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Randy —

You might be interested in this.

We had asked the OECD to do some work on climate change as part of their research program (Janet felt, I think, that they would be more sympathetic to the economists' worldview). This paper will be discussed when Becky goes to Paris on the 23rd and 24th of this month. (I also gave Joe a copy.)

— Jeremy

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ECONOMICS DEPARTMENT
ECONOMIC POLICY COMMITTEE

Working Party No. 1 on Macroeconomic and Structural Policy Analysis

OECD WORK ON CLIMATE CHANGE: ECONOMIC THEORY AND POLICY IMPLEMENTATION

This document has been prepared by the Economics Department for the Working Party No. 1 of the Economic Policy Committee.

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1. Introduction

1. Beginning the early 1990s, the OECD executed an extensive project on the economics of climate change -- the expected warming of the climate due to human-made emissions of so-called greenhouse gases. This project dealt mainly with the long-term economic costs of reducing the energy-related emissions of greenhouse gases. This issue is now subject to renewed interest for several reasons, including further evidence that has accumulated regarding the historical effect of greenhouse gases on the climate and improved climate modelling that has refined predictions regarding future climate change.

2. But the most important development has been the sequence of international meetings and agreements on climate change. At the 1992 Earth Summit in Rio, countries adopted the United Nations Framework Convention on Climate Change (UNFCC), under which so-called Annex I countries (OECD countries except Mexico and Korea, plus Russia, Belarus and the countries of central and eastern Europe) committed themselves to take action to reduce emissions of all greenhouse gases and to enhance and protect forest areas. In 1995, the First Conference of the Parties to the Convention adopted the Berlin Mandate, in which the Parties strengthened commitments to elaborate policies and measures for abatement and to set quantified objectives within specified time-frames, such as 2005, 2010 and 2020. The Kyoto Protocol, adopted on 10 December 1997, specifies that Annex I countries as a group should reduce their greenhouse gas emissions by at least 5 per cent, relative to their 1990 levels, between 2008 and 2012 (Box 1).

3. This paper reviews work that was done in the Economics Department in the early 1990s, with some reference to work done elsewhere, including within the OECD and the International Energy Agency. It does not attempt to systematically review work that has been carried out at the OECD since then, some of which is discussed in a Secretariat document (OECD, 1996) and in Annex 2. Nor is the vast non-economic literature relevant to climate change reviewed. Of course, the work surveyed here was carried out well before the Kyoto agreement was envisaged and does not assess that agreement.

4. The key conclusions of the Economics Department work can be briefly summarised. First, since the economies of developing countries will grow faster and become more industrialised over the coming decades, these countries will contribute an increasing proportion of greenhouse gas emissions. As a result, an agreement among only OECD, or Annex I, countries to limit emissions would not succeed in stabilising global emissions; eventually, developing countries will have to be included in an agreement. Second, the need for abatement efforts from developing countries raises the difficult issue of international equity: how to share the burden of emission abatement, in particular between OECD and developing countries. Under reasonable assumptions, compensation in terms of explicit international transfers could run into hundreds of millions of dollars annually, dwarfing current intergovernmental transfers. Third, given agreed emission abatement targets, it is economically efficient to equalise marginal abatement costs across countries, firms and plants. Requiring proportional cuts by all parties instead could approximately

Box 1. From Rio to Kyoto: a Growing Concern about Earth Climate

In 1995, more than 150 countries adopted the UN Framework Convention on Climate Change at the Earth Summit in Rio de Janeiro. Annex I countries (OECD countries, except Mexico and Korea, plus Russia, Belarus and the countries of central and eastern Europe) committed to stabilising their CO_2 emissions. This Convention came as a response to mounting scientific evidence collected by the Intergovernmental Panel on Climate Change (IPCC), which was established in 1988 by the UN Environment Program and the World Meteorological Organisation in order to produce assessment reports written and reviewed by about 2000 scientists and experts world-wide. The general conclusion of the second IPCC report, published in 1995, is that "the balance of evidence suggests a discernible human influence on climate".

Subsequently, it became clear that industrialised nations would fall short of their targets adopted in Rio and that a protocol specifying legally binding quantitative constraints needed to be adopted. This was the main objective of the Third Conference of the Parties (COP3) to the Convention, held in Kyoto in December 1997.

For this meeting, the European Union proposed the most ambitious reduction target: a 15 per cent emissions reduction relative to the 1990 level by 2010. Japan proposed a cut of 5 per cent from 1990 levels over a period of 10 to 14 years. The United States proposal was to return emissions to their 1990 levels by 2010. The European Union favoured country-specific regulation (taxes) to meet emission goals, whereas the United-States suggested tradable permits.

The result was a protocol which, for the first time, commits industrialised nations to stabilise their emissions of greenhouse gases. This protocol involves the following major provisions:

- Annex I countries as a group will cut their greenhouse gas emission by about 5 per cent relative to 1990 levels. These commitments have to be met in the 2008 to 2012 period (the first commitment period). The reduction commitments are specified country by country. The Protocol mentions that they have to be met by countries, individually or jointly. The reduction targets range from an increase in emissions of about 10 per cent in Iceland to reductions of 8 per cent in the European Union. The United States would reduce its emissions by 7 per cent and Japan by 6 per cent. The Russian Federation and eastern European countries would stabilise their emissions at their 1990 levels which, given the reforms that these countries are undertaking, could be achieved without further measures.
- The Protocol covers six greenhouse gases: carbon dioxide, methane, nitrous oxide and three synthetic fluorinated compounds.
- The Protocol allows for emission trading among Annex I countries. Emissions reductions can be "banked", in the sense that countries that more than meet their commitments in the first commitment period can use the surplus reductions for future commitment periods.
- The Protocol makes provision for joint implementation through a "Clean Development Mechanism".
- Net emissions changes from land-use change and forestry are included in the Protocol for activities undertaken since 1990.
- The Protocol will enter into force 90 days after 55 Parties accounting for 55 per cent of total CO_2 emissions of Annex I countries in 1990 have ratified it. Future meetings will define the relevant modalities, rules and guidelines for emission trading and ways to verify the compliance to agreed commitments.

double the aggregate costs. Equalising marginal abatement costs, however, would mean that countries with relatively low costs -- including many developing countries and, in particular, China -- would be required to do the most abatement.

5. The structure of the paper is as follows. The second section reviews the evidence about costs of and benefits from a world agreement to reduce CO_2 emissions and illustrates why regional and sectoral differences in costs and benefits will be a central concern in shaping further world-wide action. The third section analyses strategies to minimise the aggregate costs of imposing emissions reductions and reviews some practical issues in the implementation of global strategies to reduce emissions. The fourth section reviews the experience of OECD countries with existing instruments used for environmental policy, comparing in particular carbon/energy taxes with tradable permits as a means to equalise marginal costs of abatement in the context of a global agreement. The fifth section stresses the importance of the efficiency-equity trade-off in implementing a global treaty to reduce greenhouse gas emissions.

2. Benefits and costs of a world-wide programme to reduce CO_2 emissions

6. A cost-benefit framework is, in principle, appropriate to evaluate alternative measures to cope with the threat of climate change. However, there is considerable uncertainty surrounding both costs and benefits of greenhouse gas emission abatement, which greatly complicates policy assessment. One reason for the great uncertainty associated with the costs and benefits of responding to climate change is the very long time frames over which climate change and the resulting impacts occur. In addition, cost analyses are uncertain because they are based on projections of the world economy many decades into the future and, also because the costing methodology relies on a large number of poorly understood parameters and assumptions. Estimates of the benefits from measures to stabilise the climate are uncertain because our knowledge of the effects of climate change is still very incomplete.

7. The work reviewed here was restricted to anthropogenic emissions of CO_2, mainly emissions from fossil fuel combustion. Carbon dioxide accounts for more than one-half the total effect of greenhouse gases on climate change. This section reviews the evidence on the projected increase of energy-related carbon dioxide (CO_2) emissions in the atmosphere and the resulting damages if no measures were taken -- this is referred to as the "business-as-usual" (BAU) scenario -- as well as the economic costs incurred if these emissions were to be abated. During the early 1990s, the OECD made a substantial contribution to the assessment of the economic costs by comparing the results of several global models. Estimating the benefits from curbing emissions requires a quantitative assessment of the damages caused by climate change. Only recently have such assessments been made available, due to the progress made by the Intergovernmental Panel on Climate Change (IPCC) in assessing likely impacts of climate change The estimated benefits reported below are quoted for illustrative purpose; they are not from OECD sources and cannot be compared with the OECD estimates of the economic costs of curbing emissions because of sharply differing underlying assumptions.

Box 2. The OECD Model Comparison Project

Early surveys of the economic costs of reducing CO_2 emissions highlighted large differences in model results, without being able to explain such differences in a satisfactory way. The OECD model comparisons project was an attempt to understand better the way various global models work by standardising key assumptions and emission-reduction targets and conducting some limited sensitivity analyses. The OECD project proceeded in close co-operation with a more comprehensive exercise by the Energy Modelling Forum of Stanford University (EMF12).

Six global models participated in the OECD project:

1. the Carbon Rights Trade Model (CRTM) (Rutherford, 1992);
2. the Edmonds and Reilly model (ERM) (Barns *et al.*, 1992);
3. the OECD GREEN model (Oliveira-Martins *et al.*, 1992);
4. the International Energy Agency (IEA) Model (Vouyoukas, 1992);
5. the Manne and Richels Global 2100 Model (Manne, 1992);
6. the Whalley and Wigle Model (Whalley and Wigle, 1992).

All were macroeconomic models with specifications of energy sectors that are substantially simpler than those of dedicated energy-sector models. Standardisation across models was carried out in two key ways: *i)* specifying a few key economic assumptions for the baseline or "Business-as-Usual" (BAU) scenario of unconstrained CO_2 emissions growth; and *ii)* specifying a set of common simulations for reducing CO_2 emissions.

Business-as-usual (BAU) assumptions

1) world population rises from 5.3 billion in 1990 to 9.5 billion in 2050 and to 10.4 billion by 2100, by which time it is hardly growing at all (World Bank projections); nearly all of the growth is in China and other developing countries;

2) output growth slows throughout the next century from 2.5 per cent per annum in the 1990s in OECD countries to only 1 per cent by 2100, and from 4 per cent to less than 3 per cent in developing countries;

3) oil prices are set exogenously at $26 per barrel in 1990, rise by $6 each decade in real terms to reach $50 in 2030, and are unchanged thereafter.

Reduction scenarios

Three of the scenarios were specified in terms of reductions (from the BAU emissions path) in the rate of growth of emissions in each region by, respectively, 1, 2 and 3 percentage points per annum. In this way, the amount of the reduction, in percentage terms, was identical across models, although the starting points (the baseline), and thus the outcome levels, varied. This method isolated the differences between models due to model structures. The fourth scenario was a stabilisation of emissions at 1990 levels in each region, which would be most stringent for those regions where BAU emissions growth is most rapid (China, for example) and least stringent for the OECD. The emission-reduction scenarios were applied across all regions, even though the baseline emissions growth varied significantly across regions. These reductions were not meant as recommendations or proposals, but were designed to reveal the properties of the models.

A 1 per cent reduction from the BAU would approximately stabilise emissions of the OECD area and perhaps those of the former Soviet Union too (though not in all models). It implies relatively rapid growth of emissions elsewhere. A 2 per cent reduction would require absolute cuts in emissions in the OECD and the former Soviet Union and allow very low growth elsewhere. A 3 per cent reduction is relatively close to the scenario of the International Panel on Climate Change (IPCC) for stabilising CO_2 atmospheric concentrations by the middle of the next century. As a matter of comparison, the commitments of the Kyoto Conference would imply a 0.4 per cent reduction of the annual growth rate of world emissions.

In all cases, the policy instrument used to achieve emission reductions was assumed to be a carbon tax levied on the carbon content of primary energy sources.

2.1 Business-as-usual (BAU) scenarios

8. Business-as-usual (BAU) scenarios project future emissions in the absence of measures to control them. In order to reduce the variability of these projections associated with different model assumptions, the OECD conducted a comparison project (Box 2 and OECD, 1993) in which all projections were based on standardised assumptions about future demographic and output growth, as well as the evolution of the international oil price[1].

9. A comparison between the BAU scenarios from these different sources shows that the projected growth rate of emissions over the next century could range from 1 to 2 per cent annually. Accordingly, world-wide emissions in 2050 would lie between 10 and 20 billion tons of carbon per year, compared with 6 billion tons now. However, more recent data suggesting that emissions growth is accelerating in developing countries, which would result in a higher BAU emissions growth path, perhaps 2 to 3 per cent annually[2]. Such a path was assumed in the OECD LINKAGE model (OECD, 1997*c*). In this case, CO_2 emissions could be more than twice their 1990 levels by 2020, with emissions from developing countries accounting for more than 50 per cent of the world total. Over the longer run, emissions growth might accelerate again during the second half of the next century, when exhausted reserves of oil and gas will be progressively replaced by carbon-based synthetic fuels, although this would also depend on whether alternative carbon-free energy sources became available at a low price.

10. As they rely on very long-term projections of economic growth, these scenarios are subject to a great deal of uncertainty. If growth proves to be higher than assumed, emissions will, all else equal, be larger. Even more important as a source of uncertainty is the rate of autonomous energy efficiency improvement (AEEI) -- roughly, the evolution of the energy-GDP ratio, all else equal (in particular, given no change in real energy prices). Model assumptions about the rate of AEEI range from zero to 1 per cent per year, but the econometric literature provides little backing for specific values. Other sources of uncertainty involve the evolution of the international energy prices and when and at which price alternative carbon-free energy sources (referred to as "backstops") will become available. Although less influential, the assumed rate of depletion of oil and natural gas reserves also plays a role in determining future emissions. Variability in future levels of emissions in the BAU scenario is an important source of uncertainty in estimating the costs of alternative reduction scenarios. Indeed, the emissions commitments agreed at Kyoto are expressed in levels (as given percentage reductions relative to the 1990 levels), so the costs of meeting these targets will depend crucially on the BAU emissions path specific to each country.

11. Another source of uncertainty relates to the link between annual emissions of CO_2 and its atmospheric concentration, an issue which was not addressed in the Economics Department work on climate change. Concentrations of CO_2 are important as they, rather than emissions, drive climate change. Concentration is now at 360 parts per million by volume (ppmv), 30 per cent above its pre-industrial level. The link between CO_2 flows and stocks is not fully understood at this stage, in particular with regard to CO_2 sinks and interactions with other gases[3]. Despite these uncertainties, models project that emission

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1. A similar exercise was conducted by the IPCC, the results of which are reported in IPCC (1996).

2. Since 1990, emissions have grown by almost 5 per cent per year in Indonesia, 3.5 per cent in China and India and 2.6 per cent in Brazil. According with the International Energy Agency, world emissions currently grow by 2 per cent per year.

3. Sinks refer to the processes by which CO_2 is removed from the atmosphere and stored in vegetation, soils and oceans.

growth rates in the range of 1 to 2 per cent a year could lead to a concentration of CO_2 of twice its pre-industrial level by 2050 (IPCC, 1996).

12. The models studied in the OECD project agree that emissions will grow much faster in developing than in developed countries (Dean and Hoeller, 1992; Hoeller *et al.*, 1992), owing to faster rates of output growth and industrialisation. Figure 1 illustrates the changing structure of world emissions, as projected by the OECD GREEN model. (See Box 3 for a description of GREEN.) By 2050 emissions from OECD countries, which currently represent almost half of world emissions, would account for only 25 per cent of world emissions, whereas developing countries would account for around 60 per cent[4]. Most of these emissions would come from coal-consuming countries with large populations, such as China and India. By 2050 even more than now, world emissions of CO_2 would be concentrated among a relatively small number of major emitters.

[Figure 1. Annual CO_2 emissions in the GREEN baseline scenario]

2.2 Emissions reduction scenarios

2.2.1 Quantification of costs

13. The first scenario that was considered in the OECD model comparison project was a hypothetical one in which every country/region agrees to apply specific carbon taxes in order to reduce the growth of its emissions by 1 per cent per year, compared with the BAU. This scenario would stabilise OECD emissions at their 1990 levels, but those of developing countries would continue to grow. Thus, world emissions would continue to grow, by 0.5 to 1 per cent per year depending on underlying assumptions about economic growth and autonomous energy efficiency. Since the same CO_2 reduction effort was assumed for every country/region irrespective of its emissions growth rate in the BAU scenario, this scenario highlights the differences in marginal costs of emissions abatements across countries/regions.

14. Figure 2 shows the levels of carbon taxes needed to achieve the assumed reductions in emissions. Up to 2020, taxes ranging from \$50 to \$125 per ton of carbon would be required in OECD countries. After 2020, taxes tend to diverge widely across models and countries/regions; taxes needed in some countries/regions are two or three times higher than in others. In general, taxes would be lower in the former Soviet Union and China. In some models, especially CRTM (Rutherford, 1992) and MR (Manne, 1992), there are wide fluctuations in carbon taxes over time, which reflect the depletion of oil and gas reserves and the phasing-in of alternative energy sources.

[Figure 2. Carbon taxes to reduce by 1 percentage point annual the growth of CO_2 emissions]

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4. These figures from GREEN are in line with recent simulation results from the Linkage model (OECD, 1997*c*), which suggest that the emissions share of OECD countries in 2020 would range from 42 per cent in the low-growth scenario to 35 per cent in the high-growth scenario. By this time, developing countries would account for 42 per cent of world emissions in the low-growth scenario and 49 per cent in the high-growth scenario.

Box 3. The OECD GREEN Model

The Secretariat developed a multi-country, multi-sector, dynamic applied general equilibrium model to quantify the economic costs of implementing policies to curb CO_2 emissions. The version discussed in this paper was used for the OECD Model Comparisons Project (Box 1). It has a medium-term focus and a 65-year time horizon from 1985 to 2050.

GREEN has a simple recursive dynamic structure, in which saving decisions affect future economic outcomes through the accumulation of productive capital. Capital accumulation is modelled in a putty/semi-putty fashion. Each production sector operates under constant return to scale and markets are perfectly competitive. Production and consumption are specified using systems of constant elasticity of substitution functions. Consumer utility functions are modelled as an extended linear expenditure system. For a description of the model specification , see Burniaux *et al.* (1992*b* and 1992*c*). See Lee *et al.* (1994) and Van der Mensbrugghe (1994) for an updated overview.

There are twelve detailed regional sub-models: four OECD regions (the United States, Japan, the European Union and other OECD) and eight non-OECD regions (the former Soviet Union, Eastern Europe, China, India, the energy-exporting LDCs, the Dynamic Asian Economies, Brazil and the "Rest-of-the-World"). Because of the global nature of the greenhouse gas problem, it was decided to pay specific attention to modelling some key non-OECD regions.

There are eleven production sectors, chosen to highlight the relationships between resource depletion, energy production, energy use and CO_2 emissions. Since the main source of anthropogenic CO_2 emissions arises from the burning of fossil fuels, the key focus is on the energy sector. Three sources of conventional fossil-fuel energy -- oil, natural gas and coal -- and one source of conventional non-fossil (so-called "carbon-free") energy are distinguished. The carbon-free energy source includes nuclear, solar and hydro power. Both carbon-based and carbon-free backstop technologies are available for all conventional energy sources at exogenously assumed costs and introduction dates.

The production side of each regional model describes in a detailed way the supply of fossil fuels and the use of fossil and non-fossil energy inputs in the productive process. Some allowance is made for shifts in the composition of production by treating agriculture as a separate sector, and by distinguishing between two broad aggregates, energy-intensive industries and other industries and services.

Consumer demand is split between four broad aggregates: food and beverages, fuel and power, transport and communication and other goods and services. Saving is treated implicitly as a "fifth good". Thus, shifts in energy prices affect the structure of consumer demands directly and the consumption/saving mix through changes in real income.

An updated version of GREEN has been made available and has been used, *inter alia,* by the Massachusetts Institute of Technology (MIT) and Columbia University of New York.

In the context of the Linkage II project, the GREEN model was updated, extended and renamed to LINKAGE. LINKAGE has a 1992 base year covering 15 regions and 26 sectors and uses the GTAP data base. LINKAGE was used to update the projections of carbon emissions through the year 2020 in both a high and low growth scenario (see OECD, 1997*c*).

15. A key element in the differences in taxes across countries and over time is the fact that different fossil fuels have different carbon contents. In particular, coal has a much higher carbon content than oil or gas. Thus, a given carbon reduction can be achieved with a lower tax if it applies on coal, which is high in carbon, rather than on oil and gas. *Ex post*, taxes correspond to the marginal cost of cutting emissions: this is lower in economies which consume coal intensively, such as Russia, China or India. However, marginal costs rise more than proportionally with the amount of carbon reduction as coal use diminishes and the burden shifts to fuels with a lower carbon content. In other words, initial cuts are relatively cheap, while more substantial cuts would eventually require very high carbon taxes. For instance, in the United States in 2100, the ERM model predicts a tax above $1 100 per ton of carbon. The taxes required would be limited if alternative, carbon-free energy sources (referred to as backstop technologies) become available. The existence of backstop technologies was assumed in all models under review except the ERM model.

16. The imposition of carbon taxes would reduce real income via the familiar dead-weight burden of a tax. By generating substitutions in demand and supply, the tax yields a sub-optimal use of resources (in a limited sense, as no account is taken at this point of the benefits of lower emissions in terms of climate change). The associated real income loss reflects the sum of consumer and producer surplus losses. In turn, these losses affect economic growth through lower saving and capital accumulation. The reallocation of laid-off workers from energy-intensive industries may also generate additional transition costs, although these were not considered in the models under review. The economic costs associated with the assumed emissions reductions vary widely across countries/regions (Figure 3). The uncertainty of the cost estimates is reflected, to some extent, in the substantial variation of the results across models. Stabilising emissions in OECD countries would entail costs ranging from 0.6 to 1.7 per cent of GDP by 2050. The costs are higher in non-OECD countries: by 2050, they range from 1.2 to 2.3 per cent, depending on the model. Overall, the level of world GDP would be lower by 0.9 to 1.8 per cent in 2050[5].

[Figure 3. GDP losses associated with a 1 percentage point reduction of the growth of CO_2 emissions]

17. The costs also vary widely through time. In particular, costs could increase more rapidly over the second half of the next century as more than proportionate tax increases are needed to obtain further emissions reductions. As carbon-free energy sources are discovered and phased-in, costs may stabilise or even decline. On the other hand, in the absence of such technologies, taxes and aggregate costs could rise substantially. The ERM model -- the only one in the comparison project without a backstop -- suggests that a reduction of emissions growth of 1 per cent a year relative to BAU in the United States could cost up to 4½ per cent of GDP by 2100 (Figure 3).

18. The impact of a carbon tax differs dramatically across sectors. All studies show that coal production would be by far the hardest hit industry. According to a study by the US Congressional Budget Office (quoted in OECD, 1995*a*), a $100 per ton carbon tax applied in the United States would almost triple the price of coal and reduce coal demand by 13 per cent. Similarly, a world carbon tax of $100 per ton would cut world coal demand by 22 per cent (Skinner, 1994, quoted in OECD, 1995*a*). Results from the OECD GREEN model suggest even more dramatic effects: a unilateral stabilisation of emissions by OECD countries could halve the output of the coal industry (Oliveira-Martins *et al.*, 1992). In comparison, the effects on the oil and gas sectors are moderate or even positive, as energy demand

5. These estimates do not take into account the growth effect from a dynamic technology response to measures to reduce greenhouse gas emissions. Also, more recent studies yield a wider range of cost estimates than reported from the OECD project (Azar, 1996; Repetto and Austin, 1997).

shifts away from coal. Energy-intensive sectors, including iron and steel, non-ferrous metals, paper and pulp, and chemicals, would also be vulnerable to a carbon tax; and their output could fall by 2 to 3 per cent on average, according to GREEN.

2.3 Benefits of controlling emissions

19. The benefits of emission abatement are the costs of not doing it -- the damage caused by climate change. Climate change is expected to have an impact on a range of economic sectors, affect human health and influence national eco-systems. It is difficult to quantify possible damages associated with many of these expected impacts, and assessment of the benefits from a global agreement is thus very tentative at this stage. However, recent advances in the building of global climate models have improved estimates, including of the regional distribution of damage from global warming[6]. As mentioned, such assessments were not part of the OECD work on climate change.

20. Most estimates concern the damage caused by an atmospheric concentration of greenhouse gases that stabilises at twice its pre-industrial level. Estimated costs of this doubling of concentrations are in the order of 1.5 to 2 per cent of world GDP. In interpreting these estimates, it is important to realise that the abatement scenario described above would not stabilise the concentration, but would only slow its rate of increase: doubling of the concentration would occur about ten years later. If the concentration of greenhouse gases does not stabilise, temperatures may continue to rise. Projections with a longer term emphasis point to GDP losses of 6 per cent of world GDP or more for a 10 C° warming by 2275 (IPCC, 1996, p. 205; Cline, 1992).

21. The distribution of damage is very uneven across regions of the world (Table 1). Africa and south-east Asia could lose up to 9 per cent of their GDP. Other countries/regions -- for instance, Canada, eastern Europe and the former Soviet Union -- could actually gain slightly from climate change. Overall, climate change would adversely affect developing countries more than developed ones. Damage would also vary by region within large countries.

[Table 1. Annual damages associated with a doubling of CO_2-equivalent concentration]

22. Most studies of the sectoral distribution of damage concern the United States. They report that the major damage categories include agriculture, forest loss, sea level rise and water supply (OECD, 1995*a*). Some sectors would gain: for instance, the demand for electricity should increase. Little has been done so far on health impacts, although any effects are likely to be spread fairly widely. However, accounting for all these effects in a consistent economic framework is still problematic.

23. As mentioned above, these damage estimates do not correspond to the benefits of reductions in emissions of the sort envisaged in the simulations reported from the OECD comparison project or agreed in Kyoto. Indeed, if Annex I countries stabilised their emissions, the projected growth of world emissions would fall only by a ½ of 1 per cent annually and, as a result, the point at which concentrations would reach twice pre-industrial levels would be delayed by no more than a decade. This has two implications. First, the costs of emissions controls described above should be set against the benefits of delaying, rather than arresting, the increase in greenhouse gas concentrations. Second, a doubling of the CO_2 concentration relative to pre-industrial level would seem nearly impossible to avoid.

6. The third IPCC report, to be published in 2000, will focus on the regional distribution of damages from climate change. A preliminary confidential version of this report is already available.

24. In fact, avoiding a doubling of pre-industrial concentration would require much larger emission reductions than imposed in the comparison project or agreed at Kyoto. In addition, time lags imply that concentrations will continue to rise even if total emissions start to fall. Thus, in practice, stabilising concentrations would require an eventual stabilisation of emissions world-wide at a level much below current levels, which cannot be achieved without the involvement of developing countries. Such an objective would be much more costly for developing countries than for developed ones because they have a larger prospective growth in emissions. For instance, GDP losses associated with stabilising emissions at their 1990 levels, estimated with the OECD GREEN model, are shown in Figure 4. While they amount to only 0.5 per cent of GDP in 2050 in OECD countries, they could exceed 5 per cent in some developing countries. The countries/regions most affected are likely to be: *i)* the oil-producing countries, which face a deterioration of their terms of trade; *ii)* developing countries whose industrial development is based mainly on coal (such as India and China); *iii)* countries with a rather high economic growth and relatively low carbon intensity (such as Brazil), since their marginal cost of abatement would increasing rapidly.

[Figure 4. GDP losses associated with the stabilisation of CO_2 emissions at their 1990 levels in the OECD GREEN model]

3. Basic principles to moderate the costs of reducing emissions

3.1 Taking advantage of no regret policies

25. A number of measures and policy reforms may improve the overall economic efficiency while also reducing greenhouse gas emissions. These measures are often described as "no-regrets" policies because they provide economic benefits beyond reducing emissions or are less costly than current practices, even without taking into account the benefit of greenhouse gas reduction.

3.1.1 Role of pre-existing distortions on energy markets

26. The clearest case for "no-regrets" measures is reform of energy subsidies. Removing these subsidies for fossil-fuel consuming activities would reduce emissions by raising the cost of energy. But abstracting from the consequences for climate change, it would eliminate the dead-weight losses associated with these subsidies and lead to greater real income. Energy is still subsidised in many, especially developing, countries. Larsen and Shah (1992) estimate that subsidies to consumption of primary fossil fuels amounted to $230 billion around 1990, equivalent to a carbon subsidy of $40 per ton. Gas was the most subsidised energy source around the world, at a rate of 32 per cent on average, compared with 17 per cent for coal (Burniaux *et al.,* 1992*a*), and the former Soviet Union accounted for the bulk of gas subsidies. Fossil fuels also receive indirect support from subsidised electricity generation. In developing countries, electricity prices were, on average, 30 per cent below long-run marginal costs (World Bank 1990, 1992, quoted in IPCC, 1996).

27. The OECD GREEN model was used to simulate how much emissions could be abated if all existing energy price distortions were eliminated. The results indicate that emissions would be lower by 18 per cent in 2050 compared with the BAU level[7], and world real income would increase by 0.7 per cent. However, transition costs -- for instance, many workers in energy-intensive industries will be displaced -- may reduce this "no-regrets" potential. To some extent, these estimates may be already out of date. In particular, reforms in Russia, the central European countries and China have already contributed to closing

7. Larsen and Shah (1992) estimate somewhat lower abatements of 4 to 5 per cent.

the gap in those countries between domestic and world energy prices. Michaelis (1996) contains a number of country case studies which show that removing coal producer grants and price supports offer a large potential for greenhouse gas mitigation, of the order of hundreds of millions of tons of CO_2 per year by 2020. In contrast, removing electricity subsidies yields a much smaller impact on emissions. Case studies, however, fail to provide a consistent estimate of the associated economic gains, and an updated estimate of existing distortions on energy markets needs to be done in order to reassess their "no-regrets" potential.

28. Another way of thinking about carbon taxes is that they offset existing subsidies. As a result, given that the subsidies would anyway have remained in place, the net cost of such taxes is lower than estimates that do not take account of these existing distortions suggest (Box 4). Simulation of GREEN (Burniaux *et al.*, 1992*a*) suggest that, taking this offset into account, the cost of stabilising emissions would be cut by half.

29. Finally, emission reductions could be achieved if the structure of existing energy taxes better reflected the carbon content of the fuels. Hoeller and Coppel (1992) estimate the implicit carbon taxes prevailing in OECD countries, concluding that oil and gas typically face high implicit carbon taxes while coal receives subsidies. "Rebalancing" existing taxes according to the carbon content of each fossil fuel would reduce OECD emissions by 12 per cent. (This reduction would occur in any case as the replacement of existing energy taxes by the equivalent implicit carbon tax narrowed the dispersion of tax rates across different fossil fuels.) It would also lower the economic cost associated with existing energy taxes from 0.4 to 0.1 per cent of GDP.

30. The importance of existing distortions suggests that reforming, and preferably eliminating, coal and electricity subsidies should be given a high priority. This priority is recognised in the Kyoto Protocol which specifies that Parties will progressively remove taxes and subsidies in achieving their reduction commitments (Article 2).

3.1.2 Technological improvements

31. A number of technologies to raise energy efficiency are already commercially available: improvements in insulation, refrigeration and lighting control; the use of electric vehicles; increased use of public transportation and telecommuting; and reduced vehicle weight. Other options involve substituting fuels with a lower carbon content for coal, oil and gas. Nuclear energy may provide a solution, but concerns about safety, waste disposal and military uses of nuclear material, by lowering investors' confidence, makes its future profitability uncertain. Finally, a number of renewable energy sources are available, but their market potential is limited by their current cost (IEA, 1997). Moreover, some renewable energies may only be able to provide energy intermittently, and so will not be able to substitute exactly for conventional energy sources. Biomass may provide an alternative energy source which is potentially carbon neutral although it could divert substantial land areas from food production, a problem which may prove critical in many developing countries (Pilat, 1995)[8].

8. Biomass sequesters carbon when it grows but this carbon is released in the atmosphere when biomass is burnt. However, to the extent that burning biomass could generate electricity in a carbon-neutral way over a given period, it could reduce carbon emissions by replacing carbon-based fossil fuels.

Box 4. Accounting for Pre-existing Distortions in Assessing Costs of Carbon Taxes

Depending on their nature, pre-existing distortions -- taxes or subsidies -- interact with subsequently imposed carbon taxes in ways that can significantly change the welfare cost of emissions abatement. These interactions are illustrated in the Figure below. In the Figure, suppose P1 is the price needed to achieve an agreed emissions target, and P3 is the market price before the imposition of a carbon tax. Thus, a carbon tax of P1-P3 is needed to achieve the emissions target. In assessing the net welfare cost of imposing such a tax the interpretation of P3 is crucial. Three cases can be distinguished:

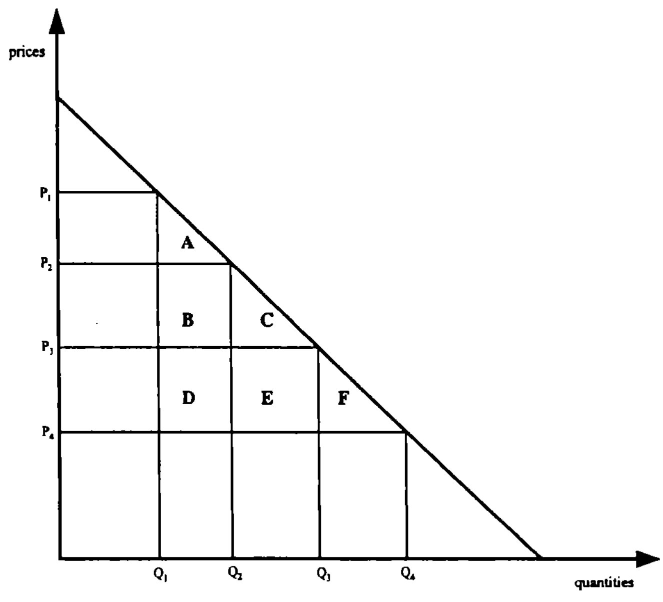
i) If P3 is interpreted as the price in an undistorted market (in the sense of no pre-existing taxes or subsidies) -- the usual assumption in the work done for the OECD comparison project -- then the net welfare cost of the carbon tax is the triangle (A+B+C).

ii) If there is a pre-existing tax equal to P3-P4, then P4 is the undistorted market price and the welfare cost of the pre-existing tax is the triangle F. The incremental welfare cost of the carbon tax is, in this case, equal to the sum of the triangle (A+B+C) and the rectangle (D+E).

iii) If there is a pre-existing subsidy equal to P2-P3, then P2 is the undistorted market price and the welfare cost of the pre-existing subsidy is the triangle C. The incremental welfare cost the carbon tax is, in this case, equal to the difference between triangles A and C.

Thus, the cost of the same carbon tax (P1-P3) will depend on whether the market is already taxed or subsidised, with the subsidy case having the lowest cost and the tax case having the highest. In case of a pre-existing subsidy, imposing a carbon tax could yield a welfare gain.

In fact, carbon is generally subsidised and if this is not taken into account the costs of imposing a carbon tax will be overestimated. Simulations using GREEN suggest that accounting for these subsidies reduces the estimated cost of stabilising greenhouse gas emissions in Annex I countries by about one-half.



Box 5. Top-down and Bottom-up Models

Two approaches have commonly been used to assess the costs and benefits of "no-regrets" policies. "Top-down" approaches, including GREEN, analyse aggregated behaviour from a macroeconomic point of view, focusing on energy-economy interactions by using price and income elasticities estimated over the past. They use an aggregate Autonomous Energy Efficiency Index (AEEI), which represents the set of technological options regarding improvements of energy efficiency. Again, the AEEI is often estimated using historical data. In general, they assume that production is technically efficient. Therefore, in such models any carbon reductions will incur a cost unless the AEEI is increased exogenously.

"Bottom up" approaches analyse policies from an engineering point of view. They describe the energy sector in a very detailed way and identify how existing and future alternative technologies to provide energy services can be combined to meet a given energy demand at least cost. Examples of "bottom up' models are the model of the US Environmental Protection Agency (US EPA, 1990) and Markal/Mensa (Intelligent Energy Systems, 1990). "Bottom up" models typically suggest a much larger "no regrets" potential than "bottom-down" approaches because apparently energy-efficient technologies are often not used in practice. From an economic, as opposed to a technological, point of view, this situation could be rationalised by assuming that market imperfections have inhibited the use of these technologies.

Different estimates of "no-regrets" potential between "top-down" and "bottom-up" approaches stem from the fact that they are asking different questions[1]. "Top-down" models assess the costs of reducing emissions given that, among other things, market imperfections embodied in econometrically estimated parameters remain unchanged. In contrast, "bottom-up" models assess which emission cuts could be achieved with existing and future technological alternatives given that the presumed barriers to their implementation are removed. Therefore, the latter provide a more optimistic assessment. However, they will tend to underestimate the costs of imposing carbon reductions if such market imperfections prove to be unimportant or insurmountable. Likewise, such models do not capture economy-wide feedbacks (general equilibrium effects) such as reduced investments in non-energy sectors, income effects entailed by increased energy efficiency and higher production costs; all of these could raise the cost of carbon abatement.

1. For a discussion of "top-down" versus "bottom-up" approaches, see, *inter alia*, OECD/IEA (1994).

32. The extent to which the implementation of these technological improvements is truly a "no-regrets" policy is a contentious issue. The critical question is whether the BAU scenario against which emission reduction scenarios are compared is characterised by the use of economically efficient production techniques or not. On the one hand, it could be argued that available technologies would already have been largely adopted if they were truly superior. Analysts using macroeconomic "top-down" approaches (including models like GREEN) assume in effect that any cost-effective emission reduction is already embodied in the BAU scenario so that there is no scope for "no-regrets" policies in this area. Alternatively, it can be argued that various market failures -- inadequate information, principal-agent problems or capital-market imperfections -- inhibit the adoption of these technologies. Engineering studies (often referred to as "bottom-up" approaches; see Box 5) often argue that such technologies can be implemented at very low cost and that policy can correct market failures (IPCC, 1996). One consequence of this different implicit point of view, is that "bottom-up" approaches tend to yield lower abatement costs than "top-down" approaches. For instance, Johansson and Swisher (1994) suggest that reductions of CO_2 emissions of up to 30 per cent can be achieved at essentially no cost by implementing known energy efficiency measures.

3.2 Equalising the marginal cost of carbon abatements across participants

33. As already noted, the marginal cost of greenhouse gas abatement differs widely across countries/regions (Figure 2). Therefore, a given reduction in emissions could be achieved at a lower aggregate cost if countries/regions with lower marginal costs abate more than those with higher costs. In particular, the equi-proportionate emission cuts embodied in the scenario discussed above is a costly way to curb emissions. In principle, marginal abatement costs would be equalised if all participating countries/regions imposed the same carbon tax (which would have to be high enough to achieve the desired aggregate emissions objective). The amount of cost saving relative to a system of equi-proportionate cuts depends on the extent to which marginal abatement costs differ *ex ante*. The same reasoning implies that marginal costs should be equalised across firms within a country, and across plants within a firm. In this regard, a system of tradable emissions permits with a single price for all countries/regions, firms and plants would be equivalent to a uniform carbon tax.

34. To estimate the benefits of marginal-cost equalisation over equi-proportinate cuts, three of the models in the OECD comparison project simulated emissions-permits trading in a scenario in which the growth of world emissions is reduced by 2 percentage point from the BAU. The results are reported in Table 2 and Box 6. All three models point to cost savings relative to the equi-proportionate reduction scenario. The OECD GREEN model reports the largest gain: in 2020, trading emissions would almost halve the aggregate cost. The cost saving is lower in the other models and tends to decline over the longer term. The estimated cost savings reflect the dispersion of the carbon taxes in the no-trade case; it depends *inter alia* on the existence of pre-existing price distortions on energy markets (energy taxes and subsidies) and on the pace at which backstop technologies come into play.

[Table 2. Cost saving from emission trading]

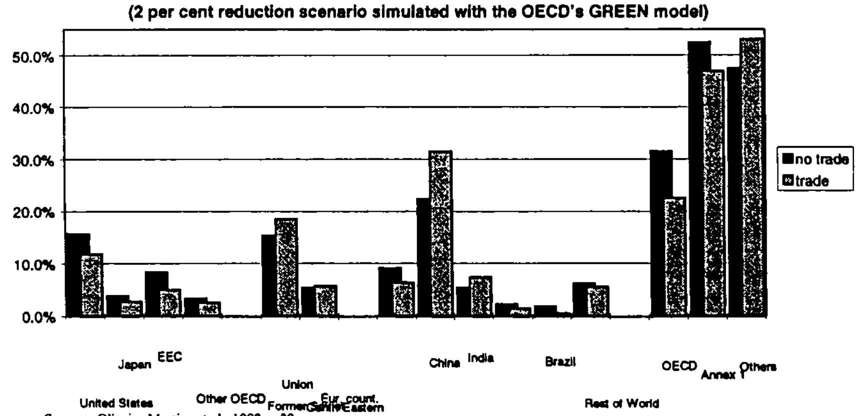
35. Taxes other than on carbon could be used to reduce CO_2 emissions. For instance, the European Union proposed earlier a mixed carbon/energy tax which would tax the energy content of primary energy sources. However, as a corollary to the principle of equalising marginal costs, a tax partly based on energy content would not minimise costs because it relates to energy use rather than to any externality associated with carbon. Although such a tax would stimulate energy efficiency investment (as would a carbon tax), it would also have the adverse effect of discouraging the substitution of low-carbon energy sources for high-carbon energy sources, blunting its effect on carbon emissions.

Box 6. Impact of Permits Trading on Emissions Reductions, GDP and Real Income

Permit trading has complex distributional implications, which are illustrated by the following scenario developed by OECD GREEN model (Oliveira-Martins *et al.,* 1992). Each country/region is assumed to receive a number of permits proportionate to their share of emissions in the BAU scenario, with the sum of the permits implying a reduction of the growth of world emissions by 2 per cent compared with the BAU. Each country/region is free to buy or sell permits. The impact of permit trading is assessed by comparing this scenario with the outcome of a counterfactual scenario in which there is no permit trading, implying that each country/region uses its entire permit allotment and, therefore, reduces its emission growth by 2 per cent relative to the BAU.

Permit trade: For countries/regions with a higher marginal abatement cost, it is more profitable to buy permits than to cut emissions. Therefore, these countries reduce emissions by less than their initial allotment. OECD countries act as major buyers and, accordingly, their contribution to abatement falls from 32 to 22 per cent of the total (Figure 6.1). For countries/regions with lower marginal abatement cost, it is profitable to sell permits as long as their price exceeds the cost of cutting emissions. Therefore, these countries achieve higher reductions than in the no-trade case. Selling countries include the large coal consumers: China, India and the former Soviet-Union. Permit trading increases the contribution of developing countries from 48 per cent of the total emission cut in the no-trade case to 53 per cent. By 2050, China alone could sell around $200 billion (1995 dollars) worth of permits and contribute 32 per cent of the total emission reduction (against 22 per cent in the no-trade case). Emissions trade would amount to 9 per cent of the total amount of emissions reduction.

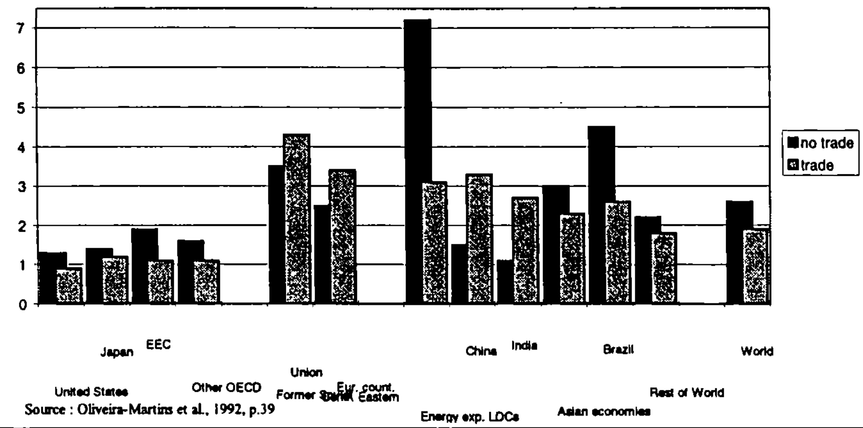
Figure 6.1 : Distribution of emissions reductions without and with tradeable permits
(2 per cent reduction scenario simulated with the OECD's GREEN model)



Source : Oliveira-Martins et al., 1992, p.39

Effect on GDP: The pattern of GDP losses reflects the reallocation of emissions reductions across countries/regions. Countries/regions which buy permits (OECD countries, Asian economies, Brazil) incur lower GDP losses than in the no-trade scenario. Selling countries/regions (China, India and the former Soviet Union) have higher GDP losses due to more stringent limits on their emissions. For the world, trading permits reduces the total GDP loss by roughly one-third. Permits trading results in the burden of carbon taxation shifting from oil and gas to coal. Thus, oil-exporting countries come out as main gainers from permits trading as their GDP losses are more than cut in half.

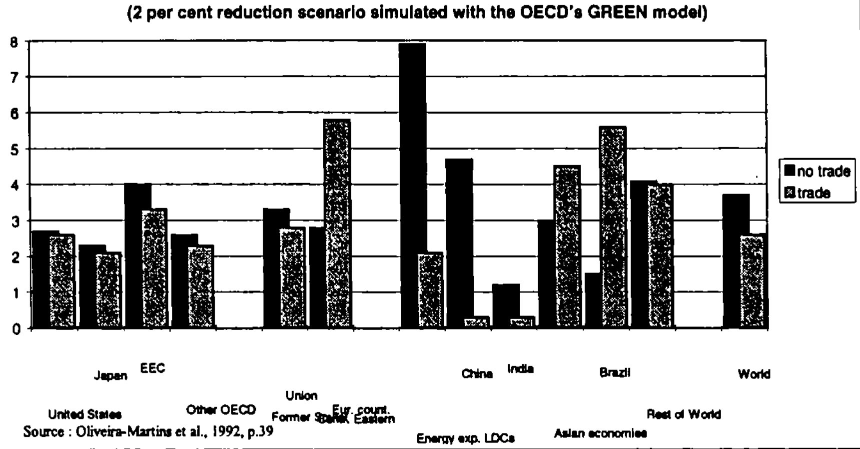
Figure 6.2 : GDP losses without and with tradeable permits
(2 per cent reduction scenario simulated with the OECD's GREEN model)



Source : Oliveira-Martins et al., 1992, p.39

Effect on real income: The distribution of real income reveals a different pattern of gainers and losers, reflecting mainly the transfers associated with permit trading. OECD countries gain less in income than in GDP because part of their efficiency gain serves to pay for the permits. In contrast, some permits sellers (China and India) get large benefits from a trading system because the proceeds from permits sales almost exactly offset their abatement costs. Oil-exporting countries would gain even more in terms of real income as the international oil price is higher than in the no-trade scenario. However, some semi-industrialised countries (Asian economies, Brazil) face a deterioration of their terms of trade both because they have to buy permits and they pay a higher price for oil imports.

Figure 6.3 : Real income losses without and with tradeable permits
(2 per cent reduction scenario simulated with the OECD's GREEN model)



Source : Oliveira-Martins et al., 1992, p.39

3.3 Stabilising atmospheric concentrations of CO_2 will require global participation

36. Industrialised countries alone are unable to stabilise world-wide emissions of greenhouse gases. The OECD GREEN model was used to simulate the impact on concentration of a stabilisation of emissions in Annex I countries. As noted above, even if this target were met, CO_2 concentrations in the atmosphere would keep rising, the share of Annex I countries in total emissions would decline, and this decline would be accentuated if only industrialised countries put policies in place to curb emissions. In addition, the effectiveness of an unilateral action by industrialised countries alone could possibly be reduced by "carbon leakage" effects. This effect arises because, in principle, carbon abatement in industrialised countries alone should increase the comparative advantage of other countries in the production of energy-intensive goods and the production in these sectors would shift to escape the abatement measures. In addition, as energy demand falls in industrialised countries, world energy prices will decline, stimulating demand in other countries.

37. The amount of carbon leakage depends on a number of key supply and substitution elasticities. Capital mobility is also a factor, though it has not been analysed in depth[9]. As a result, estimates of the amount of carbon leakage differ considerably across models (OECD, 1995*b*). The results of the OECD GREEN model indicate only small leakages, less than 5 per cent of the emission reduction achieved by Annex I countries. However, a different model, 12RT (Manne and Oliveira-Martins, 1994), yields a leakage of up to 35 per cent of the initial emission cut, which reflects the assumption in that model that a large fraction of tradable goods is homogeneous[10]. Although Burniaux and Oliveira-Martins (1994) show that the supply elasticities of fossil fuels may be more influential than the substitution elasticities, the amount of leakage depends on the value of the substitution elasticities between goods originating from different countries. On this ground, the leakage effect should be rather small because econometric evidence suggests that these elasticities are low (Barker and Johnstone, 1997; Baron and ECON, 1997). Overall, the magnitude of carbon leakages, and thus the extent to which they might reduce the effectiveness of a unilateral action by industrialised countries, remains an open question.

38. In any event, the scope for leakages is reduced as more countries participate in an abatement agreement. Results from the GREEN model show that the costs of a given carbon reduction can be lowered substantially by widening the geographical coverage of the agreement. For instance, extending the country coverage of a given emissions reduction from OECD to Annex I countries could reduce the overall cost by more than half (Table 3). Moreover, all participating countries/regions would be better off under this extended coalition (referred to as the Annex I coalition in Table 3) than under the OECD coalition. Widening the coalition further (the global coalition in Table 3) reduces the costs, mainly in Annex I countries, but at the expense of some developing countries (China, India and rest of the world). That is, cost savings arise via an increased flexibility to shift abatements to low-cost countries but in the absence of compensation the real income losses incurred by these countries is larger than if they did not participate at all.

[Table 3. Average real income losses with different geographical coverage]

9. Hanslow *et al.* (1995) report rather low leakages (3.8 per cent) but, when international capital mobility is allowed in a dynamic version of their model, leakage rates are much higher. On the other hand, the G.Cubed model (McKibbin *et al.*, 1997), which incorporates fully specified international capital markets, still shows moderate leakage rates.

10. Another model with homogeneous goods, by Whalley and Wigle, also suggests very high leakage rates of up to 80 per cent (Pezzey, 1992), although these have been questioned by Babiker *et al.* (1997).

3.4 Choosing the optimal time path of emissions reductions may lower the aggregate costs

39. Costs of meeting emissions goals also depend on the distribution of reductions through time. Abatement costs will probably fall over time because abatement technology will improve and alternative low-carbon sources of energy will become available or less costly. Phasing in abatement could also reduce cost by allowing natural depreciation of existing equipment. Therefore, it may be argued that it is less costly to time further abatement carefully and to concentrate critical efforts on "no-regret" policies. Credible pre-announcement of future abatement measures is required, however, if investors are to properly anticipate the effects of abatement programmes and adjust their investment and production strategies.

40. On the other hand, a number of arguments can be made in favour of early, but moderate abatement. Delaying action would increase the carbon concentration, all else equal. This may result in damage in the form of climate change that is high and irreversible; the lifetime of carbon in the atmosphere is in the range of 50 to 100 years. Early reductions may therefore be justified as risk management. The possibility of unexpected and catastrophic consequences from global warming adds weight to this argument. Finally, the announcement of a slower abatement policy may not prove credible, in which case some of the benefits of that policy would not be realised and concrete action would be required to ensure adjustment in capital and technology.

41. Models have been used to assess the costs of alternative paths of emission reductions (OECD, 1995*b*). These estimates, like others reported in this paper, are subject to great uncertainty. Simulations made by Richels and Edmonds (1993) indicate that one possible low-cost scenario could be along the following lines: emissions are allowed to rise along the BAU trajectory until about 2010, are gradually reduced between 2010 and 2050, and are sharply reduced thereafter. Their results also show that the scenario in which emissions are stabilised early at their 1990 levels entails the highest costs. Since the time horizon is extremely long and mitigation costs tend to come earlier than the benefits, the choice of an appropriate discount rate is critical (Lee, 1995)[11]. Given the substantial uncertainties involved, the degree of risk aversion is also important.

3.5 Recycling tax revenues

42. Carbon taxes would generate additional revenues to government, as would tradable emission permits if they were initially auctioned by governments. Existing estimates suggest that these revenues could be significant. For instance, the mixed carbon/energy tax which was proposed by the European Commission might have yielded revenue of 1 to 2 per cent of GDP (Smith, 1994, quoted in OECD, 1994). A moderate tax of $50 per ton of carbon applied to OECD countries might have raised about $150 billion in 1990 (OECD, 1995*b*).

43. These revenues could, in theory, be used in a wide variety of ways. However, results from model simulations suggest that the costs of imposing carbon taxes could be lowered substantially if investment and corporate income taxes were cut, rather than payroll or personal income taxes (IPCC, 1996). Jorgenson and Wilcoxen (1994) found that GDP could actually increase if carbon-tax revenues were used to lower taxes on capital income. On the other hand, the overall effect on employment of

11. It should be noted that some analysts argue that the appropriate discount rate to be used for climate change policy should be the "social rate of time preference" which discounts the consumption of different generations and ranges between 0.5 and 3 per cent per year. However, using another discount rate, such as the market returns to investment (3-6 per cent per year) would yield a different least-cost path.

carbon taxation and associated tax reductions elsewhere is not clear (OECD, 1995*b*). For example, reductions in the social security contributions for low paid workers might lower unemployment. Such results may reflect largely assumptions embodied in the models regarding, for example, the relative distortionary effect of different taxes.

4. Carbon taxes versus tradable emissions permits

44. As already mentioned, minimising the cost of reaching a global CO_2 emissions target would imply equalising marginal costs of abatement. Market-based instruments -- uniform carbon taxes and tradable permits -- are thus less costly than regulatory measures because they allow private agents to meet abatement goals in the least-cost way. A uniform carbon tax could be implemented by a treaty in which all participating countries agree to levy the same domestic carbon tax, the so-called "harmonised domestic carbon tax", and, perhaps, to redistribute part of the revenues from this domestic tax to other countries according to an allocation rule[12]. Alternatively, a treaty based on tradable permits would specify the total amount of permits (related to agreed emissions targets) and the initial distribution of permits. Transfers across participating countries would then be determined endogenously as a result of permits sales and purchases. An international permit market could coexist with domestic markets or some countries may apply taxes regulations to ensure that their national permit holdings are not exceeded (Mullins and Baron, 1997). Individual firms could be allowed to trade permits internationally. In this sense, both options -- a uniform carbon tax or a tradable permit system -- can be applied together with complementary measures to mitigate the distributional impacts of carbon abatements in the shorter term, and such systems could be extended to include carbon sinks as well (IPCC, 1996).

45. This symmetry between a uniform tax and a permits system is valid only under the restrictive assumptions on which most models are based: i.e. that markets are perfectly competitive, operate under certainty and with no transaction costs. However, under more realistic conditions, there is no longer symmetry between uniform carbon taxes and tradable permit systems.

4.1 Dealing with uncertainty and risk

46. Using a carbon tax, the amount of emissions reduction depends on the underlying costs incurred, and thus the decisions made, by individual agents. As the taxing authority does not know these costs with certainty, the outcome may not correspond to the desired emissions reduction and further tax adjustments may be needed. On the other hand, the marginal economic costs of the emissions reduction itself are relatively easy to assess -- they are just the tax rates. By contrast, limiting emissions through permits makes the level of abatement much more certain but introduces more uncertainty about the marginal economic costs of achieving the required abatement.

4.2 Experience with carbon/energy taxes

47. The focus of this section is restricted to taxes with an explicit purpose of reducing CO_2 emissions, as distinct from energy taxes more generally[13]. Given this restriction, the experience in OECD countries appears very limited so far and is mainly in European countries. **Denmark** has applied a CO_2

12. An alternative option involves an international agency which applies a uniform tax all participants and redistributes the tax revenues.

13. This section is based on Baron (1996). See also OECD (1992*b*) and Haugland (1993).

tax on energy consumption since 1993. In 1996, a new tax scheme was implemented with differentiated rates across sectors, from \$3 per ton of CO_2 in heavy industry to \$89 per ton for heating. **Finland** applies a mixed carbon/energy tax on all primary energy sources, the carbon component of which is equivalent to \$25 per ton. Since 1988, the **Netherlands** has had two carbon/energy taxes: the environmental tax roughly corresponds to \$3 per barrel of oil equivalent (half on energy and half on carbon content); the energy regulatory tax, introduced in 1996, applies to gas and electricity use of small consumers (households and companies). **Norway** has applied a tax since 1991 which ranges from \$61 per ton of carbon for petroleum and coke to \$200 per ton of carbon for gasoline and gas. The Norwegian tax covers about 60 per cent of all emissions. Finally, **Sweden** introduced a carbon tax in 1990 which has been increased regularly, together with frequent reductions of previously existing energy taxes.

48. Distributional, as distinct from efficiency, concerns have clearly had a significant weight in the design of these carbon taxes. First, not all countries have adopted a tax based on carbon content only. The mixed carbon/energy taxes applied in some countries, although less cost-effective in terms of carbon abatement, spread the costs on a wider range of producers[14]. Second, all existing schemes have many exemptions, often concerning electricity, heavy industries and companies with high energy intensity or operating on competitive international markets. These exemptions have shifted the burden of the tax onto final consumers and households. The fact that most countries have implemented differentiated taxes across sectors and users is an important departure from the principle of a uniform tax. Governments have also attempted to increase the political acceptability of carbon/energy taxes by reducing other taxes or existing energy taxes.

49. Related to political acceptability is the issue of where the tax should be applied. A number of arguments suggest that the carbon tax should be levied as far "upstream" as possible (the mine for coal, the well-head for crude oil or gas, and so forth). This would ensure that the tax percolates through the economy, and would lower administrative costs. However, to be effective in energy-importing countries, a carbon tax applied on national energy producers has to be accompanied by equivalent taxation of imports, which can be complex. Also, in practice, the ability to tax upstream has been limited by the existing structure of energy contracts, as some producers argue that they are unable to pass the tax on in their prices. Shifting the tax downstream makes it more feasible to exempt some industries or companies from its effect (see the experience with the US BTU tax, reported by Baron, 1996). Therefore, the perceived distributional effect of such taxes has played an important role in their acceptability.

50. A common carbon tax applied to all Annex I countries may help to allay concerns related to "international competitiveness". However, as trade patterns and existing taxation differ across Annex I countries, changes in competitiveness would not be similar for all of them anyway. In addition, any common carbon tax would have to deal with the same implementation issues that have been experienced at the national level (Baron, 1996).

4.3 Experience with tradable permits

51. Experience so far with tradable permits is mainly restricted to the United States and largely concerns problems where the location of the pollution source matters[15]. Although *a priori* tradable

14. The EU proposal to reduce emissions provided another example of a mixed carbon/energy tax. It suggested the introduction of a tax based half on the energy content and the carbon dioxide content of all energy sources. Such a tax design would tend to shift the tax burden from coal to carbon-free energy sources (nuclear).

15. For a review of existing permits systems see OECD (1992*c*) and Mullins and Baron (1997).

permits ought to be particularly well suited to global problems, where the location of emission is unimportant, it is not certain to what extent the US experience is relevant for global warming. There is very little experience in international permits trading.

52. The US experience ranges from failure to success. Water effluent permits were disappointing, with very little trade taking place (OECD, 1997*b*). Within the context of the 1997 Clean Water Act, local permit trading was allowed between plants which discharged wastes that increased biological oxygen demand (Fox River, Wisconsin), phosphorous (Dillon Reservoir, Colorado) or nutrients causing eutrophication (Tar-Pamlico River, Colorado). The failure of these schemes has been attributed to trading restrictions, administrative requirements (each trade needed government approval), the lack of economic incentives and the oligopolistic nature of the dischargers. On the other hand, the US sulphur dioxide (SO_2) allowances programme, started in 1995, has resulted in a substantial volume of transactions. This is a tradable permit system with a national emissions cap aimed at cutting sulphur dioxide emissions by 9.07 million tons in 2000, a 40 per cent reduction from 1980 levels. The Phase I concerned 110 coal-burning plants in eastern and midwestern states. Phase II, beginning in 2000, will extend the programme to all US plants. Allowances are allocated on a "grandfathering" basis, can be traded without restriction and can be "banked" for future use[16]. A guiding principle in the design of this programme was to minimise the role of government (no government approval is needed to trade). Transaction costs have been low and substantial trading have taken place, both between and within companies. Between these two cases, the "Emission Reduction Credits" (ERCs) programme reveals a mixed outcome. It is a nation-wide programme set up in 1990 as part of the Clean Air Act and covering hydrocarbons, NO_x, particulates, SO_x and CO. Analysis shows that cost savings have been lower than expected and achieved mainly from internal trading (between plants of a company), which suggests that significant transaction costs have arisen when firms trade with each together (IPCC, 1996, p. 423; OECD, 1997*b*, p. 59; Mullins and Baron, 1997, p. 42). Factors limiting the efficiency of the ERC market have involved the difficulty of identifying suitable trading partners, the need to obtain bureaucratic approval for trades (which took between five and twelve months), the uncertainty of the approval process (40 per cent of trade proposals were rejected) and frequent amendments to the detailed regulations governing the market.

53. The national experience of the United States suggests that high transaction costs may adversely affect their performance and reduce efficiency gains. A number of elements are important to minimise these costs: clear rules for ownership rights and obligations; high regulatory certainty and low regulatory requirement (Mullins and Baron, 1997). Enforcing such a system requires a reliable monitoring of emissions, a compliance instrument which is legally-binding and enforceable and stable rules for permits trading. However, the system has to be flexible enough, without unnecessary restriction on who uses the permits, when and where they can be used.

4.4 Project-based joint implementation

54. The Kyoto Protocol makes provision for joint implementation projects under Article 6. These are bilateral agreements made between legal entities (private companies and public or non-governmental organisations) under the responsibilities of any Party included in Annex I. Any Party may transfer to or acquire from any other Party emission reduction units resulting from projects aimed at reducing emissions or enhancing the removal of CO_2 from the atmosphere. It is supplemented by Article 12 which provides for a similar mechanism (the Clean Development Mechanism) between Annex I and non-Annex I

16. Although this system operates without regard to the spatial distribution of emissions, it did not give rise to excessive concentration of emissions ("hot spots"); see OECD (1997*b*).

countries and by Article 16bis which allows trading of emissions among Annex I countries. Guidelines for the implementation of joint implementation projects, including for verification and reporting, will be elaborated thereafter. Reductions under these provisions are supplemental to domestic actions undertaken in order to meet the Kyoto commitments. Thus, joint implementation and the clean development mechanism would contribute to allocate emission reductions among Annex I countries and between Annex I and non-Annex I countries in a less costly way. A network of joint implementation programmes could, in principle, develop into an international tradable quota system once countries commit themselves to binding targets (which would in effect become their tradable quotas). Therefore, one potential merit of a mechanism like joint implementation is to facilitate immediate progress in abating emissions while providing the framework for the completion of a wider international agreement.

55. The GREEN model was used to simulate a mechanism similar to joint implementation in which transfers to developing countries were assumed to be tied to an improvement in energy efficiency. The results reveal that sizeable reductions of world emissions could be achieved without imposing an excessive burden on the real income of non-OECD countries participating in such an agreement (Burniaux *et al.*, 1995). However, experience to date with international projects, such as the ones specified under the joint implementation provision of the Kyoto Protocol, has been limited to small pilot projects (Mexico and Norway; Netherlands, Poland and India). A major problem with such schemes is that credits to the party that reduces emissions are made on the basis of an assessment of the emission reduction specific to a given investment and relative a the baseline. Such in assessment is highly uncertain and subject to a large deal of contention[17]. Here again, transaction costs are likely to be high unless investor confidence is reinforced by monitoring, information (clearinghouse, brokers, and the like) and indemnifying institutions. The development of joint implementation projects will require clear internationally agreed guidance; that is a set of rules that can be uniformly and consistently applied to all projects by all countries, firms or other participants. One conclusion of Dudek and Wiener (1996) is that acceptance of the policy innovation by the regulators themselves and clarification of property rights of all participants are critical to the success of joint implementation.

5. The trade-off between efficiency and equity

56. In addition to meeting environmental goals in an economically efficient manner, any international agreement will have to solve the contentious issue of who should pay for the needed abatements. Given the rule of equalising marginal abatement costs, the burden of abatement can be redistributed through the use of international transfers. Such transfers could be in terms of redistributing the revenues of a uniform carbon tax or in terms of initial endowments of tradable emissions permits.

57. The OECD has estimated the economic consequences of alternative redistributive schemes with its GREEN model. These estimates are based on the important assumption of complete separability between efficiency and equity (see Box 7). A number of basic principles could govern the decision of how the costs of curbing emissions should be distributed. An egalitarian approach would support the view that each human being should be entitled to the same amount of emissions. Alternatively, according to the equal-burden principle each country should share the cost in proportion to its GDP. The polluter-pays principle would suggest that the industrialised countries should bear most of the cost of stabilising climate in an early stage, since they now contribute most to the emissions. The developing world would contribute more and more in the longer run, although it can be argued that industrialised countries bear a

17. Parties to a joint implementation project have incentives to exaggerate the effectiveness of their investment.

historical responsibility for the past build-up of CO_2 in the atmosphere. Finally, countries could pay what they are willing to pay given the potential damage they face and how they value these damages, although this principle would be problematic because of free rider problems, lack of knowledge of marginal impacts and the inability of some countries or regions that may be most adversely affected by climate change (such as Africa) to pay.

58. It is important to note that equalising marginal costs across countries, by shifting the burden of abatement to low-income coal-consuming countries contradicts all such equity principles. This is illustrated by a scenario of a uniform carbon tax applied to major CO_2 emitters, described in Box 8. To meet such principles, a uniform tax would have to be augmented by inter-regional transfers or adequate amounts of tradable permits would have to be distributed to participating countries. Box 8 illustrates the real income impacts from various alternative formula used in allocating permits or redistributing tax revenues, as they were simulated with the OECD GREEN model (Coppel and Lee, 1995). Regional impacts on real income vary depending on which formula is used: for instance, for countries like China and India, impacts might range from a real income loss of 1.7 per cent to a gain of 4 per cent. Therefore, how abatement costs are allocated among participants may play a crucial role in obtaining wider support to curb emissions. Transfers associated with these alternative scenarios are huge: they range around \$270-\$300 billions (1995 dollars) per year. As a comparison, total net transfers of financial resources of net-debtor developing countries amounted to \$94 billions in 1995.

Box 7. Can Equity and Efficiency be Separated?

A key conclusion of the analysis reviewed in the main paper is that equalising the marginal cost of abatement across countries, industries, firms and plants is the least-cost solution. The logic is clear: if marginal costs are not equalised, then reducing abatement a bit in a high-cost country (or industry, and so forth) and raising it a bit in a low-cost one will reduce overall costs. Equalisation of marginal costs can, in principle, be implemented through a uniform carbon tax or through a system of tradable emission permits that has a uniform world price. Moreover, distributional considerations can, again in principle, be met by a system of side payments or, under a permit scheme, an initial allocation of permits. Since such measures do not affect marginal abatement costs, efficiency and equity are separate.

This rule does not, however, indicate what the tax should be or, alternatively, how many permits should be issued. That is, it does not determine the optimal level of abatement, which depends on both the costs and the benefits of abatement. (The benefits of abatement equal the costs of the effects of global warming in the absence of abatement.) In general, these should be equalised at the margin.

Climate change affects everyone, and in this sense greenhouse gas abatement can best be thought of as a public, or non-rivalrous, good: thus a given degree of abatement enters each person's (or each country's, if aggregation is allowed) utility function by the same amount. In this case, the so-called Samuelson rule states that the optimal provision is obtained when the marginal rate of transformation in production (the marginal cost of abatement relative to the marginal cost of producing other goods) equals the sum of the marginal rates of substitution (the marginal benefit of abatement relative to the marginal benefit of other goods). However, summing marginal rates of substitution implicitly or explicitly involves the comparison, or weighting, utilities across individuals (or countries). Thus, the optimal degree of abatement will depend on equity considerations. Nevertheless, and irrespective of the optimal degree of abatement, the rule that costs are minimised when marginal abatement costs are equalised remains valid, as does the associated proposition that this can be achieved by a uniform tax on greenhouse gas emissions.

Another way of looking at this problem, however, is to suppose that policy is to maximise a global social welfare function consisting of individual utility functions, each of which consumes the public good (i.e. abatement) in equal amounts. Because of its public-good nature, equalising marginal utilities, as weighted in the social welfare function, implies a system of differentiated taxes, rather than a uniform tax (Chichilnisky and Heal, 1994). But such an equalisation is arbitrary in the sense that it does not lead to a welfare optimum (Oliveira-Martins and Sturm, 1996).

How might such theoretical considerations affect an economic analysis of policies to deal with climate change? Public goods considerations introduce the significant complication of making interpersonal utility comparisons. On the other hand, cost-benefit analysis also involves implicit interpersonal utility comparisons when monetary values are assigned to the very disparate types of damages that might occur due to global warming. How might such utilities be judged? The outcome of actual climate change negotiations could be viewed as reflecting marginal utilities, at least on a national level and as transformed by political and policy processes. Thus, for example, the modest abatement targets agreed in Kyoto and the reluctance of developing countries to participate at all could be interpreted as reflecting the tastes of the countries involved. (It could also reflect judgements about the costs and benefits of abatement policies that differ from those presented here.) This revealed-preference perspective is not, however, fully satisfactory. Cost-benefit analysis is meant as a guide to the policy process, not an *ex post* ratification of it. In the absence of such an analysis, it is unclear to what extent decisions have been made on an informed basis.

Box 8. Alternative Schemes of Cost Redistribution

Redistribution of the costs of greenhouse gas abatement may be crucial to achieving international agreement and, in any case, is bound to figure prominently in negotiations of any such agreement. The figures in the Table are based on a scenario in which major emitters (Annex I countries plus China and India) cut their annual emission growth rate by 0.5 per cent on average (equivalent to the amount needed to stabilise emissions of Annex I countries). This is achieved by applying a uniform carbon tax or a system of tradable permits.

The first column reports the real income effects of a uniform carbon tax applied without any redistribution of the tax revenues, which is equivalent to a "harmonised tax" in which each participating country/region keeps its own tax revenues. Without redistribution, China and India would incur the largest real income losses. The central panel of the table compares alternative permit allocation rules. The redistributive rule, in which permit entitlements are in direct proportion to population and indirect proportion to GDP, favours poor populated countries, like China and India. At the other extreme, under the "grandfathering" rule, developing countries would lose even more than under the scenario with no redistribution. The former Soviet Union and Eastern European countries lose most under a mixed equity/efficiency rule which favours poor countries and energy-efficient countries at the expense of less populated countries with a low level of energy efficiency. Finally, OECD countries would lose less (as little as in the no-redistribution case) if permits were allocated following efficiency or "grandfathering" criteria. The right-hand panel shows the effects of two alternative schemes of redistributing part of the tax revenues of an international carbon tax fund.

Average real income changes when major emitters stabilise Annex I emissions under alternative allocation rules

		Tradable permits systems					International carbon tax fund	
	Uniform tax with no redistribution[1]	Tradable permits with redistributive alloc.[2]	Tradable permits with equity/efficiency alloc.[3]	Tradable permits with egalitarian alloc.[4]	Tradable permits with efficiency alloc.[5]	Tradable permits with grandfathering alloc.[6]	International carbon tax fund with redistribution[7]	International carbon tax fund with redistribution[8]
OECD	-0.25	-1.00	-0.80	-0.70	-0.30	-0.30	-0.69	-0.94
FSU + CEET	0.27	-2.05	-2.90	-0.70	-2.40	1.80	-2.27	0.30
China + India	-1.08	3.30	2.80	1.30	0.30	-1.60	2.03	1.95
Rest of World	0.06	0.04	0.05	0.07	0.09	0.07	0.04	0.05
Annex I	-0.20	-1.10	-1.00	-0.70	-0.50	-0.10	-0.84	-0.82
Major emitters	-0.35	-0.35	-0.35	-0.36	-0.36	-0.36	-0.35	-0.35
WORLD	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25

1. Each government perceives the revenues from the carbon tax.
2. Permits allocated in inverse proportion to country/region's GDP per capita scaled by population size.
3. Permits allocated in inverse proportion to country/region's fossil fuel consumption per capita.
4. Permits allocated in inverse proportion to country/region's population shares.
5. Permits allocated in inverse proportion to the ratio of CO_2 emissions to GDP scaled by population size.
6. Permits allocated on the basis of past country/region's emission shares.
7. 75 per cent of tax revenues are diverted and redistributed according to population size.
8. Same as 7 but only tax revenues from OECD countries are redistributed.

Source: Based on Coppel and Lee (1995).

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OECD WORK ON CLIMATE CHANGE: ECONOMIC THEORY AND POLICY IMPLEMENTATION

ANNEX 1: TABLES AND FIGURES

This is Annex 1 to "OECD Work on Climate Change: Economic Theory and Policy Implementation" [ECO/CPE/WP1(98)7].

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OECD WORK ON CLIMATE CHANGE: ECONOMIC THEORY AND POLICY IMPLEMENTATION

ANNEX 1. TABLES AND FIGURES

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Table 1. **Annual damages associated with a doubling of CO_2-equivalent concentration**

Percentage of GDP

Regions	Frankhauser (1995) (1)	Tol (1994) (2)	Mendelsohn (1994) (2)
OECD	**1.3**	**1.6**	
Canada			-0.6
Europe	1.4		
United States	1.3		0.3
Mexico			1.7
Non-OECD	1.6		2.7
Eastern Europe and former Soviet Union		-0.3	
Russia	0.7		-0.2
Centrally-planned Asia	4.7	5.2	
China			1.9
South and south-east Asia		8.6	
Thailand			1.3
Indonesia			0.6
Philippines			0.6
Africa		8.7	
Latin America		4.3	
Chile			2.9
Columbia			1.8
Middle East		4.1	
World	1.4	1.9	

1. As reported in IPCC (1955), Chapter 6, p. 205.
2. As reported in OECD (1995), p. 35.

Table 2. **Cost saving from emission trading**

Percentages

	Edmonds-Reilly Model (ERM)			OECD GREEN			Manne-Richels Global 2100 Model (MR)		
	GDP loss without trade [1]	GDP loss with trade [2]	% reduction of cost [2]/[1]	GDP loss without trade [1]	GDP loss with trade [2]	% reduction of cost [2]/[1]	GDP loss without trade [1]	GDP loss with trade [2]	% reduction of cost [2]/[1]
2020	1.9	1.6	-15.8	1.9	1.0	-47.4	n.a.	n.a.	n.a.
2050	3.7	3.3	-10.8	2.6	1.9	-26.9	n.a.	n.a.	n.a.
2100	5.7	-5.1	-10.5	n.a.	n.a.	n.a.	8.0	7.5	-6.3

Source: OECD (1993).

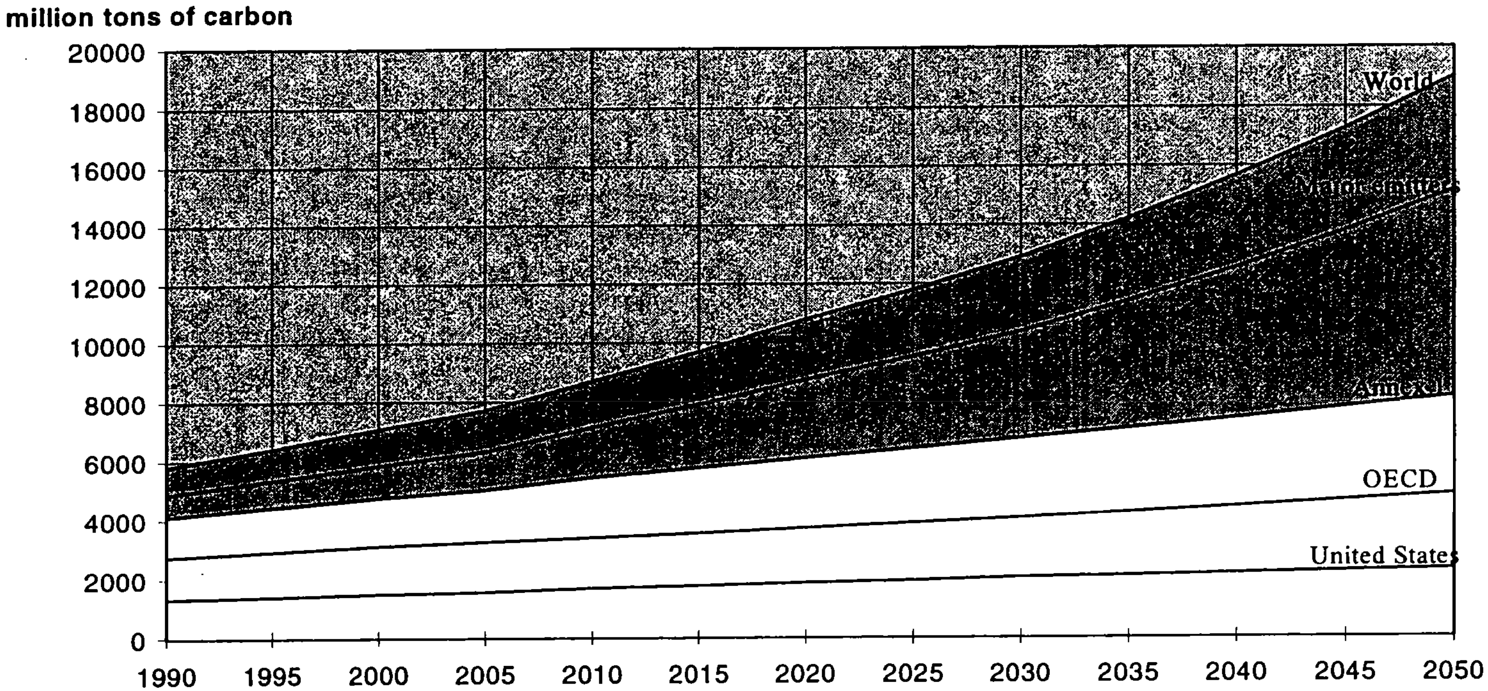
Table 3. **Average real income losses with different geographical coverage**

	OECD[1]	Annex I[2]	Global coalition[3]
OECD	**-0.76**	**-0.56**	**-0.15**
Eastern Europe and former Soviet Union	-0.94	-0.61	0.48
China and India	-0.35	0.17	-0.71
Energy-exporting countries	-3.32	-0.31	-0.18
Rest of the World	-0.40	0.14	-0.43
World	**-0.97**	**-0.36**	**-0.22**

Source: OECD (1995).

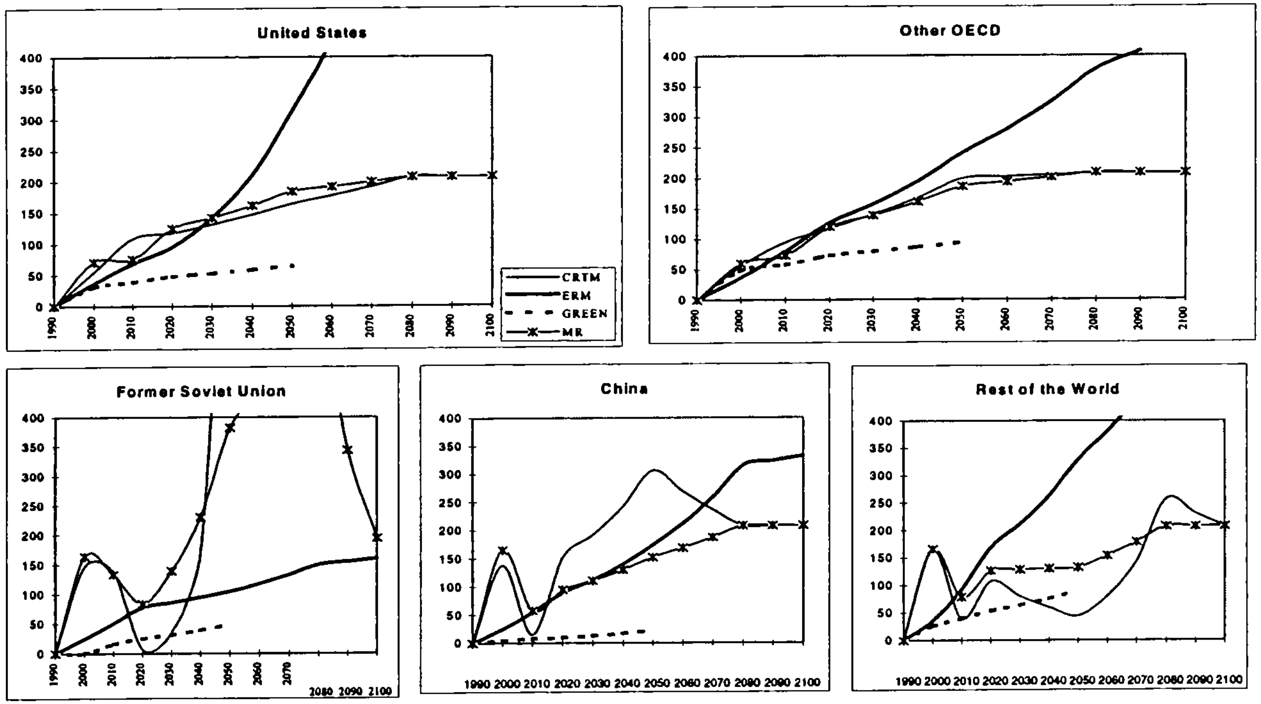
1. OECD countries reduce emissions by an amount equivalent to the stabilisation of Annex I country emissions (by applying a common tax).
2. Annex I countries stabilise their emissions (by applying a common tax).
3. A world coalition reduces emissions by an amount equivalent to the stabilisation of Annex I country emissions (by applying a common tax).

Figure 1. Annual CO_2 emissions in the GREEN baseline scenario



Source : OECD GREEN model
Major emitters: Annex I countries, China and India.

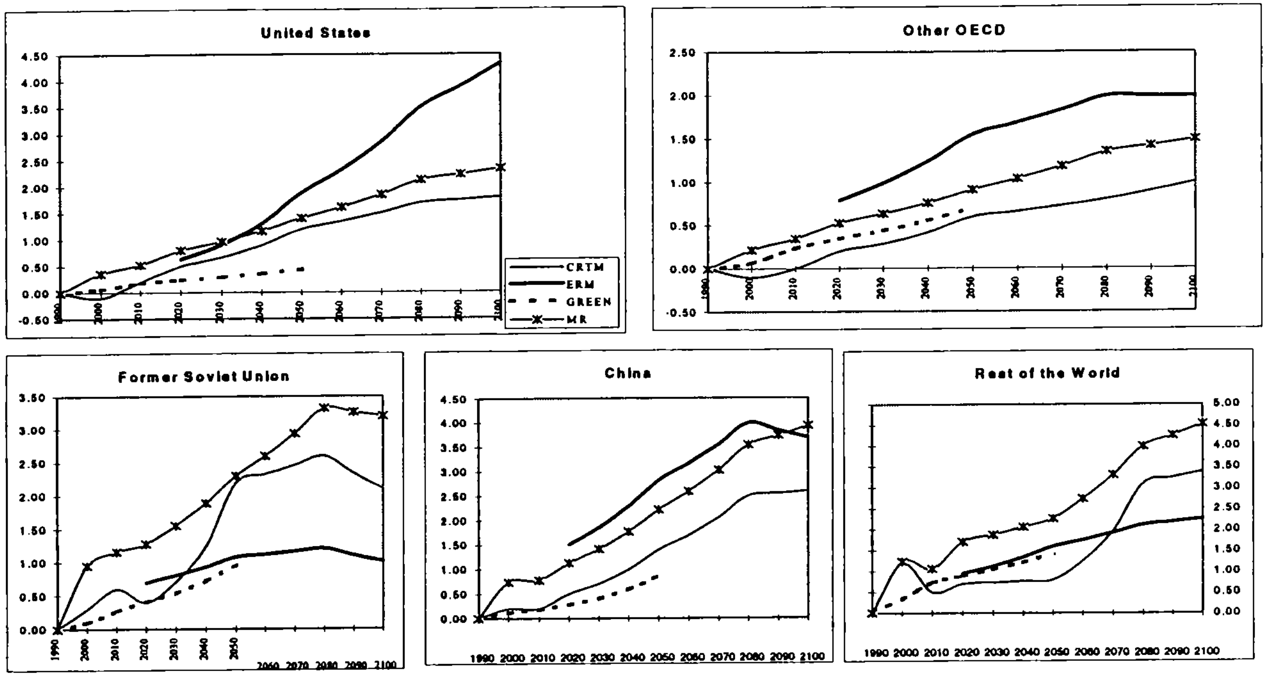
Figure 2. Carbon taxes to reduce by 1 percentage point annually the growth of CO_2 emissions



Sources : OECD (1993)

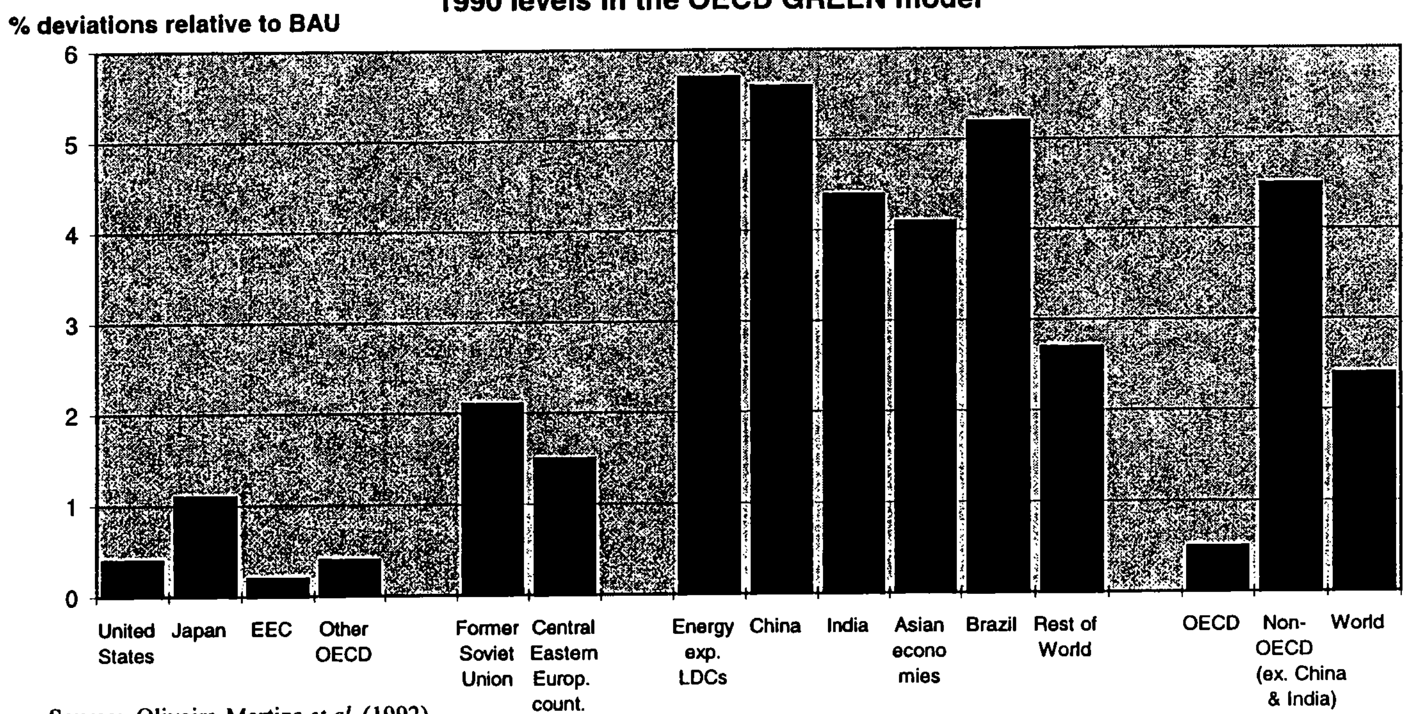
CRTM : Carbon Rights Trade Model (Rutherford, 1992).
ERM : Edmonds-Reilly Model (Barns et al., 1992).
GREEN : OECD Model (Oliveira Martins et al. , 1992).
MR : Manne-Richels Global 2100 Model (Manne,1992).

Figure 3. GDP losses associated with a 1 percentage point reduction of the growth of CO_2 emissions
Percentage deviation relative to baseline



Sources : OECD (1993)
CRTM : Carbon Rights Trade Model (Rutherford, 1992).
ERM : Edmonds-Reilly Model (Barns et al., 1992).
GREEN : OECD Model (Oliveira Martins et al., 1992).
MR : Manne-Richels Global 2100 Model (Manne,1992).

Figure 4. GDP losses associated with the stabilisation of CO_2 emissions at their 1990 levels in the OECD GREEN model



Source: Oliveira-Martins *et al.* (1992).

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OECD WORK ON CLIMATE CHANGE: ECONOMIC THEORY AND POLICY IMPLEMENTATION

ANNEX 2: CONTRIBUTIONS OF THE OECD TO CLIMATE-RELEVANT ACTIVITIES

This is Annex 2 to "OECD Work on Climate Change: Economic Theory and Policy Implementation", [ECO/CPE/WP1(98)7].

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OECD WORK ON CLIMATE CHANGE: ECONOMIC THEORY AND POLICY IMPLEMENTATION

ANNEX 2. CONTRIBUTIONS OF THE OECD TO CLIMATE-RELEVANT ACTIVITIES

1. Working Party No. 1 of the Economic Policy Committee undertook work on the economic aspects of climate change during the period from 1990 to 1994. Since then, many other Departments and Committees of the OECD and the IEA have been involved in activities related more or less directly to climate change and the emission of greenhouse gases (GHG). A review of these activities can be found in OECD (1996). The climate-relevant activities of the OECD and its affiliated bodies reviewed in this annex can be grouped into four categories: work carried out for the Annex I Expert Group, economic and energy market assessments, the Climate Technology Initiative and national greenhouse gas inventories.

A. The Annex I Expert Group

2. The Annex I Expert Group is currently working to support the implementation of the FCCC. Previous analyses on policies and measures for common action produced 19 studies of different policy instruments or sectoral strategies to reduce emissions. The rest of this sub-section summarises these studies.

Sustainable transport policies: CO_2 emissions from road vehicles (Michaelis, 1996*a*)

3. Rising greenhouse gas emissions from the transport sector have been identified as one of the most difficult challenges in addressing climate change. This study examines GHG mitigation strategies for the transport sector including: removing subsidies and other market distortions; internalising environmental and other external costs; and introducing policies to accelerate the process of technological, behavioural and institutional innovation in the sector. A wide range of policies could play an important role: shifting taxes from fixed to variable costs; introducing user fees to reflect the full cost of road transport; additional measures to internalise external costs; and energy efficiency standards and tax incentives to bypass failures in the market for energy efficiency in new cars. The study concludes that these policies could achieve large reductions in emissions from road transport relative to the underlying trend, but they would not achieve an absolute reduction in emissions from this sector. Absolute reductions in transport emissions are possible, but would require moving beyond no regrets measures to achieve significant changes in vehicle technology or mobility patterns.

Policies and measures to encourage innovation in transport behaviour and technology (Michaelis, 1997*a*)

4. The transport sector is responsible for 25 per cent of global CO_2 emissions from fossil fuel use, and its share is growing. Of all energy-using activities, transport is the area where governments find it hardest to find politically feasible policies that can mitigate GHG emissions. Projections for Annex I countries indicate that, without new CO_2 mitigation measures, road transport CO_2 emissions might grow from 2 500 million tonnes in 1990 to between 3 500 and 5 100 million tonnes in 2020.

5. This study considers strategies to encourage innovation in transport behaviour, institutions and technology to achieve reductions in traffic relative to projected levels, reductions in the energy intensity of vehicles, a switch to low-carbon fuels, or a shift to transport modes with lower GHG emissions. Several case studies of local government transport policies, and of policy evaluation exercises, indicate that GHG emission reductions in the range of 10-20 per cent are achievable with strategies currently considered reasonable. The technical potential for reductions in vehicle energy intensity by 2020 is in the region of 20-50 per cent, while switching to alternative fuels could reduce GHG emissions per unit of energy by 80 per cent or more. The economic potential is much smaller: only 10-40 per cent emission reductions are achievable through energy efficiency improvements and fuel switching without increasing the overall cost of transport.

Reforming coal and electricity subsidies (Michaelis, 1996*b*)

6. Market distortions from subsidies and other forms of government support may hinder the ability to design cost-effective strategies to curb emissions. Action to level the playing field may therefore be an important part of any climate change response strategy. However, state support to energy and transport forms part of a complex web of policies created for social, political, economic, and sometimes environmental reasons. Reforming subsidies normally leads to aggregate economic gains but reforms must be carefully designed to ensure that environmental and social objectives are met. Some of the most promising areas in the energy sector are: removing coal producer grants and price supports; reforming subsidies to energy supply industry investment or protection from risk; and removing barriers to energy trade.

Energy market reform: full-cost pricing (Keppler and Kram, 1996)

7. Competitive markets maximise economic welfare if all costs of production are accounted for. However, since private actors do not take environmental costs into account, there are inefficiencies. In order to eliminate these inefficiencies, full-cost pricing can be implemented to include environmental, or external, costs into private production and consumption decisions.

8. The study uses MARKAL[1] models of three countries -- Italy, the Netherlands and the United States -- to examine the impact of full-cost pricing of particulates, SO_2 and NO_x from electricity generation on CO_2 emissions. The study finds that, in general, the introduction of full-cost pricing would lead both to overall increases in energy efficiency and to reductions in local pollutants and CO_2 emissions. However, in instances where the imposition of full-cost pricing would lead to efficiency decreasing abatement measures, such as certain kinds of scrubbers, the imposition of full-cost pricing for local pollutants might theoretically increase CO_2 emissions. The study also concludes that the impact on CO_2 emissions of full-cost pricing of local and regional emissions of particulates, SO_2 and NO_x are likely to be small or negligible in many countries.

Electricity sector: penetration of renewable energy (Preville and AEA Technology, 1997)

9. Most renewable energy technologies (solar, wind, hydro-electricity, bioenergy and geothermal) suffer a significant cost disadvantage relative to major fossil-fuel technologies. However, the costs of

1. MARKAL models are detailed dynamic linear programming models of energy sectors built at the country level.

renewables are expected to decrease more quickly relative to fossil-fuel technologies. So far, the potential for renewables is generally poorly exploited due to a combination of technical, economic and market impediments.

10. The aim of this study is to identify measures to support the market penetration of electricity generating renewable energy technology to be undertaken on a common basis by Annex I countries. These measures involve: support to technical development through extended international collaboration on R&D in the renewables area, full-cost pricing of competing energy technologies and full-value pricing of electricity produced by renewables, including the full social, environmental and economic benefits of using renewables and market stimulation (dissemination of information, financing assistance).

Electricity sector: utility voluntary agreements to reduce GHG emissions (Newman, 1997)

11. Voluntary Agreements (VAs) between electric utilities and government seek to encourage industry-led initiatives to set and meet environmental goals, to raise the profile of environmental issues in corporate decision making and to give participating countries the flexibility to meet these goals in the best way, considering their particular economic, social and political circumstances.

12. The study assesses the potential of VAs between government and electric utilities as a policy instrument for international common action to achieve GHG reductions. VAs examined in this report differ considerably in their objectives, design, funding, incentive and reporting schemes. It is impossible to assert that one type of VA is more effective than another. Moreover, as they are still young and evolving, it is difficult to fully ascertain their longer-term effectiveness. The diversity of country-specific circumstances would make the design of a single common programme across countries extremely complex. However, common action could take the form of enhanced information exchange, harmonised regional VAs and/or voluntary international standards.

Electricity sector: market reform (Justus, 1997)

13. Electricity sector reform focuses primarily on reducing the costs of electricity production and the price charged for electricity delivered to customers. Environmental achievements are not their primary objective. However, market reform has environmental implications, in particular on GHG emissions. These implications are complex, case-specific and difficult to forecast in a quantitative way. In particular, they depend on pre-existing circumstances such as fuel mix, plant vintage, as well as on relative changes in price for different fuels. The effect of electricity restructuring reform is already evident in a number of countries: increased competition favours a different mixture of technologies than reliance on large central stations built to take advantage of economies of scale.

International GHG emission trading (Mullins and Baron, 1997)

14. As part of an international response strategy, emission trading may offer several unique features. First, a credible emission trading system cannot begin without clear agreement on the environmental performance objective of the system, or the overall system target. Given emissions targets, such as those proposed at Kyoto, an international emission trading system can help to minimise the total cost of emission reduction and, by providing financial incentives to participants, might also encourage wider participation in an agreement.

Lessons from existing trading systems for international GHG emission trading (Mullins, 1997)

15. Geographical and temporal flexibility may enhance the cost-effectiveness of achieving new greenhouse gas reduction objectives. Experience in OECD countries indicates that emission trading may be a means of ensuring an agreed environmental outcome while, at the same time, allowing the market to minimise the costs of achieving this outcome. International experience with emission trading systems is very limited. Relevant national experience can be found in the United States with the use of tradable permits to achieve various air and water pollution reduction objectives, as well as in New Zealand with fishing quota trading. Internationally, some relevant experience exists under the Montreal Protocol in its provisions for industrial rationalisation . Evaluation of the performance of these programmes points to a number of important elements for success: clear rules for ownership rights and obligations; high regulatory certainty and low regulatory requirement, hence minimising transaction costs. Agreement on monitoring and reporting procedures, producing verifiable performance data is also essential to ensure environmental performance.

Economic/fiscal instruments: taxation (i.e. carbon/energy) (Baron, 1996)

16. Several OECD countries have implemented carbon and/or energy taxes as part of their national climate change response strategies. National carbon and energy taxation schemes observed to date are, however, characterised by: tax rates set too low to have little observable impact on carbon emissions; exemptions for energy-intensive industry; tax rates that are not proportional to the carbon content of taxed products; and embedding the tax constraint in larger fiscal reform packages which reduce energy costs and trigger increased energy demand and higher emission levels. The study looked at experience with model results, including taxes based on the carbon and/or energy content of different fuels, and also explored the rationale for co-ordinated taxation within Annex I countries. It concludes that: while an international scheme might help to reduce opposition to a tax on competitiveness grounds, differences in trading patterns among developed countries complicate the issue; any international carbon or energy taxation scheme must deal with the same implementation issues that have been experienced at the national level; and an international strategy might include progressive implementation of carbon/energy taxes, along with fiscal reform, and a clear schedule for their evolution over time could help to minimise the costs of CO_2 reduction.

Competitiveness issues related to carbon/energy taxation (Baron and ECON, 1997)

17. A major concern related to carbon/energy taxation in developed countries is that such taxation could reduce the competitiveness of carbon-intensive exports and lead to leakage of emissions through increased production in developing countries. A specific issue is the extent to which a uniform tax implemented by all developed countries would have the same effect on competitiveness occurs in all of them. Existing industrial energy prices, energy and carbon-intensities (per unit of value added) vary widely across industries and countries. A uniform tax would reduce the variability of industrial energy prices across regions, but would also result in different increases in production costs. For energy-intensive industries in most of the selected nine OECD countries, a tax of $100 per ton of carbon would result in a static cost increase of about 2 per cent. For other sectors and for whole countries, estimates range from 0.6 to 11 per cent.

18. This study clarifies the notion of competitiveness in the context of taxation and, by illustrating orders of magnitude, helps to assess the importance of this question for different regions. Beyond the fossil fuel sector, not covered here, only a few sectors in certain countries would face significant cost

increases in the short term. The study also reviews the evidence about carbon leakages. Although leakage estimates differ between models, depending on their structure, most studies conclude rates of leakages will be modest.

Special issues in carbon/energy taxation: marine bunker fuel charges (Michaelis, 1997*b*)

19. Marine bunker fuel combustion was responsible globally for approximately 400 million tonnes of CO_2 (109 million tonnes of carbon) in 1994. Despite recent rapid growth, maritime transport is responsible for only 7 per cent of global transport sector CO_2 emissions, or about 2 per cent of global CO_2 emissions from fossil fuel use. Shipping is also the most energy-efficient means of freight transport. Air freight, the only alternative for inter-continental and much international trade, has a CO_2 intensity two orders of magnitude higher than that of maritime freight.

20. This study assesses the potential impact of a marine bunker charge on maritime CO_2 emissions; the direct and wider economic costs that might be associated with a charge; the other policy issues associated with bunker charges, including trade, employment and competition; issues that need to be considered in the implementation of any charge; the rationale for common action to implement a charge; and the possible approaches that developed countries might take to implement a bunker charge in common. The study concludes that a carbon charge on bunker fuel could internalise social costs resulting from CO_2 emissions from maritime transport, but would be feasible, fair and economically efficient only if globally imposed and if all other transport modes also paid their full social costs. However, a bunker fuel charge would not necessarily lead to significant net GHG emission reductions, mainly due to the likelihood of avoidance strategies and modal shifts. Such a charge could also have significant negative impacts on international trade, and would therefore need to be carefully negotiated on a multilateral basis.

Special issues in carbon/energy taxation: carbon charges in aviation fuels (Michaelis, 1997*c*)

21. Commercial aviation in 1990 was responsible for approximately 420 million tonnes of CO_2 emissions (114 million tonnes of carbon), of which about half was due to international traffic. NO_x emissions from aircraft resulted in increased tropospheric ozone concentrations whose radiative impact may be as large as that of their CO_2 emissions. Most countries follow the recommendation of the Council of the UN International Civil Aviation Organization (ICAO) that fuel used for international aviation should be tax-exempt. Aviation fuel taxation is also precluded in most countries by provisions in the bilateral Air Transport Agreements, which are the main legal framework for the operation of international civil aviation. However, charges are often imposed for environmental purposes. Some airports have landing fees related to aircraft noise levels, and various countries have considered or introduced more general environmental charges which could extend to aircraft GHG emissions.

22. This study considers the potential impact of fuel charges on aviation CO_2 emissions; the direct and wider economic costs that might be associated with aviation fuel charges; the other policy issues associated with fuel charges, including trade, employment and competition; issues that need to be considered in the implementation of charges; the rationale for common action to implement charges; and the possible approaches that Annex I countries might take to implement aviation fuel charges in common.

23. The study concludes that carbon emission reductions of 30 per cent could be achieved by 2020 by imposing a charge on civil aviation of about $125 per ton of carbon. This charge has to be applied uniformly in order to avoid changes in air traffic patterns which could lead to increased CO_2 emissions.

Given the rapid rate of air traffic increase and cost reduction, a charge raised gradually would not have any noticeable effect on airlines profits and employment in the aviation industry, provided that the charge is uniform and global.

Demand side efficiency: energy efficiency standards for traded products (Mullins, 1996)

24. Energy efficiency standards and labelling schemes for appliances and equipment play an important role in many OECD countries energy and environmental strategies. The OECD has analysed the potential for efficiency standards to achieve cost-effective reductions in CO_2 emissions among industrialised countries. Application of cost-effective energy efficiency standards could deliver no-regrets CO_2 reductions within Annex I countries in the near term. If one considers the potential technology spill-over effects to non-Annex I regions, the abatement potential would be even greater. Energy efficiency standards may be designed and implemented in many different ways, e.g. as technical specifications or industry norms, implemented through regulations or voluntary agreements. Harmonised measurement procedures and testing protocols would facilitate international comparisons and could be a first step to harmonised energy efficiency standards. Moving toward harmonisation would also lower trade barriers and create global markets for energy-efficient products.

Demand side efficiency: voluntary agreements with industry (Storey, 1996)

25. Voluntary agreements (VAs) are agreements between government and industry to facilitate voluntary action to reduce GHG emissions, which is encouraged by the government and to be undertaken by the participants based on self-interest. VAs typically incorporate a wide range of mechanisms, ranging from regulatory relief, to economic incentives, to public recognition to encourage or support industry participation. VAs are relatively new environmental policy instruments and figure prominently in OECD countries programmes to respond to climate change. Voluntary agreements can be used to overcome market barriers that hinder investment in cost-effective options to improve energy efficiency or overall system performance. VAs may take many different forms. The different forms of VA among OECD Member countries, and the lack of experience in the monitoring of results, make it difficult to generalise about their potential to achieve substantial reductions.

Financial energy efficiency in countries with economies in transition (IIEC, 1996)

26. Substantial savings of CO_2 may be achieved at no net cost by capturing the economic and achievable energy efficiency potentials in economies in transition (EIT). The energy saving potential is not constrained by the supply of cost-effective energy saving projects, but by the barriers associated with developing, managing and financing cost-effective projects. This study analyses the potential for energy efficiency improvements in six countries in central and eastern Europe and the Commonwealth of Independent States. It also identifies barriers to financing investments in energy efficiency and proposes some areas for government action to improve financing for further study.

Policies and measures for financing energy efficiency in countries with economies in transition (Mullins *et al.*, 1997)

27. There is large scope for cost-effective GHG mitigation in countries that are making the transition to a market economy. Energy efficiency often provides the most cost-effective opportunities for GHG

mitigation and energy supply, but funds for investment in this area, as in others, seem limited. Many EIT countries have not been able to attract significant amounts of private-sector investment and only a small portion of total finance that goes to EIT countries is spent on energy efficiency.

28. The study identifies measures that governments could take to build capacity and redirect current financial flows towards energy efficiency. Donor governments can adjust their spending priorities, both in aid plans and through official support provided to their exporters. The private sector clearly has an important role to play in providing finance that could be used for energy efficiency investments in EIT countries. However, many of the most important measures to attract foreign investors are measures that only EIT governments can implement: reforming macro-economic policy frameworks, reforming energy market structures and pricing, banking reform, debt recovery programmes, strengthening the commercial and legal framework for investment, and setting up judicial institutions and enforcement mechanisms.

Agriculture and forestry: identification of options for net GHG reduction (McKenzie Hedger, 1996)

29. Agriculture contributes about one-fifth to one-quarter of the total anthropogenic emissions of CO_2, half of CH_4, and up to 80 per cent of N_2O. Agriculture accounts for one-fifth of the annual increase in anthropogenic greenhouse gas emissions. Forests are critical components of the climate system: they contain up to 60-80 per cent of the above-ground, and approximately 40-50 per cent of the below-ground carbon (i.e. excluding fossil fuels). Measures in the forestry and agricultural sectors are thus an important component of a comprehensive approach to address climate change. This paper provides a catalogue options for reducing and sequestering greenhouse gas emissions in the forestry and agriculture sectors. The study identifies a wide range of policy instruments which have effects on GHG emissions in these sectors, including economic instruments such as subsidies/taxes, regulatory measures and restrictions, voluntary and information sharing approaches, and research and development opportunities.

The climate implications of agricultural policy reform (Storey, 1997)

30. Agricultural policies directly influence the role of agriculture as a source and sink of greenhouse gases through their impacts on agricultural practices such as land use, fertiliser use and livestock numbers. This paper discusses the role of the agriculture sector as a source and a sink of emissions both globally and in OECD countries, summarises recent trends in agricultural policies in OECD countries and discusses the relationships between agricultural policy reform and emissions and removals of greenhouse gases (CO_2, CH_4 and N_2O). Finally, stressing certain caveats and areas where further information is needed, initial conclusions are made as to the impacts of recent agricultural policy reforms on net emissions of GHGs.

B. Economic and energy market assessments

31. Seminars were organised by the IEA dealing with the assessments of the impacts on energy markets of implementing Quantified Emission Limitation and Reduction Objectives (QELROs), the efficiency gap in energy responses to climate change, the understanding of no regrets and other cost-effective energy response measures.

C. The Climate Technology Initiative (CTI)

32. Dealing with inventories of national and international activities related to climate friendly technologies, the CTI constructed databases covering organisations involved in these technologies (GREENTIE), and information on demonstration projects in energy-efficient and renewable energy technologies (CADDETS).

D. National Greenhouse Gas Inventories

33. This is a joint IPCC/OECD/IEA programme to develop and improve approaches for estimating and reporting sources and sinks of national GHG. The main product of this programme was the publication of the IPCC Guidelines for National Greenhouse Gas Inventories (see WMO/UNEP/OECD/IEA, 1996). Over the coming years, work will be done on methods development, including assessment, monitoring and validation of the IPCC Guidelines.

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OECD WORK ON CLIMATE CHANGE: ECONOMIC THEORY AND POLICY IMPLEMENTATION

ISSUES FOR DISCUSSION

Background to these issues is contained in "OECD Work on Climate Change: Economic Theory and Policy Implementation", [ECO/CPE/WP1(98)7].

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OECD WORK ON CLIMATE CHANGE: ECONOMIC THEORY AND POLICY IMPLEMENTATION

ISSUES FOR DISCUSSION

1. Beginning in the early 1990s, the OECD Secretariat carried out an extensive project on the economic costs of reducing CO_2 emissions. This issue is now of renewed interest, in particular because of the recent Kyoto agreement. The work by the Secretariat yielded several key conclusions: market-based instruments, such as carbon taxes or tradable permits, are cost-effective ways to meet agreed emissions targets, although there are many practical hurdles to implementing such schemes; gradual phasing in of emissions targets is likely to be less costly than imposing tight targets immediately, although a "go slow" approach also has risks; stabilising atmospheric concentrations of greenhouse gasses will require the participation of both OECD and non-OECD countries; any global agreement would raise significant international equity issues, effectively calling for very large explicit or implicit international transfers. The broad outlines of these findings appear to remain valid today, although there has since been considerable refinement in both the science of climate change and the economic modelling of policies to respond to it.

2. With this background, Delegates may wish to address the following issues:

a) The model comparisons project generally reported relatively low costs for stabilising emissions: broadly on the order of 1 per cent of GDP in fifty years' time for OECD countries. This would seem to be difficult to reconcile with opposition to such an agreement. Are such cost estimates credible and, if not, what factors are missing from the models?

b) If it is agreed that market-based instruments are a cost-effective way of meeting emissions targets, what are the major impediments to implementing such policies on a global scale? In view of the increasing contribution of non-OECD countries to greenhouse gas emissions, how urgent is the need to bring them into an agreement to curb emissions? How should such policies be best implemented in international agreements, and in this connection, how should the issues of international equity best be handled?

c) How can the OECD best contribute to the process begun by the Rio summit and continued in Kyoto? What is the role of economic analysis in this process, and what should be its focus? Where are the major gaps in the knowledge of the economics of this process? Is there a strategy for filling these gaps?

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TAKING ACTION AGAINST CLIMATE CHANGE: THE KYOTO PROTOCOL

ISSUES FOR DISCUSSION

Background to these issues is contained in "Taking Action Against Climate Change: the Kyoto Protocol", [ECO/CPE/WP1(99)6].

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Taking Action Against Climate Change: The Kyoto Protocol

Issues for Discussion

1. Work on climate change issues takes place in a number of fora across the OECD. For example, the Environmental Policy Committee will discuss a number of domestic implementation issues at its meeting on 24-26 March; the Annex 1 Expert Group meets regularly under the auspices of the OECD and International Energy Agency to discuss issues related to the implementation of the Kyoto Protocol; and the Forum on Climate Change, which comprises a number of non-OECD countries and NGOs, will meet on 9 and 10 March to discuss follow-up to the Buenos Aires Action Plan.

2. Considerations of comparative advantage suggests that WP1 focus on the economic policy requirements to implement the Kyoto Protocol and to move further towards the goal established at the "Earth Summit" in Rio de Janeiro of stabilising atmospheric concentrations of greenhouse gases. Accordingly, it is suggested to have a discussion in two rounds organised around these two issues.

Immediate policy requirements: implementing the Kyoto Protocol

3. The estimates presented in the paper (ECO/CPE/WP1(99)6) suggests that the average annual costs of implementing the Kyoto targets might be of the order of ½ per cent of GDP if Annex 1 countries/regions use cost-effective domestic instruments but do not attempt to align marginal abatement costs across countries through emission trading. With emission trading, economic costs would become almost insignificant, amounting to about ¼ per cent of GDP for OECD countries. The paper also concludes that any restrictions on emission trading will tend to raise costs; that early and gradual action is the best way to keep costs down and that, accordingly, it is desirable to establish early agreement on the modalities for implementing the Kyoto Protocol; that a first-best way to reduce emissions is to eliminate energy subsidies; and that consideration of non-CO_2 gases may tend to lower cost estimates.

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- **Do Delegates believe the cost estimates for implementing the Kyoto Protocol are realistic? If not, what are their main concerns?**

- **Is it agreed that emission trading, and the use of other flexibility mechanisms, can provide significant cost savings? What are the main economic, political and implementation problems of a scheme for emission trading and for the other flexibility mechanisms? Do these concerns justify restrictions on the use of the flexibility mechanisms?**

LDC's

- **Are there other conclusions from the paper that Delegates want either to emphasise or to contest? How can future work by the Secretariat best serve as background for the continued negotiations in this area?**

Longer term policy issues: moving beyond the first target period

4. Achieving the Kyoto targets will be only a first step towards the goal of stabilising atmospheric concentrations of greenhouse gases. Model simulations suggest that extension of the Kyoto commitments to 2050 would considerably increase compliance costs. Moreover, the impact on global emissions would be limited given the rising importance of non-Annex 1 countries as emitters. This raises the question how

non-Annex 1 countries can be induced to participate in a more comprehensive agreement to reduce emissions. Central to this issue is the burden sharing implied by the allocation of emission targets across countries. The analysis in the paper is predicated on the assumption that, eventually, there will have to be convergence around an "egalitarian" burden sharing, i.e. one which implies equalisation of per capita emissions across countries. The paper also argues that such a burden sharing scheme would have significantly higher global costs if not accompanied by emission trading. The paper also notes that an egalitarian burden sharing combined with emission trading may be insufficient to induce participation by all relevant emitters among non-Annex 1 countries, and that side-payments, in the form of international transfers, may have to be contemplated – in which case the costs of an agreement to Annex 1 countries could be substantial. This is the more so since a move towards eventual stabilisation of atmospheric concentrations would require emissions to fall to very low levels.

5. Current emission levels, not to speak of the increased emissions by non-Annex 1 countries under a scenario of extending the Kyoto agreement, would lead to a strong increase in atmospheric concentration levels. Indeed, it is difficult to imagine scenarios, even ones involving eventual very significant cutbacks in global emissions, that do not lead to a sizeable increase in concentration levels. On the basis of current scientific knowledge, the implication would be significant changes in climates. The economic costs (or benefits) of such changes in climate as may occur are largely unknown but will depend on how well countries adapt. So far, few countries have analysed the potential challenges posed by adaptation to climate change.

- **How difficult will it be to establish a global coalition to reduce greenhouse gas emissions? Do Delegates agree that a wider international agreement to reduce emissions would have, eventually, to be based on an egalitarian burden sharing? And that permit trading may be required to contain global costs of such a scheme? How important are ancillary benefits and costs in determining countries' incentives to join a global agreement?**

- **What are the main challenges in adapting to climate change? Has any analysis been made of these issues in Delegates' home countries? How could this issue best be analysed?**

Comments on OECD Draft Report
"Taking Action Against Climate Change: The Kyoto Proposal"
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The OECD draft report assesses the costs of meeting Kyoto targets. It looks at scenarios that differ according to assumptions about international emissions trading, market structure, and other institutional factors. The report addresses aspects of domestic policies and measures, developing country participation, and future commitments. The report surveys relevant literature, including new findings from ~~the~~ OECD's GREEN model.[1] Overall, the report is less helpful than advertised or expected. Like many other surveys, the report indicates that Annex I trading could reduce the marginal costs of meeting the Kyoto targets by more than half.[2] Drawing a general conclusion from the literature, the report finds that "both the European Union and Japan would tend to meet a higher percentage of their obligation by buying permits and thus would benefit relatively more from trading permits than other OECD Parties." (See paragraph 71.) Unfortunately, however, the literature is not lock step in agreement on this point. For example, the European Commission's POLES model suggests that the United States could need trading even more than the European Union.[3] Moreover, the GREEN model suggests that the United States could *lose* from Annex I trading. (See discussion below.) The report provides an even-handed, albeit familiar, discussion of liability. It raises serious concerns about buyer liability and concludes, "Whether Buyer or Issuer liability results in increased compliance will continue to depend on how seriously the different parties take their Kyoto commitments." (See paragraph 46.)

Equity: LDC Post.

Discussions about developing country participation, per capita emissions, and equity are especially troubling. The report does not consider the possibility of growth targets; rather it focuses on per capita emissions criteria. The report considers scenarios "which are built on the notion that eventually per capita emissions rights will have to converge across countries." (See paragraph 11.) Furthermore, it concludes, "revenues from permit selling may not provide sufficient incentive for all developing countries to participate in a global agreement" and raises the specter of side payments. (See paragraph 11.) The report suggests that few countries will undertake voluntary commitments in the absence of side payments. (See paragraph 10.) The report links discussions about per capita emissions and equity, "equity concerns may over the next half century or so call for much larger cuts in emissions by Annex I countries than by developing countries, whose per capita emissions levels are many times smaller." (See paragraph 10.) The report also discusses per capita emissions in the context of demands for trading restrictions. In particular, "developing countries typically refuse to consider quantitative emission limits which restrict their per capita emission rates to levels far below those of developed countries unless the developed countries are willing to show

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[1] The GREEN model is the OECD's own 'in house' general equilibrium model.
[2] This conclusion summarizes the findings of several models. In addition, the GREEN model suggests that total real income losses for OECD could be about halved.
[3] One cannot draw a firm conclusion from the presentation in the OECD draft report. Table 3 of the report presents GDP costs in the absence of Annex I trading, but does not present GDP costs with trading. As a result, one can only assume that countries with higher GDP losses in the absence of trading will benefit more than countries with lower GDP losses.

some commitment to reduce their own emissions.... it may make sense to insist that Annex I countries do undertake 'unnecessarily' high abatement costs [because of restrictions on trading] in order to induce some major developing countries to accept quantitative limits." (See paragraph 73.)

Hot-Air

The report may provide fodder for attacks on so-called "hot air," especially relating to international emissions trading and demands for "real reductions." The report indicates that "part of the apparent gains from trading would come from higher overall emissions," owing to trading in Russian and Ukrainian hot air.[4] (See paragraph 5.) Taken out of context, this statement is unhelpful and potentially misleading. Even with trading in hot air, Annex I Parties will meet their 5.2% aggregate commitment in the first commitment period. Without trading in hot air, some countries will make additional emissions reductions, but their actions will not affect concentrations. The analysis points out that attempts to restrict trading, for the purposes of eliminating hot air and further reducing Annex I emissions, will be ineffective given opportunities for banking.[5] For example, if Russia doesn't sell the hot air now, it can sell it or use it later.[6]

GREEN Specifics

For the most part, the report surveys "old" model results, including some presented at an OECD workshop in September 1998. Where the report presents new results, i.e., from the GREEN model, it sometimes provides counterintuitive "insights." Whether these insights really shed light on current thinking, or merely reflect the peculiarities of the model, remains to be determined. Some of the GREEN model's results require further examination and discussion. For example:

- The United States loses from international emissions trading, owing apparently to a strong terms-of-trade effect. (The price of oil drops less precipitously with Annex I trading than without. For the United States, the effect of the cost differential outweighs the benefit of emissions trading *per se*.)

- The CIS does not necessarily benefit from reducing domestic subsidies on oil consumption. The net effect depends on whether there is international emissions trading. If there is international emissions trading, the CIS does not benefit from removing these subsidies, though other Annex I countries benefit on average. (The removal of consumption subsidies results in an increase in the supply of emissions permits and a decline in the price of permits. For the CIS, the net effect of the lower permit price outweighs the efficiency gains.)

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4 In the GREEN model, the CIS benefits from inflows amounting to about $39 billion, of which about $12 billion come from selling hot air. On this basis, the CIS accrues more than 60 percent of the gains from Annex I trade. (See paragraph 71.)

5 This line of reasoning -- although arithmetically and institutionally accurate -- may generate some unintended antagonism toward banking.

6 Though Russia could opt for a more stringent target in the future to compensate, this is a matter for future negotiations.