agency[4], and over the potential for international trading of sulphur emission rights in Europe[5]. Another example is the Swedish scheme for controlling NOx emissions (see Smith, 1998).

Economic instruments are seen as particularly well-suited to the control of carbon dioxide, as it is a pollutant whose effects (in terms of climate change) are spread globally. Tietenberg (1990) stresses that economic controls are much more straightforward for such uniformly mixed pollutants. The early literature (see the review in Clarke et al, 1996) concentrated on the use of carbon taxes, and carbon or carbon/energy taxes have been introduced, or are under discussion, in many European countries, in the wake of the

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2 A sample of US studies of command and control policies for sulphur, nitrogen, particulates, aerosols and noise pollution, surveyed in Tietenberg (1990), showed costs ranging from 1.72 to 22 times the least cost solution. Only one study showed costs 1.07 times the hypothetical least cost level.

3 See Baumol and Oates (1971) for a discussion on the relative merits of price- and quantity-based controls.

4 See, for example, Tietenberg, 1999 or the SEO report 1998 for discussion on the practice of such schemes.

5 See Klaassen's study (1996). Sulphur trading schemes are more complicated in some ways than carbon permit trading, due to the fact that the location where the sulphur is emitted has significant effect on the costs it imposes.

Kyoto agreement in 1997 on limiting greenhouse gas emissions[6]. However, following pressure from the United States, the Kyoto Protocol also includes provisions for countries or firms to trade their agreed quotas in an international market, so following on an international scale the example set by sulphur emissions trading in the U.S.A., and making it possible to equalise marginal abatement costs across countries.

For a global pollutant, such as carbon dioxide, a system of auctionable permits works in many ways like a carbon tax, although it is the total volume, rather than the marginal abatement cost, which is being fixed. However, a permit scheme has various advantages, particularly if it allows for international trading[7]. In addition, unlike a carbon tax, a permit system where permits can be saved for future use- which makes sense given that carbon is a long-lasting global pollutant - allows carbon users greater freedom of choice over the intertemporal path of carbon consumption, and facilitates the development of a futures and options market in carbon use (see Cramton and Kerr, 1998).

This paper examines various internal economic instruments for a country to control carbon emissions in compliance with its Kyoto targets: these include a carbon tax, a fully-auctioned permit system, or various systems of allocating tradable permits to certain energy users. The paper concentrates on the case of the United Kingdom, and employs numerical simulation using a computable general equilibrium (CGE) model of the U.K.

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[6] For example the UK government announced in the 1999 budget its intention of introducing a business energy tax from 2000 (see H.M.Customs and Excise, 1999).

[7] Though Barrett (1998) points out there are drawbacks to the international trading of quotas.

While the analysis is in principle applicable to other countries, the economic outcome will depend on the structure of the economy and pre-existing distortions.

Carbon permit allocation in the United Kingdom: the Marshall Report.

Lord (formerly Sir Colin) Marshall's Report (1998) to the UK government on *Economic instruments and the business use of energy* reviews a number of the main arguments, and recognises that a major argument for a permit scheme is the potential for permits to be traded internationally, which in turn allows extra cutbacks in pollution to be made in those countries which have lowest marginal abatement costs, and then 'sold' to countries with higher marginal abatement costs. In theory, this equalises marginal abatement costs and reduces total abatement cost. The Kyoto Protocol allows for such international trading in greenhouse gas emissions to begin in 2008, when the commitment period for meeting emissions targets begins.

The report argues (paragraph 46) that trading should be extended to company-to-company trading, on the grounds that 'firms, not governments, are best able to spot abatement opportunities and best placed to decide whether it is most cost-effective in their interests to reduce their own emissions or buy permits'[8]. It does, however, acknowledge (paragraph 55) that 'participation in trading will probably never extend to the small business sector'[9], due to high costs of participation. As a result, there is likely to be a

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[8] The argument is debatable because firms also have freedom of action under a system where the government trades permits, and then sets a tax to equate total emissions to what the UK is allowed.

[9] This conclusion is in line with Tietenberg's (1990) conclusion that 'emissions trading is probably not equally applicable to large and small pollution sources', due to high transactions costs.

two-tier system of carbon emission control, with large companies – perhaps those who currently participate in the Integrated Pollution Prevention and Control Directive (IPPC)[10] - trading in permits, while smaller companies (those too small to participate in the permit market) and households pay a carbon tax on fuel inputs.

There are various possible schemes for allocating permits. Large companies, concerned about their balance sheets, favour a scheme of '*grandfathering'* emissions permits, to be allocated free to companies in proportion to emissions in a base year, or number of years, and to be resaleable. Such a scheme would bring objections concerning its competitive effects, which give advantages to incumbents in industries against newcomers (and possibly undermining recent reforms of the electricity market), and concerning equity, as it involves handing out 'windfall gains, in the shape of valuable permits, to failing companies or those who had been slow to act before'. A two-tier system under which large firms would be given trading permits, while small firms would pay a carbon tax, would discriminate against small firms, and favour manufacturing against services.

An alternative to straightforward grandfathering is *'benchmarking'*, where firms are allocated permits according to a target for carbon emissions based on a regulator's judgement of best-practice emissions for that industry (i.e. somewhat akin to the Best Available Technology principle used in the IPPC directive). This would be fairer in terms

[10] IPPC is a directive covering large energy users in the UK, under which firms are set emissions limits for various non-carbon pollutants based on 'Best Available Techniques'. Failure to meet BAT is a prosecutable offence.

of ensuring large and small companies paid for carbon use, but more bureaucratic, and would involve and difficult to apply in less homogeneous sectors[11].

The third, and possibly fairest, method of allocation would be a public *auction*, which would also raise revenues, which could be recycled in a variety of ways. This was the method Marshall preferred, although he believed political pressures from large energy users would result in a hybrid scheme.

The economic effects of different methods of permit allocation.

This paper aims to compare the effects of different methods of allocation of permits within the UK. For simplicity, it is initially assumed that no net international trading takes place (i.e. the system is simply an internal UK system).

Allocation of the permits by means of a regular *public auction* has broadly similar economic effects to a carbon tax, certainly in the case of a competitive market[12]. First, energy input prices rise, due to the need to purchase permits. For energy-intensive industries, this is the most important effect. In the short run, with capital immobile, the main effect is likely to be to drive down profits in such industries. In the longer run,

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[11] Tietenberg (1990) mentions that, in practice, it is rare for emissions trading schemes have allocate permits to new entrants.

[12] This depends to some extent on the choice of auction method. Cramton and Kerr, 1998, argue that in the case of the USA, no single user, or small group of users, would have sufficient monopolistic power to rig the market, so a simple ascending clock auction would be efficient. The situation in the UK may be rather different, as it is conceivable the two largest electricity generators could exert some monopsonistic power to force down permit prices.

however, assuming full mobility of capital, the capital stock, output and employment in energy-intensive industries will be reduced and the output price raised, restoring profits to 'normal' (assuming the industry is competitive).

For less energy-intensive industries, the secondary general equilibrium effects will be just as important. Depending on how it is recycled, revenue from the sale of permits will compensate consumers for the rise in energy-intensive product prices, and lead to an increase in spending on less energy-intensive products. If the recycling reduces the tax burden on labour, its supply may rise, and real product wages may be reduced. In turn, the exchange rate and terms of trade may be altered by the introduction of the permits.

Overall, a permit system is likely shift demand away from manufacturing towards services - see the SEO study of the Netherlands (1998) for an example of this. Effects on profitability are assumed to be short-term – in the long-run it is output, capital stock, employment and output prices that will adjust. Farrow (1995) discusses these general equilibrium effects.

The most frequently discussed system of *grandfathering* (e.g. in the SEO report) is to make allocations based upon companies' emissions in a single year, or set of years, prior to introduction of the system. Allocations would be restricted to the initial group of recipient firms, gradually being reduced in volume in proportion to the national emissions quota. The permits would be resaleable. In a partial equilibrium analysis, with perfect capital markets and profit-maximising firms, the fact that some companies are being given an allocation of free permits rather than having to buy them in an auction would not affect decisions on input or output prices or volumes. The *opportunity cost* of fuels would be the same as under an auction system, since a company can gain revenue from selling the permits it does not use. However, profits of companies are higher when they receive permits free instead of having to buy them. This is analytically similar to making them buy the permits at an auction (or pay a carbon tax) and reimbursing them in a lump sum for a fixed amount of those permits[13]. In the short run, this would just offset losses from introduction of the permits. In longer run, prices would rise and output fall just as under an auction system to the point where the rate of profit on *new capacity*, or for a new entrant, who would have to purchase permits, is normal. This would give a windfall, supranormal profit to incumbents who receive the free permit allocation.

There are some qualifications to the analysis of grandfathering as a lump-sum transfer. Firms may keep plants open which would have closed under an auction system, if closing them would mean losing allocation. If companies face imperfect capital markets or are not profit-maximising, the better cash-flow position of incumbents under grandfathering could affect behaviour. Perhaps more significantly, there are different general equilibrium effects, since the government no longer gets revenue from sale of permits, and cannot use them, for example, to cut taxes on labour. Higher distributed profits would, of course raise consumer spending, but there is a possibility, if company shares are foreign-owned,

[13] For the systems to be analytically equivalent, it is necessary to assume if firms wanted more permits than the fixed allocation, they would be able to buy them at the auction. If their allocation exceeded the amount they would have demanded at the auction price, they could re-sell them at the same price.

that some of the windfall from grandfathering would be repatriated to foreign owners, and have negative implications for the exchange rate and terms of trade[14].

Parry et al (1997) estimated, using a CGE model of the USA, that the costs of reducing US emissions by 10 per cent were more than three times higher under a grandfathered permit system than with a carbon tax, due to the inability to recycle revenue. This is also backed by Smith (1998), who discusses the potentially large sums involved in carbon tax revenues, and the fact that grandfathering means loss of the possibility of recycling these in the form of reducing other tax distortions[15]. Cramton and Kerr point to the likely costs of political lobbying and legal challenges to any system which allocates permits free to some firms but not others[16].

There are alternatives to the lump-sum system of grandfathering. Objections from newcomers to the industry about the unfairness of favouring incumbents may lead to periodic reallocation of quotas. But where companies expect that under a rolling reallocation of permits, emitting more carbon now may well lead to getting a larger permit allocation in the future, there would be a counterbalancing incentive to continue emitting. It follows that, to have much effect on carbon emissions, a system with periodic

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[14] The effects would depend on the extent to which the profits are repatriated, or retained and reinvested in the country issuing the permits, which is not easy to guess *a priori*.

[15] Smith quotes a study by Ballard et al, 1985, estimating that, at the margin, tax receipts in the USA had a deadweight welfare cost of 20-50 per cent.

[16] Grandfathering makes more sense in some cases, where those participating in the scheme are the only ones who face economic penalties for polluting. There is a parallel, as Smith (1999) notes, with the case of Swedish controls on Nox emissions, where only large emitters pay a pollution tax, and the revenues are consequently recycled directly to participating firms, in order to maintain a level playing field vis-à-vis firms too small to take part.

reallocation would need to be more of the *benchmarking* variety, where companies only receive allocations according to the assessment of outside experts on the amount a firm in their industry could reasonably be expected to emit.

The effects of regularly revised allocations with benchmarking would be quite different to those of grandfathering as discussed above. Although companies would still be penalised for consuming more carbon-intensive fuels than best-practice for their industry and size, a company which expands in output would expect before long to receive a larger quota allocation, and newcomers could also expect to receive quotas. Consequently, a benchmarking system would not have the same disincentive effects on output in carbon-intensive industries, with the result that output is higher and prices lower in these industries. If free permits are available to newcomers and there are no other major barriers to entry, the allocation of permits would no longer create windfall profits to incumbents, but would instead be reflected in lower output prices (analytically equivalent to recycling the revenue of permit sales by each industry as an offsetting output subsidy to that industry[17]). This would help lower consumer prices, and could be seen as a form of revenue recycling, though the effects on labour supply are in theory ambiguous[18].

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[17] The actual present value of increasing carbon use now in order to obtain a higher permit ration in the next round of allocation depends on the length of time between reallocation, the rate of interest, the factor by which next round's permit allocation is expected to be reduced compared to current 'best-practice' emissions, and the expected rate of increase in permit prices. If the reallocation is frequent, then these factors become less important, and the value is close to the current permit price.

[18] Depending on whether the effect of cheaper consumer goods in raising the marginal value of income for work offsets the wealth effect, whereby people prefer more leisure as their real income (including income from non-labour sources) rises.

Some papers on ‘grandfathering’ may have had more this kind of scheme in mind. An example is Boehringer, Rutherford and Voss’ paper on unilateral introduction of carbon permits by Germany, which discussed the possibility that free allocation of permits would prevent carbon-intensive industries from moving to countries not introducing the scheme. This assumes the permit allocation is not simply a lump-sum gift to incumbent firms, but affects marginal output decisions.

In the following sections, we attempt to model the two methods of grandfathering (with quotas either based on existing emissions or made adjustable according to ‘benchmark’ estimates of needs), and compare these with the simulated effects of an auction of permits.

Methodology.

We use a computable general equilibrium (CGE) model, which simulates how the economy in a base year would have looked if tax or permit changes were in place. The CGE model has 12 sectors, 9 being fuels and three non-energy. All sectors are perfectly competitive. There are two factors, labour, which is fully mobile within a country, and capital, which is mobile internationally. Details of the model are given in Edwards and Hutton (1998), while elasticities are those in Edwards and Hutton (1999). The model is derived initially from that in Fehr et al (1995) and Ruocco (1996).

Treatment of carbon permit allocation.

This study focuses in particular on the example of the United Kingdom, which has adopted a target of a 20 per cent reduction in carbon dioxide (CO_2) emissions by 2010, compared with 1990. Actual 1990 emissions were estimated at 168 MtC, while the UK government's business as usual (BAU) projection for 2010 is 163 MtC. Meeting the target would imply a further reduction to 134.4 MtC, or 17.5 % below BAU.

The focus of this paper is on the *internal* allocation of carbon permits. An examination of the effects of international trade in permits would complicate the issue, so that is not done here, and it is assumed for simplicity that other countries stick to business as usual strategies.

Carbon emissions are hypothetically reduced by two methods in this paper. Large energy consumers are assumed to require permits, while smaller consumers face a carbon tax. The large consumers are assumed to be basically those companies currently participating in the Integrated Pollution Prevention and Control Directive (IPPC – see Table A1 in the Appendix), which covers 79 per cent of energy consumption in our energy-intensive sector, 33 per cent in our other industry sector and all of oil refining and coke ovens. Manufactured fuels and power generation are also assumed to participate in the permit scheme, while services, transport and agriculture do not (though IPPC does cover some farms). For the purposes of modelling, we assume that in a sector in which, say, 79 per cent of production was covered by the permit scheme, all firms would pay 21 per cent of the carbon tax rate and (if they had to purchase permits at auction) 79 per cent of the permit price on their emissions.

Emissions permits are assumed to be either auctioned, or allocated to those firms participating in the permit scheme, using either grandfathering based on emissions in the base case or a benchmark scheme available to all companies according to independently-judged 'best practice' standards relative to output. In both the grandfathering and benchmarking schemes, the total amount of permits is reduced relative to base case emissions in proportion to the target reduction in national emissions compared with base.

In the rest of the economy a carbon tax is applied (on an upstream basis, based on fossil fuel inputs and carbon contents[19]).

In common with other CGE models of permit systems (eg SEO and Boehringer et al) the permit systems are modelled by assuming the permits represent an implicit tax on carbon to the sectors holding them. There is, of course, a possibility with two schemes in operation that the implicit tax rate on carbon to the permit-using sector might differ from the tax rate to other sectors: since this would again introduce complications, it has been assumed the government is able to buy and sell carbon permits to equalise the tax rate and the implicit tax rate on permits.

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[19] Marshall suggested a 'downstream' carbon tax, applied to the sale of refined fuels to final users. This would allow for exemption of some consumers (eg the domestic sector) but is not easy to model, and would

The free allocation of permits is dealt with in two ways. In the case of pure *grandfathering*, the free allocation of permits to companies is seen as a lump-sum transfer. This is essentially a windfall transfer to shareholders. The total amount of this windfall transfer in the case of industry n is $tc.C_{n0}.\Phi_n.(1\text{-}CT)$, where:

tc = carbon tax rate per tonne carbon.

C_{n0} = carbon input to industry n in base case.

Φ_n = proportion of carbon input to industry n judged to be emitted by that industry (in the case of coal products or oil refining it excludes energy throughput).

CT = corporation tax rate (assumed to be 33 %).

Two variants of this are assumed: in the first case, all windfall profits are distributed to UK shareholders only, while in the second fixed proportions are distributed to shareholders abroad, amounting to 25 %[20] of total windfall profits.

In order to approximate the working of the benchmarking scheme, we have rebated the same total amount to the industry[21]. However, as it is assumed to be available to all output, including newcomers to the industry, it is rebated as a per unit rebate on

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also introduce more economic complications, such as which sectors to exempt. This proposal has been adopted in the 1999 budget proposals for a fuel tax on industrial users.

[20] In 1990 in the UK, according to Economic Trends 1992 Table 39, dividends on ordinary and preference shares distributed in the UK amounted to £ 22.115 billion, while profits due abroad amounted to 7.337 billion, or 24.9 per cent of the total.

[21] In principle, the value of expected future ‘benchmark’ allocations will depend on the frequency of reallocation, the rate of interest, the expected future change in permit prices and the amount of permits to be allocated free in future compared to current consumption qualifying for free permits. In practice, if

production[22], and so should act to reduce total prices by the same amount as the direct effects of the carbon tax increases them.

Recycling the rest of the revenue.

Carbon tax revenue and (in the auction scheme) the government's revenue from sale of permits is recycled via a general reduction in other taxation. Marshall was keen on recycling these revenues to business, either via energy efficiency subsidies or a reduction in non-wage labour costs. The notion of recycling taxes to industry is, however, not a clear one in a long-term general equilibrium framework, since the incidence of a tax is quite different from who nominally pays it. In the long term, taxes do not affect profit rates, as capital is assumed to be mobile. In our long-run general equilibrium framework, all tax changes, including changes in VAT, feed through to labour input costs, since the wage rate is not fixed and changes in the cost of living will affect labour supply.

As a fairly 'neutral' initial starting point, we decided to simulate recycling the revenue from a carbon tax/permit auction through lower consumption taxes. The analysis here therefore assumes initially that revenues are used to cut general VAT rates (which, by reducing the price of the consumer bundle, increase the real wage). This would involve less distribution away from low-wage earners towards the better off than a cut in income

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reallocation is done on a frequent basis, the value should be close to the current permit price, which is what we have assumed.

[22] For simplicity, our computable general equilibrium model includes many taxes and subsidies to industry (other than the energy sectors, where more detail is applied) in a single production tax (/subsidy). This is the value which is reduced (/increased) in the benchmarking scheme.

tax or other labour taxes. For a more detailed discussion of the distributional effects of different methods of revenue recycling, see Barker and Kohler, 1998.

The model assumes the government budget balances, so the exact amount rebated in lower VAT will not just equal the changes in carbon tax/permit sale revenue, but will also reflect changes in economic output and the tax base.

It is assumed in all runs that revenue from those sectors paying a carbon tax (assumed to be domestic households plus other small energy consumers) is recycled via lower VAT. This allows the paper to concentrate on the treatment of large energy users, who would participate in a permits market, and on different means of allocating those permits or recycling the revenue if they are auctioned.

Results.

Table A2 (in the Appendix) summarises the results of a number of scenarios, using actual 1992 data as a base case. The data are expressed as percentage change compared to the base (business as usual) case. Six cases are considered for the allocation to large industry:

(i) auctioning of permits with revenues recycled as lower VAT,

(ii) and (iii) free allocation by grandfathering (with and without allowing for 25 % of profits to be exported);

(iv) free allocation on a regularly-revised basis using benchmarks;

(v) auctioning of permits, with revenues used for a general subsidy/tax cut on industrial and commercial output;

(vi) auctioning of permits, with revenues used to cut employers' national insurance contributions.

In all cases, emissions are reduced by around 17 ½ per cent compared to BAU (though there are some slight discrepancies due to difficulty in getting the model to achieve targets exactly). This is equivalent to the proportional cut compared to BAU it is expected the U.K. will needs to make to achieve its carbon emission target by 2010. The carbon permit price is assumed to be the same as the carbon tax on tax-paying sectors.

The first comment is that the carbon tax/implicit permit price hardly varies across the scenarios: the use of grandfathering only marginally reduces the effectiveness of a given carbon tax in reducing carbon emissions. Perhaps surprisingly, the tax/permit price in a benchmark system is lower than when permits are grandfathered, or even when they are auctioned, even though (see Table A3) output of energy-intensive industries is higher. This is because benchmarking leads to a reduction in electricity prices, which allows electricity to substitute more for dirty fuels such as coal. Table A3 shows a small rise in electricity output in the benchmarking case, with a large fall in coal products output, as coke use in steel plants is replaced with electricity. By contrast, grandfathering makes little difference to industrial structure compared with auctioning the permits.

Interestingly, many of our scenarios bear out the notion of a 'double dividend', or at least, negligible net costs of emission reduction. In fact, with auctionable permits, the 17 ½ per cent reduction in carbon emissions compared to BAU is achieved at zero cost to GNP (and a slight increase in utility, taking account of increased leisure). This is partly because the Harberger triangle measure of the deadweight loss from the tax in a partial equilibrium analysis (see Clarke, 1993, or Edwards, 1998) is offset by other effects. These include not just the benefits from reducing VAT rates, which would not in themselves be enough to offset the partial equilibrium costs of the carbon tax[23] , but also the effects of the carbon tax in reducing energy imports, reflected in a rise in sterling and improved terms of trade, as well as the interaction with existing indirect taxes. In 1992, Britain had no VAT on domestic fuels, so application of a carbon tax to fuel (and using the revenue to lower VAT rates) would up to a point help to equalise tax rates across different commodities, reducing the deadweight loss cost of collecting tax revenue, though at the cost of increasing the cost of living for low-income groups.

As might be expected, the grandfathering of permits reduces welfare and GNP compared with auctioning. This is because the efficiency gains from using auction revenues to cut other taxes are lost – income instead going as windfall profits. The result is that the cost of living is higher and labour supply reduced. In addition, in the case where profits are remitted abroad, there is a loss of income to the U.K. While the costs of grandfathering - 0.08 % compared with auctioning where profits are exported, and just 0.03 % when

[23] Bovenberg and De Mooij, 1994, point out that introducing a narrowly-based tax such as a carbon tax, and using the revenue to reduce more broadly-based taxes, is likely, other things equal, to reduce national income.

profits are not repatriated - do not look great compared to GNP, they amount to around £400 m and £150 m per annum respectively in the case of the U.K.

Perhaps the most surprising result is that regular redistribution by benchmarking, actually improves GNP and our welfare measure (equivalent variation) by 0.17 % and 0.13 % compared with auctioning, even despite the terms of trade improvement being much less. The reasons lie mainly in the labour market: in the benchmarking case, the allocation of permits acts like a subsidy on output of certain industries, which feeds through to lower output prices and higher sales for home-produced goods, which feed through into consumer prices. Unlike the VAT recycling in the auction case, the benchmarking encourages a switch of expenditure to domestically-made industrial products, which increases labour demand, the real wage and induces higher labour supply. In addition, by increasing the taxable base, there is a second-round effect that VAT rates can be cut more to balance the budget, compared to under grandfathering.

This demand switch towards domestic production has quite a marked positive effect on welfare and GNP even in this model where the labour market is continuously clearing and the labour supply elasticity with respect to the real wage is relatively low (0.15). The increase in employment is not great: 0.03 per cent compared to base, or 0.04 per cent compared to the case with auctioning. In a model with involuntary unemployment, we might expect the switch of demand to have more substantial Keynesian-style effects on UK output.

A slight caution is needed to these results: it may be that in a more disaggregated model, the implicit subsidy towards energy-intensive subsectors (from avoiding the cost of carbon permits) would have more effect on industrial structure than in our model. As a result, output from energy-intensive subsectors would be higher, and a higher permit price would be required to meet a given permit target.

For comparison, Scenario (v) looks at the case where the permits are auctioned to large energy users, and the revenues used to subsidise or cut taxes on output across industry as a whole. The benefit to GNP and measured welfare is slightly higher than where the permits are re-allocated using benchmark valuations: a rise of 0.18 per cent in GNP and 0.14 per cent in utility (against 0.17 per cent and 0.13 per cent respectively under benchmarking). This implies that, while benchmark reallocation is not the most effective way of realising the potential 'double dividend' from carbon permits, it achieves most of what is feasible.

Employment is slightly higher with benchmark reallocation than in scenario (v), though both perform much better in this respect than under standard grandfathering. However, there is a larger employment gain (though still only 0.05 per cent in our model, which has clearing labour markets) when revenues are recycled as lower national insurance contributions[24]. In our model, where the labour market clears and capital is fully mobile between countries (and could be driven abroad if substituted by cheaper labour), recycling

[24] The 1999 UK budget included recycling of the industrial energy tax as lower NICs.

as lower labour costs produces less gain to national income and welfare than recycling as an output subsidy.

Sensitivity to different production side elasticities:

Our model estimates the tax rate/permit price needed to achieve the 17.5 per cent cut in carbon emissions compared to BAU to be around £22 or £23 per tonne carbon in 1992 prices, equivalent to around $4.20-$4.50 per barrel of oil at 1992 prices and exchange rates. This is not easy to compare with other studies, due to differences between dates, countries covered and the proportional reduction in carbon emissions assumed. For example, the SEO study for the Netherlands indicates a permit price equivalent to well over £300 per tonne carbon – but this is for a much larger assumed proportional reduction in carbon emissions. For a 20 per cent cut in emissions in Germany, Boehringer and Rutherford (1995) quote a carbon tax range of 1990 DM 45.5/tC to DM 112.27/tC (around £16 - £39 in 1992 prices) depending on elasticity assumptions. For the USA, Parry et al (1997) quote a carbon tax range of $43.4 - $188 per tonne Carbon (1990 dollars), which equates to around £26 - £113 per tonne. Our estimates for the permit price are therefore well within the range of the German study, but are lower than might be indicated by the US study.

Appendix Table A4 lists the elasticities of substitution in our main runs, while Table A5 shows the effects of using 60 per cent lower assumed elasticities of substitution between fuels in the production sectors, and between energy and other inputs at the top level of the production function. The effect is to raise the permit price needed to achieve emissions targets to around £50 per tonne carbon. The economic changes on Table A2 are surprisingly small, although grandfathering looks more expensive compared to the other options, particularly if profits are repatriated abroad.

Conclusions.

This paper has looked at various means of allocating carbon emission permits to large energy users, as a step towards a country participating in an international permits market as envisaged in the Kyoto accord. We have chosen to look in particular at the case of the United Kingdom, and the current deliberations in the UK over how to meet the country's commitments on carbon emissions. Because of the complexity of the economic issues raised by a permit system, we have set up the scenarios to look simply at the issue of grandfathering of permits as an internal matter, rather than at the issues associated with international trade in permits.

Our model suggests that the kind of emissions reductions being discussed for 2010 are unlikely to prove costly to welfare or national income, and some of our scenarios indicate that there is a potential 'double dividend' to be reaped if revenue from a permit auction is recycled to industry in the form of output subsidies or employment tax cuts[25].

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[25] This is in line with, among others, the estimates of Barker and Koehler, 1998. Barrett (1998) is another who has suggested 'he benefits of undertaking the Kyoto reductions should exceed the corresponding costs provided these are achieved cost-effectively'.

Our results on the cost of straightforward grandfathering compared to an auction are in line with the analyses of Cramton and Kerr, Parry et al and Goulder et al (1996) for the USA, or the SEO study of the Netherlands, among others. When permits are allocated free, the government is forgoing potential auction revenues, which could be used to reduce other taxes and associated distortions. The cost is larger once we take account of the possibility that foreign-owned companies could treat the free allocation of permits as a windfall to repatriate to shareholders.

However, our 'benchmarking' scenario indicates that free allocation of permits is not necessarily such a costly option. The important difference compared with standard grandfathering is that the use of benchmarking makes it possible to reallocate permits regularly, so that new entrants, or companies wishing to expand output, expect soon to get a free allocation in line with that enjoyed by incumbents. This means that there is more incentive to expand output of energy-intensive industries in the country issuing the permits, and reduce prices to consumers. GNP and welfare are actually raised compared with the case where permits are auctioned and VAT reduced.

This result should be taken as very tentative. Regular reallocation of permits is only consistent with reducing carbon emissions if it is possible to base the allocation on some outside estimate of the 'benchmark' energy consumption of an energy-efficient firm, rather than on actual energy consumption and carbon emissions. This may be easy in some industries where large-scale production processes are very standardised, but for other industries, estimation of 'best-practice' could be costly and controversial. As Smith

(1998) points out, regulatory capture is a potential problem of systems where the regulator allocating permits is dependent on firms for information necessary for making the allocation. In addition, the competitive structure of the industry, and ease of new entry, would play a crucial part in determining whether free allocation of permits becomes a windfall to incumbents or an encouragement to output, offsetting the costs of a carbon tax. In the case of the United Kingdom, recent reforms increasing competition and easing entry into power generation and gas distribution may mean benchmarking is more viable than it would previously have been. In addition, the knowledge gained over recent years by the regulators of those industries may make policing the energy efficiency of power plants more feasible.

Overall, the costs of traditional grandfathering of permits to large energy users compared to auctioning the permits and recycling the revenue as output subsidies/tax cuts amount to around 1/4 per cent of GNP, or £1250 million per annum in the U.K. This more than squanders any potential double dividend from recycling the revenue from carbon abatement. Regular reallocation on the basis of benchmark estimates of carbon needs can potentially offset most of the losses from grandfathering, though it may prove difficult to implement, and is still probably not the most beneficial measure economically.

A final point: this paper has concentrated on the costs of different permit systems for complying with the Kyoto targets for carbon emissions in 2010. But the carbon emissions cuts agreed for 2010 (20 per cent in the case of the U.K.), are likely to be only the beginning, as many studies, such as Schmalensee et al (1998), indicate a need for much tighter controls beyond that date, especially given expected rapid growth in carbon use outside the OECD area. This implies that taxes and permit prices could eventually rise far higher than the levels considered here – which makes the issues of allocation of permits and recycling of revenues potentially even more important.

Appendix Table A1:

Marshall Report Table D1: IPPC coverage by sector

Sector	Energy PJ 1995	Used by cos liable to IPPP	covered by IPPC	CO2 emissions IPPC Sites	NO of IPPC Installns
Iron and steel	335	289	86%	7500	100-120
Non-ferrous metals	48	30	63%	1100	478
Non-metallic minerals	30	3	10%	70	15
Bricks	21	20	95%	360	77
Cement	69	69	100%	1600	34
Glass	31	29	94%	600	57
Potteries	16	3	19%	70	8
Chemicals	254	211	83%	5000	333
Mech engineering	84	10	12%	290	538
Electrical engineering	38	0	0%	0	0
Vehicle engineering	68	11	16%	290	165
Food, drink & tobacco	174	41	24%	850	1597
Textiles, leather & clothing	49	27	55%	650	27
Other industries	27	0	0%	0	0
Paper man & util	151	96	64%	2400	99
Plastics and rubber	56	3	5%	80	1
Energy-intensive	788	626	79%	16000	
Other industry	663	216	33%	4860	
Total manufacturing	1451	842	58%	20860	3529-3549
Coke ovens	29	29	100%	700	9
Oil refineries	270	270	100%	5600	16
Gas production	189	189	100%	2800	1
Waste					1738
Agriculture					974
Total UK industries	1939	1330	69%	29960	5293-5313

TABLE A2.

United Kingdom: CGE simulations of the effects of different schemes of allocating permits to large energy consumers as part of a scheme to reduce overall carbon emissions by 17 1/2 per cent compared to base.

	Auction	**Grandfathering Profit export**	**Grandfathering NO profit export**	**Benchmk and re-allocn.**	**Uniform output tax cut**	**Uniform labour tax cut**
Implicit carbon tax 1992 £ per tonne Carbon.	22.39	22.50	22.61	22.32	23.13	22.47
carbon emissions % change	-17.51%	-17.40%	-17.42%	-17.41%	-17.40%	-17.56%
VAT % change	-5.62%	-2.89%	-3.06%	-4.04%	-4.36%	-3.72%
Terms of trade % change	0.45%	0.45%	0.48%	0.21%	0.20%	0.43%
GNP % change	0.00%	-0.08%	-0.03%	0.17%	0.18%	0.03%
Real wage	-0.02%	-0.28%	-0.23%	0.34%	0.35%	0.17%
Utility	0.01%	-0.04%	0.00%	0.13%	0.14%	0.01%
Employment	-0.01%	-0.07%	-0.08%	0.03%	0.02%	0.05%

TABLE A3:

United Kingdom: CGE simulations of the effects of different schemes of allocating permits to large energy consumers as part of a scheme to reduce overall carbon emissions by 17 1/2 per cent compared to base.

Effects on economic structure

	Auction	Grandfathering Profit export	Grandfathering NO profit export	Benchmk and re-allocn.	Uniform output tax cut	Uniform labour tax cut
Energy-intensive Industry	-0.34%	-0.40%	-0.42%	0.50%	0.10%	-0.30%
Other industry	-0.08%	-0.16%	-0.16%	0.24%	0.29%	-0.06%
Services, agriculture and transport	-0.20%	-0.25%	-0.23%	-0.05%	0.08%	-0.15%
Hard coal	-22.00%	-22.04%	-22.09%	-19.76%	-22.58%	-21.95%
Soft coal	UNDF	UNDF	UNDF	UNDF	UNDF	UNDF
Coal products	-2.05%	-2.07%	-2.04%	-14.28%	-1.42%	-2.12%
Crude oil	-5.41%	-5.51%	-5.55%	-6.15%	-5.27%	-5.39%
Natural gas	-9.60%	-9.62%	-9.63%	-9.70%	-9.69%	-9.51%
Gas distribution	-2.25%	-2.24%	-2.21%	-3.41%	-2.05%	-2.15%
Refined oil	-2.07%	-2.27%	-2.26%	-3.07%	-2.05%	-2.03%
Electricity	-3.24%	-3.33%	-3.31%	8.74%	-1.58%	-3.16%
Nuclear/renewable electricity	0.00%	Output assumed fixed exogenously.				0.00%

TABLE A4:

Elasticity assumptions :

Production Function:

(i) Between imported intermediates from different countries: SIG4 = 2

(ii) Between imported and non-imported intermediates: SIG3 = 2

(iii) Between capital and labour: SIG2 = 0.8

(iv) Between fuels: SIGEN = 2 for UK or Germany. 1.25 for Other EU12 or ROW.

except in power generation SIGEN = 4 for UK/Germany and 2.5 for Other EU12/ROW.

or in ag/comm (which includes transport) SIGEN = 0.8 for UK/Germany or 0.5 for Other EU12/ROW.

(V) Top level between energy, non-energy and value added:

SIGMATOP = 0.5

Consumption Function:

(i) Between imports from different source countries: SIGMA3 = 2

(ii) Between composite imports and home-produced goods: SIGMA2 = 2

(iii) Between different consumption goods: SIGMA1 = 0.5

Labour Supply:

Uncompensated labour supply elasticity: ELLSUP = 0.15

TABLE A5:

United Kingdom: CGE simulations of the effects of different schemes of allocating permits to large energy consumers as part of a scheme to reduce overall carbon emissions by 17 1/2 per cent compared to base.

Elasticities of substitution between fuels and at top level of production reduced by 60%.

	Auction	Grandfathering Profit export	NO profit export	Benchmk and re-allocn.	Uniform output tax cut/ subsidy
Implicit carbon tax 1992 £ per tonne Carbon.	51.40	51.40	51.40	51.40	51.40
carbon emissions % change	-17.38%	-17.56%	-17.52%	-16.60%	-17.38%
VAT % change	-13.25%	-5.96%	-7.24%	-8.30%	-8.53%
Terms of trade % change	0.79%	0.81%	0.90%	0.44%	0.79%
GNP % change	0.01%	-0.18%	-0.07%	0.09%	0.01%
Real wage	-0.14%	-0.75%	-0.64%	0.14%	-0.14%
Utility	0.03%	-0.08%	0.01%	0.07%	0.03%
Employment	-0.07%	-0.21%	-0.24%	-0.01%	0.01%

Bibliography:

Ballard, C., Shoven, J., and Whalley, J. (1985): 'General equilibrium computations of the marginal welfare costs of taxes in the United States'. *American Economic Review*, 75, 128-38.

Barker, T. and Koehler, J. (1998): 'Equity and ecotax reform in the EU: achieving a 10 per cent reduction in CO_2 emissions using excise duties', *Fiscal Studies*, 19, 4, 375-402.

Barrett, S. (1998): 'Political Economy of the Kyoto Protocol'. *Oxford Review of Economic Policy*, Vol. 14, issue 4, pp 20-39.

Baumol, W.J. and Oates, W.E. (1971): 'The use of standards and prices for protection of the environment'. *Swedish Journal of Economics*, Vol. 73 no. 1.

Boehringer, C. and Rutherford, T. (1995): 'Carbon taxes with exemptions in an open economy: a general equilibrium analysis of the German tax initiative'. *Mimeo*, Institut fuer Energiewirtschaft und Rationelle Energieanwendung, Stuttgart.

Boehringer, C., Rutherford, T. and Voss, A. (1998): "Global CO_2 emissions and unilateral action: policy implications of induced trade effects" *International Journal of Global Energy Issues*, 11 (1-4), 1998, pp 18-22.

Bovenberg, A.L. and De Moji, R.A. (1994): 'Environmental Levies and Distortionary Taxes'. *The American Economic Review*, 1994.

Cramton, P. and Kerr, S. (1998): 'Tradeable Carbon Permit Auctions: How and why to auction not grandfather'. *Discussion paper*, University of Maryland, USA.

Clarke, R. (1993): 'Energy taxes and subsidies: their implications for Co2 emissions and abatement costs', *International Journal of Environment and Pollution*, 3(1-3): 168-78.

Clarke, R., Boero, G., and Winters, L.A.(1996): 'Controlling Greenhouse Gases: a survey of global macroeconomic studies'. *Bulletin of Economic Research, 48 (4):* 269-308.

Edwards, T.H. (1998): 'Modelling the Effects of Energy Market Distortions on the Costs of Carbon Abatement: Computable general equilibrium and partial equilibrium assessment'. In Fossati, A. and Hutton, J.P.(Eds) *'Policy Simulations in the European Union'*, Routledge, Andover, U.K.

Edwards, T.H., and Hutton, J.P. (1998): 'Adaptation of a standard multi-country general equilibrium model to assess the effects of EU member countries' energy and environmental policies in an integrated market'. *Working Paper n. 7/98*, Istituto di Finanza dell' Universita, Genova, Italy.

Edwards, T.H, and Hutton, J.P. (1999): 'Carbon abatement and its international effects in Europe including effects on other pollutants: a general equilibrium approach'. *University of York Economics Discussion Paper 98/26*, March 1999.

Farrow, S. (1995): 'The Dual Political-Economy of Taxes and Tradable Permits', *Economics Letters*, 1995 Vol. 49, No.2, pp.217-220.

Fehr,H., Rosenberg, C., and Wiegard, W. (1995): *Welfare Effects of Value-Added Tax Harmonisation in Europe.* Springer.

Goulder, L.H., Parry, I.W.H. and Burtraw, D. (1996): Revenue-Raising vs. Other Approaches to Environmental Protection: The Critical Significance of Pre-Existing Tax Distortions'. *NBER Working Paper No. W5641*. June 1996.

Klaassen, G. (1996): '*Acid Rain and Environmental Degradation. The Economics of Emissions Trading'*. Edward Elgar, Cheltenham, UK. IIASA reference BK-96-002. ISBN 1-85898-489-0.

Marshall, Lord C, (1998): 'Economic instruments and the business use of energy'. *Report to Chancellor of the Exchequer*, Nov. 1998, H.M.Treasury, London.

Parry, I.W.H., Williams, R.C., and Goulder, L.H. (1997): 'When can carbon abatement policies increase welfare ? The fundamental role of distorted factor markets'. NBER Working Paper No. W5967.

Ruocco, A. (1996): 'The GAMS-version of the Fehr-Rosenberg-Wiegard (FRW) multi-country CGE model: A user's manual. *Mimeo*, Karls-Eberhard-Universitaet, Tuebingen, Germany.

Schmalensee, R., Stoker, T.M. and Judson, R.A. (1998): 'World carbon dioxide emissions: 1950-2050'. *Review of Economics and Statistics*, LXXX, Feb 1998 no 1. pp 15-27.

S.E.O. (1998): '*Market performance and environmental policy'*. Institute for Economic Research, University of Amsterdam.

Smith, S. (1998): 'Environmental and public finance aspects of the taxation of energy'. *Oxford Review of Economic Policy*, Vol 14. No 4.

Tietenberg, T.H. (1990): 'Economic Instruments for Environmental Regulation'. *Oxford Review of Economic Policy*, vol 6, 1990, OUP.

Tietenberg, T.H. (1999): 'Tradable Permits and the Control of Air Pollution in the United States', *Mimeo*, Colby College, Maine. Paper written for the 10th anniversary jubilee edition of the Zeitschrift Fuer Angewandte Umweltforschung.