VII. THE ECONOMICS OF CLIMATE CHANGE

The issue of climate change – specifically the effects of global warming due to increasing atmospheric concentrations of human-made emissions of so-called greenhouse gases – is the subject of renewed interest, in large part owing to the adoption of the Kyoto Protocol on 10 December 1997 (Box VII.1). Policies to slow the rise in concentrations by controlling greenhouse gas emissions raise a number of economic issues. This chapter reviews some of these issues based on work done at the OECD; more detailed accounts of this work can be found in *Global Warming* (OECD, 1995) and the special issue of *OECD Economic Studies* (OECD, 1992).

Although there have been significant recent advances in both the science and economics of climate change, the key conclusions of this work remain largely valid. These can be summarised as follows. Developing countries will grow rapidly and become significantly more industrialised over the coming decades, implying that they will contribute an increasing proportion of global greenhouse gas emissions. As a result, these countries will have to be included in any agreement that hopes to stabilise either emissions or atmospheric concentrations of greenhouse gases. Second, this 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. Third, given agreed emission abatement targets, it is economically efficient to equalise marginal abatement costs across countries, firms and plants. This could be implemented through a common tax on carbon emissions or a global system of tradable carbon emission permits. Equalising marginal abatement costs, however, would mean that countries where emissions cuts can be made most cheaply – including many developing countries and, in particular, China – would be required to do the most abatement and, in the absence of explicit or implicit international transfers, bear much of the cost.

The next section reviews evidence on costs of a global agreement to reduce CO_2 emissions and illustrates why regional 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. The fourth section reviews the experience of OECD countries with taxes and tradable permits.

Box VII.1. **From Rio to Kyoto: a growing concern about climate change**

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, Korea and Turkey, plus Russia, Belarus and the countries of central and eastern Europe) committed to stabilising their CO_2 emissions. This Convention was 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".

(*continued on next page*)

Box VII.1 (*continued*). **From Rio to Kyoto: a growing concern about climate change**

Subsequently, it became clear that industrialised nations would fall short of their commitments adopted in Rio, and the main objective of the Third Conference of the Parties to the Convention, held in Kyoto in December 1997, was to agree legally binding quantitative targets. 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"; abatement investments financed by an Annex I country would count against the target of the former.
- 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 relevant rules and guidelines for emission trading and ways to verify the compliance to agreed commitments.

The costs of a world-wide programme to reduce CO_2 emissions

The effects of climate change are uncertain

The considerable uncertainty surrounding both costs and benefits of greenhouse gas emission abatement greatly complicates policy assessment. An important source of uncertainty is the very long time periods over which climate change is expected to occur. Climate change and its effects may appear in the second half of the next century, and virtually nothing is known for sure about economic conditions and technological opportunities that far ahead. In addition, our knowledge of the links between emissions and atmospheric concentrations of greenhouse gases, and of the effects of climate change is still very incomplete, although improving.

The analysis is restricted to anthropogenic emissions of carbon dioxide (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, but other gases are also important and have been explicitly included in the Kyoto Protocol. A major contribution of the OECD has been to compare the results of several global economic models under standardised assumptions (Box VII.2).[1] The economic costs of abating CO_2 emissions were assessed by contrasting a "business-as-usual" (BAU) scenario in which no abatement efforts are undertaken with alternative abatement scenarios. The abatement scenarios were not chosen to duplicate any particular agreement (and certainly not the Kyoto Protocol), nor were they intended as specific policy advice.

1. A similar exercise was conducted by the IPCC (1996).

Box VII.2. **The OECD model comparison project**

Early surveys of the economic costs of reducing CO_2 emissions highlighted large differences in results, without being able to explain such differences in a satisfactory way. The OECD model comparisons project was an attempt to understand better why results differ 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 (EMFl2). Six global models participated in the OECD project (see Dean and Hoeller, 1992, for details): the Carbon Rights Trade Model (CRTM); the Edmonds and Reilly model (ERM); the OECD GREEN model; the International Energy Agency (IEA); the Manne and Richels Global 2100 Model; the Whalley and Wigle Model.

All were macroeconomic models with specifications of energy sectors that are substantially simpler than those of dedicated energy-sector models. Key economic assumptions for the "Business-as-Usual" (BAU) scenario and a set of common simulations for reducing CO_2 emissions ensured some standardisation across models.

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 $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 relative to the BAU in the rate of growth of emissions in each region by, respectively, 1, 2 and 3 percentage points. In this way, the amount of the reduction, in percentage terms, was identical across models, although the starting points (the BAU), and thus the resulting emissions levels and costs, varied. This method isolated the differences between model structures, providing insight into the economic and technical factors leading to different predictions. 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.

For reference, 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 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 percentage point 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.

Business as usual

With unchanged policies CO_2 emissions may rise threefold by 2050

In the BAU scenario emissions growth could range from 1 to 2 per cent annually over the next hundred years. Accordingly, world-wide emissions in 2050 could lie between 10 and 20 billion tons of carbon per year, compared with about 6 billion tons now. Much of the increase in emissions would come from coal-consuming countries with large populations, such as China and India.

Key sources of uncertainty in such projections include: assumed economic growth (economic and emissions growth tend to move together); the assumed rate of exogenous efficiency improvement (roughly, the evolution of the energy-GDP ratio, all else equal); the evolution of international energy prices; and when and at what cost alternative carbon-free energy sources, referred to as "backstop technologies", will become available. Uncertainty in the BAU scenario itself is, in turn, an important source of uncertainty in estimating the costs of alternative reduction scenarios. Notably, the commitments agreed at Kyoto are expressed relative to 1990 emissions levels, so the costs of meeting them will depend crucially on what the path of emissions would have been in the absence of abatement measures. In general, the higher this emissions path, the greater will be the required abatement efforts.

Reducing emissions growth by 1 percentage point

Reducing emissions growth by one percentage point would not stabilise emissions or concentrations...

Compared with the BAU scenario, a reduction in annual emissions growth of 1 percentage point by all countries (or regions) would stabilise the emissions of OECD countries at 1990 levels, but those of developing countries would continue to grow. Thus, world emissions would grow by 0.5 to 1 per cent per year, depending on assumptions about economic growth and energy efficiency. Concretely, lower emissions growth could be brought about by tighter regulation, taxation of carbon or energy, or a system of tradable emissions permits. The last two are examined below.

The abatement efforts needed to reach such a target path for emissions would have to intensify over time, at least until the carbon-free "backstop" became available; thus, carbon tax rates or the price of emissions permits would have to rise to induce further abatement. This is because initial cuts in carbon emissions come relatively cheaply through substitution of high-carbon fuels, such as coal, for low-carbon fuels, such as natural gas. As such substitution possibilities become fully exploited, further cuts become more costly and higher taxes are needed to induce them. Likewise, assuming that each region makes the same percentage cuts implies that abatement efforts and costs will vary across regions. Those that rely relatively extensively on high-carbon energy – such as China, India and Russia – can reduce emissions relatively cheaply relative to those which have already substituted extensively away from coal – notably the OECD countries. As discussed below, such equi-proportionate emissions cuts are economically costly relative to a programme in which more of the abatement takes place in countries that can abate cheaply.

Abating emissions would reduce real income, or GDP, by distorting resource use and economic activity. This should not, however, be seen as a net loss to society as a whole, because abatement would also bring benefits in terms of less global warming. Emissions abatement and global warming would generate both transition costs and longer-term costs once a new equilibrium had been reached. Ideally, abatement would be carried to the point where the difference between its benefits and its costs and were maximised.

... and could cost up to 2 per cent of GDP

The economic costs of emission reductions, as projected by the models in the OECD comparison project, took the distortionary costs, but not the transition costs, into account; the benefits of less global warming were not taken into account. Depending on the underlying assumptions enumerated above, by 2050 the assumed emissions cuts would entail costs ranging from 0.6 to 1.7 per cent of GDP in OECD countries and from 1.2 to 2.3 per cent in non-OECD countries. Overall, the level of world GDP would be lower by 0.9 to 1.8 per cent in 2050.[2] It is worth emphasising the importance of the assumed existence of the "backstop" technology; in the absence of such a technology, the economic costs of abatement could be much higher.

2. More recent studies yield an even wider range of cost estimates (Azar, 1996; Repetto and Austin, 1997).

It is also worth emphasising that cuts in the growth of 1 percentage point relative to the BAU would stabilise neither emissions nor atmospheric concentrations of greenhouse gases. Stabilising emissions at 1990 levels, which would be more ambitious than cuts of 1 per cent, could cost 5 per cent of GDP in some developing countries, according to simulations with the OECD GREEN model. Even this, however, would not be sufficient to stabilise atmospheric concentrations of greenhouse gases at the benchmark level of twice the pre-industrial concentration.

The role of global participation

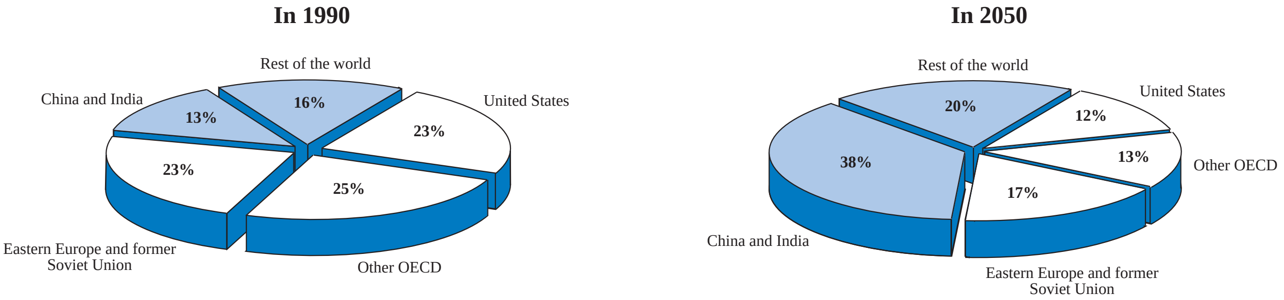
Developing countries will account for increasing amounts of CO_2 emissions

Figure VII.1 shows the distribution of future emissions as projected by the OECD GREEN model, and illustrates the increasing importance of developing countries. Emissions of CO_2 from OECD countries are now almost half of world emissions, but by 2050 would account for only 25 per cent; developing countries would account for around 60 per cent. More recent data suggest that these projections are optimistic in the sense that emissions growth from developing countries appears to be higher than earlier projected. If this higher growth were to continue, developing countries would account for a larger proportion of emissions and, of course, global emissions would grow more rapidly as well.

Therefore, OECD countries alone cannot stabilise global emissions

One implication of these emissions projections is that, in practice, it is unlikely that industrialised countries alone will be able to stabilise world-wide emissions of greenhouse gases. In addition, the effectiveness of action by industrialised countries alone could possibly be reduced by so-called carbon leakage effects. Carbon abatement in industrialised countries would increase the comparative advantage of other countries in the production of energy-intensive goods, which therefore shift to countries not making such efforts. As a result, the abatement efforts in industrial countries would be partly offset by induced higher emissions elsewhere. This effect would require still more stringent controls in industrial countries if the global target were to be met. The amount of carbon leakage depends on a number of key supply and substitution elasticities, and estimates vary substantially (OECD, 1995).

Figure VII.1. **Annual CO_2 emissions: the increasing importance of developing countries**



Source: OECD GREEN model simulations.

Reducing the costs of controlling emissions

Equal emissions cuts by each region would be a costly way of meeting abatement targets

The policy of equi-proportionate emissions reductions by region or country, which was described in the previous section, is a relatively costly way of achieving a global emissions target. Some policy reforms could both reduce emissions and improve economic efficiency. These are referred to as "no-regrets" policies because they would be worth implementing even if global warming were to turn out to be no threat. Substantial costs could also be saved if emissions reductions were timed to minimise transition costs, notably the obsolescence of capital, and to take advantage of the possibility that cheaper abatement technologies may be developed in the future. Finally, equalising the marginal cost of abatement across countries or regions would ensure that total costs were minimised for a given amount of global abatement. The logic of this last point is straightforward: if marginal costs are not equal, then reducing abatement a little in a high-cost country and raising it an equal amount in a low-cost one would reduce overall costs. This logic applies equally to firms and plants within a country.

"No-regrets" Policies

Reform of subsidies and overcoming barriers to the use of energy-efficient technologies can both reduce emissions and raise welfare

The clearest case for a "no-regrets" policy is reform of energy subsidies. This priority is recognised in Article 2 of the Kyoto Protocol, which specifies a progressive removal of subsidies and reform of taxes as a means of achieving reduction commitments. Removing subsidies would reduce fossil-fuel use and, therefore, CO_2 emissions, while at the same time eliminating an allocative distortion. Results from the OECD GREEN model indicate that removing subsidies would reduce emissions by 18 per cent in 2050 compared with the BAU level and would increase world real income by 0.7 per cent. (Transition costs, however, were not taken into account.) To some extent, countries have already begun to reap such gains: in particular, reforms in China, the central European countries and Russia have helped to close the gap in those countries between domestic and world energy prices.

Emission reductions could also be achieved if the structure of existing energy taxes better reflected the carbon content of fuels. Currently, oil and gas typically face high implicit carbon taxes while coal receives subsidies (Hoeller and Coppel, 1992). Rebalancing existing taxes according to the carbon content of each fossil fuel could reduce OECD emissions by 12 per cent and lower the economic cost associated with existing energy taxes from 0.4 to 0.1 per cent of GDP.

Another "no-regrets" policy would be to encourage technologies that raise energy efficiency. A number of these 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. The extent to which this is truly a "no-regrets" policy depends in part on why such technologies are not already in wider use. On one view, firms and households would have already adopted them if they were, in fact, less costly. In this case, inducing their adoption would not truly be "no regrets". On the other hand, there may be numerous market failures inhibiting the adoption these technologies, including inadequate information regarding alternative costs, principal-agent problems (those paying are not those making the decisions about what technology to adopt) and capital-market imperfections (some cannot borrow to pay for the up-front cost of installing the new technology). Overcoming such market failures would both raise welfare and reduce greenhouse gas emissions.

The timing of abatement

Phasing in abatement would reduce costs, but at greater long-term risk

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 costs by allowing natural depreciation of existing capital equipment. On the other hand, delaying action involves risks, since it would result in higher atmospheric carbon concentrations, all else equal. Early reductions may therefore be justified as risk management, and the possibility of unexpected and catastrophic consequences from global warming adds weight to this argument. Although models have been used to assess the costs of alternative time paths of emission reductions, the results are subject to a great deal of uncertainty. In addition to the sources of uncertainty already mentioned regarding model simulations, the relative costs of such paths also depend on the likelihood of cost-reducing abatement technologies being discovered, the social discount rate used and, in view of the risk-management issue, the degree of risk aversion assumed.

Equalising marginal emissions costs

Using economic instruments can minimise the cost of meeting abatement targets

Since the marginal cost of greenhouse gas abatement differs widely across countries and regions, the equi-proportionate cuts of the scenario discussed above is a costly way to meet a global emissions-reduction goal. Equalising marginal abatement costs would mean those countries or regions with lower costs would abate more. Such an outcome could be implemented either through a uniform world-wide tax on carbon emissions, or through a global market for tradable emissions permits with a single price for all countries.

As part of the OECD comparison project, a scenario was constructed in which global emissions growth was cut by 2 percentage points, relative to the BAU, but marginal abatement costs were equalised across regions. The cost of this scenario, as judged by three models, were compared with the costs of the same global reduction but involving equi-proportionate cuts for all regions (Table VII.1). All three models pointed to cost savings from equalising marginal costs, with the OECD GREEN model reporting the largest gain: by 2050, trading emissions would reduce the aggregate cost by about one-third. Estimated cost savings reflect assumptions about the *ex ante* differences in marginal abatement costs across regions (the larger these differences, the greater the saving), and on the pace at which backstop technologies come into play (the later they appear, the greater saving).

Table VII.1. **Cost of alternative abatement strategies**

Per cent of GDP

	Edmonds-Reilly **Model ERM**		**OECD GREEN**		Manne-Richels Global 2100 **Model MR**	
	[1]	[2]	[1]	[2]	[1]	[2]
2020	1.9	1.6	1.9	1.0	n.a.	n.a.
2050	3.7	3.3	2.6	1.9	n.a.	n.a.
2100	5.7	5.1	n.a.	n.a.	8.0	7.5

[1] Equi-proportionate reductions.
[2] Equalisation of marginal costs of abatement.
Source: OECD (1993).

Least-cost abatement is likely to result in a burden on developing countries

A programme of equalising marginal abatement costs also has much different distributional implications from one of equi-proportionate cuts, for any given global target (Oliveira-Martins *et al.*, 1992). For the target of a 2 percentage point reduction in emissions growth relative to the BAU, simulations of GREEN suggest that OECD countries – which have high marginal abatement costs – would contribute 22 per cent of the total abatement in the former case, rather than 32 per cent in the latter. As a result, the loss of GDP in OECD countries would be reduced by more than a third. By contrast, equalising marginal costs would mean greater abatement by developing countries, and their costs could increase relative to a programme of proportional emissions reductions.

Thus, redistributive measures will be needed if global costs are to be minimised

As a result, these countries may prefer a programme similar to equi-proportionate cuts (or even one in which the burden falls more than proportionally on OECD countries) because it would lower their costs even though it would increase global costs. This point raises the issue of burden sharing, which is addressed in the next section in the specific context of carbon taxes and tradable emission permits.

Carbon taxes and tradable emissions permits

Taxes and permits in theory

Carbon taxes and tradable permits are two tools for achieving emission goals

It is increasingly accepted that economic instruments are more effective than regulations for controlling pollution externalities, including those associated with greenhouse gas emissions. In a nutshell, economic instruments allow firms and households to meet environmental goals in a least-cost way, whereas regulations often lock in technologies or market practices that turn out to be inefficient.

The two economic instruments most actively considered in the context of global warming due to CO_2 emissions are carbon taxes and tradable permits to emit carbon.[3] Carbon taxes would raise the cost of emitting, thereby providing an incentive to abate. If carbon taxes were uniform (per ton of carbon emitted), then this incentive would act to equalise the marginal cost of abatement across countries, industries, firms and plants. The same incentive would operate in the case of permits, but would be less direct. Permits would be issued allowing emissions of a fixed amount of carbon, with the total amount equal to the emission-reduction target. Decisions on abatement would depend on the market price of the permits: at any price, those with relatively high abatement costs would prefer to buy permits and increase emissions, whereas those with low costs would find it profitable to sell permits and abate more. In a well functioning market, this process would continue until marginal abatement costs in each country (and industry, and so forth) equalled the world price of permits.

But they differ in terms of how the costs of abatement are distributed

Thus, both taxes and permits would yield the same economically efficient outcome, at least in theory. They differ in other respects, however. Consider first the issue of the distribution of the burden of abatement costs: equalisation of marginal

3. Energy taxes have also been proposed. But compared with carbon taxes, they would tend to shift the burden away from high-carbon energy sources, such as coal, to low-carbon ones, such as natural gas and even hydroelectric and nuclear power. From the point of view of climate change, therefore, they would be more costly.

abatement costs would result in developing countries bearing more of this burden than would equi-proportionate reductions, and even the latter might impose an unacceptable burden on them. This burden could be shifted, however, through a system of international transfers, which would probably have to be quite large. Such transfers could be implemented in either a tax or a permit system. In the case of a carbon tax, they would have to be explicit. In the case of permits, however, redistribution would be implicit in the initial distribution and subsequent sale of permits. The effects of an abatement programme on national incomes would then depend on both the amount of abatement undertaken (which would affect GDP) and the explicit or implicit transfers (Box VII.3).

They also differ because of uncertainty about the costs of abatement...

A second difference between taxes and permits involves uncertainty. The marginal abatement costs of countries, industries, firms and plants are not known to governments with certainty and there are obvious incentives for emitters to exaggerate them. A carbon tax adds a known amount to the cost of emitting and thus would pin down the marginal costs of abatement. However, the amount of abatement cannot be known with certainty *ex ante*: for example, if marginal costs rose faster than governments had expected, then the point at which the marginal cost of abatement

Box VII.3.

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 percentage points on average (equivalent to the amount needed to stabilise emissions of Annex I countries). This is assumed to be achieved by applying a uniform carbon tax or a system of tradable permits.

The first panel in the table reports the real income effects of a uniform carbon tax applied without any redistribution of 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 initial allocations of tradable permits. Under the "grandfathering" rule, developing countries would lose more than under the scenario with no redistribution. The "redistributive" rule favours poor populated countries, like China and India. The right-most panel shows the effects of an alternative scheme of redistributing part of the revenues of an international carbon tax fund.

Real income changes and international redistribution

	No redistribution	Tradable permits		Carbon tax with redistribution[3]
		Grandfathering[1]	Redistribution[2]	
OECD	–0.25	–0.30	–1.00	–0.69
Former Soviet Union and Eastern Europe	0.27	1.80	–2.05	–2.27
China and India	–1.08	–1.60	3.30	2.03
Rest of World	0.06	0.07	0.04	0.04
Annex I	–0.20	–0.10	–1.10	–0.84
Major emitters	–0.35	–0.36	–0.35	–0.35
WORLD	–0.25	–0.25	–0.25	–0.25

1. Permits allocated on the basis of past country/region's emission shares.
2. Permits allocated in inverse proportion to country/region's GDP per capita, scaled by population size.
3. 75 per cent of tax revenues are diverted and redistributed according to population size.

Source: Based on Coppel and Lee(1995).

equalled the tax would be reached at a lower level of abatement than planned. By contrast, limiting emissions through permits would make the level of abatement much more certain, as it would simply be the number of permits issued, enforcement issues aside. However, the cost of achieving that abatement would not be certain.

And public-sector involvement is different

A third difference involves the role of the public sector. In both cases, there are important issues of monitoring and enforcement (tax collection in one case and emissions in excess of permits held in the other). However, for a tradable emissions permit system to deliver the desired result, there must be an active and efficient secondary market for permits. As discussed in the next sub-section, the limited practical experience with permits suggests that a relatively large number of traders and minimal governmental regulation of trades both help to ensure a "deep" market and low transactions costs.

The experience with taxes and permits

Some European countries have carbon/energy taxes

The experience in OECD countries with taxes explicitly designed to reduce CO_2 emissions is limited: Denmark, Finland, the Netherlands, Norway and Sweden have introduced carbon or energy taxes. Mixed carbon/energy taxes have been applied in some cases, and all schemes have many exemptions, often concerning electricity, heavy industries and companies with high energy intensity or operating on competitive international markets. The fact that most countries have implemented differentiated taxes across sectors and users is an important departure from the principle of a uniform tax that would minimise overall abatement costs.

The United States has implemented tradable permits, notably for sulphur dioxide emissions

There is essentially no experience with tradable permits in the context of CO_2 emissions, and experience in other areas is restricted to the United States. The largest and most successful programme is the US sulphur dioxide (SO_2) allowances programme, started in 1995, which aimed to cut emissions by 40 per cent relative to 1980 levels. In Phase I, which concerns 110 coal-fired electricity generators, transactions costs have been low and substantial trading has taken place, both between and within companies. Two other programmes – emission-reduction credits (covering a range of air pollutants) set up in 1990 and water effluent permits begun in 1997 – have been rather less successful.

A key difference between the SO_2 programme and the others is the degree of government involvement in the permit-trading market. In the SO_2 programme, the government plays essentially no role beyond issuing the permits initially and ensuring compliance. But in the emission-reduction credit programme government approval was needed for trades. Such approval took between five and twelve months to obtain and 40-per cent of proposed trades were rejected. Likewise, each trade needed government approval in the water-effluent programme. This approval process appears to have raised transactions costs to the point where little market activity occurred and so little savings were realised. Another difference is the number of participants. In the case of the water-effluent programme in particular, there were few participants, which limited the number of trades and may have led to strategic or monopolistic trading actions.

US experience suggests permits work best when transactions costs are low and markets liquid

Finally, so-called joint implementation projects, which are provided for under Article 6 of the Kyoto Protocol, are a limited form of emissions trading. Joint implementation projects are bilateral agreements in which one party finances emission-reducing investments in another in exchange for a relaxation of its own abatement efforts. Experience with such projects has been limited to small pilot projects between countries (Mexico and Norway; Netherlands, Poland and India). The Kyoto Protocol allows such projects between "legal entities", not just countries. 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 to a baseline. Such an assessment is highly uncertain and subject to a large deal of contention. Thus, transactions costs are likely to be high unless investor confidence is reinforced by monitoring, information-gathering (clearinghouse, brokers, and the like) and indemnifying institutions.

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