Climate Strategies

Rejecting Kyoto

Final revised edition

A study of proposed alternatives to the Kyoto Protocol

Benito Müller,

Axel Michaelowa,

Christiaan Vrolijk

Additional contributions from
Michael Grubb and Roger Fouquet

HWWA HAMBURG

THE ROYAL INSTITUTE OF INTERNATIONAL AFFAIRS

About this report

This report forms one of three research projects convened by Climate Strategies in immediate response to the collapse of The Hague negotiations in November 2000 and the subsequent statements by the new US Administration rejecting the Kyoto Protocol. The companion report, "Keeping Kyoto - A study of approaches to maintaining the Kyoto Protocol on Climate Change", examines the issues raised by, and the prospects for, maintaining the Kyoto Protocol. The third study, "Carbon sinks and biomass energy", addresses technical issues surrounding the treatment of carbon sinks, and linkages to the use of carbon sinks in the form of biomass energy; the main study is not published as hard copy but is available from the Climate Strategies website. This report is a collaborative venture between the named authors, convened by Climate Strategies.

The views and judgments expressed are the collective responsibilities of the named authors and do not necessarily imply endorsement by other members of Climate Strategies. Members of Climate Strategies were given opportunity to comment upon the drafts, but carry no responsibility for the final material in this report.

About the authors

Dr Benito Müller is a Senior Research Fellow at the Oxford Institute for Energy Studies, which he joined in February 1996, a member of Oxford University's Philosophy Faculty and an Associate Fellow of the University's Environmental Change Institute and of the London based Royal Institute of International Affairs. His work in the field of climate change has focused on socio-economic and political issues, in particular issues of equity in allocating emission targets and in burden sharing. He has co-authored a major study on the impacts of the climate change regime on global fossil fuel markets, and has written analytic pieces on the US climate policy scene and the potential for US ratification of the Kyoto Protocol.

HWWA HAMBURG

Axel Michaelowa is head of the Programme "International Climate Policy" at the Hamburg Institute of International Economics in Germany. He has been analysing climate policy issues since 1994 and focuses on the design of the Kyoto Mechanisms. The rele-vance of interest groups on different levels of climate policy is another field of interest. Linking academic research, policy proposals and consulting of companies is a declared aim of Michaelowa´s programme.

THE ROYAL INSTITUTE OF INTERNATIONAL AFFAIRS

Christiaan Vrolijk is a Research Fellow of the Energy and Environment Programme at the Royal Institute of International Affairs, Chatham House London. His research looks at international negotiations, in particular the Kyoto mechanisms and emission reduction policies in the power sector in Europe. His work includes modeling the Kyoto mechanisms, the relationship with Russia and the CDM.

IGES Institute for Global Environmental Strategies 財団法人 地球環境戦略研究機関

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PREFACE

This study was conceived in the aftermath of the announcement by President Bush that he rejected the Kyoto Protocol. Shortly afterwards, the US Administration announced that it would come forward with constructive proposals for an alternative approach to the climate change problem, indicating that these could be expected before the next major global negotiating session, which had already been deferred until mid July 2001 to accommodate the original request from the new Administration to give them more time to prepare.

Given this situation, *Climate Strategies* decided to convene an exploration of what such alternatives might entail, so as to be better able to provide informed comment on proposals that might emerge. In the event, the US Cabinet Review published on 13 June 2001 gave no indication of what alternatives might be proposed, and at the international consultations on 27 June the US representative stated that the US would not after all be proposing any alternative before the next negotiating session.[1]

The Bonn Agreement secured in July 2001 makes it more likely that the rest of the world will proceed with the Kyoto Protocol; a companion *Climate Strategies* report presents the case for doing so.[2] The uncertainties have, however, given fresh impetus to debates about alternative approaches, and that is the focus of this report. Some of these debates remain relevant not only to the question of whether proceeding with Kyoto is the right course. The analysis in this report also aims to help understand the difficulties of crafting alternatives, of the kinds of approaches that the US may seek to foster outside of the Kyoto system, and of the ideas that may still be useful in elaborating what has already been and in approaching future dimensions, potentially including expansion of the Kyoto core and the design of second period commitments.

One kind of proposal that has been presented as an alternative to Kyoto, namely to focus upon longer term targets, is in fact not structurally different from the Kyoto agreement, which does require countries to negotiate longer term targets in the future. Whether or not countries should sign up to the nearer-term, first period commitments under Kyoto, irrespective of US participation, is a separate question that we analyse in our companion report *Keeping Kyoto.* The options for longer term targets that might be negotiated at future dates is a distinct, and hugely important, topic for debate on which Climate Strategies hopes to publish in the future.

This report however focuses upon proposals that, at least at first sight, are structurally different from Kyoto. It also considers the thinking that has underpinned the Administration's rejection of the Kyoto Protocol, and in particular the reasons which the US Administration has given for claiming that the agreement is unfair, and hence that will influence the nature of any proposals that the Administration might seek to bring forward in the future.

It would have been hard to find anyone better qualified than Dr Benito Müller to lead such a study. Dr Müller gained his PhD in philosophy, and since joining the Oxford Institute for Energy Studies he has focused upon climate change as one of the most complex moral issues of our time - whilst also gaining a deep appreciation of the real world energy-economy issues that it raises. Trying to prepare concrete analyses of ideas that are rumoured or are available in different forms but not formally proposed, and also analysing the thinking which led to unilateral rejection of the only global negotiating framework, is not an easy task. Climate Strategies is deeply indebted to Dr Müller and his colleagues for their intense efforts in these difficult circumstances.

Michael Grubb
Head, *Climate Strategies*

[1] In this situation we took the unusual step of releasing, as a pre-publication copy for general distribution and commentary, a draft of this report and we are grateful for the subsequent comments received.
[2] M. Grubb., J.C. Hourcade, S. Oberthür, *Keeping Kyoto: a study of approaches to maintaining the Kyoto Protocol on Climate Change*, Climate Strategies, www.climate-strategies.org, July 2001.

EXECUTIVE SUMMARY

The United States administration's withdrawal from the Kyoto Protocol has placed an onus upon advocates of rejecting Kyoto to clarify what might form a credible basis and structure for an alternative international agreement. As companion to the 'Keeping Kyoto' study, this analysis seeks to shed some light on the main reasons for the US rejection and to examine some of the most prominent alternative proposals.

Prominent and long-standing American objections to the Kyoto Protocol are that it is ineffective and unfair to the US due to the lack of 'meaningful participation' by key developing countries; and that any agreement should also include concurrent commitments from these countries. Neither past, present nor projected business-as-usual emissions warrant these claims. No developing country is projected to surpass total US carbon emissions in the next 20 years. Furthermore, equity considerations have to be assessed in terms of 'average' inhabitants: emissions of the average US citizen are many times higher than, and are projected to continue growing faster than, the global average, while those of the average Chinese and Indian are below the average and will grow at the world average rate if not substantially below it. Many US analyses have also tended to amplify the likely costs of Kyoto, and most suggestions for simultaneous developing country commitments neglect commonly-held principles concerning the equity implications of large international income disparities as well as agreed principles of industrialised country leadership.

As of October 2001, there is no clear indication of what the US Administration might propose as an alternative global approach. There have only been tentative hints from the Administration concerning approaches that might be under consideration to alleviate US emission reduction obligations (and US costs). Some suggestions, such as voluntary non-binding targets or reliance solely upon agreeing specific policies and measures, regress to options already attempted and shown to be inadequate during the 1990s. The US research community has, however, discussed alternative options, which appear to fall into three main categories.

(A) ***Intensity targets*** focus upon emissions per unit GDP and thus allow emissions to expand with economic growth. However, they have a number of important drawbacks:

- They cannot guarantee the *environmental effectiveness* of the regime, even under global compliance;
- They pose much greater problems to running *efficient flexibility mechanisms* such as international emissions trading;
- Intensity growth rates are highly sensitive to the choice of *economic output measure* (such as exchange rate or purchasing power parity measures), and other problematic variables.
- While providing some measure of protection against curtailment of above-average economic growth, they can be *catastrophic in the context of economic recession;*
- If applied uniformly across a group of countries, they are tantamount to 'grandfathering allocations with growth'
- Given the current differences between the world's economies, they would almost inevitably be *regressive* in the North-South context and could also lead to considerable inequities between developing countries.

It may be possible to address some of these points by turning to some form of carbon indices (section 3.2). A global regime based on legally binding intensity targets, however, is unlikely to be either fair, effective, or find sufficient international approval to replace or succeed the Kyoto Protocol.

(B) ***Price cap*** proposals – allocating emission permits beyond the original emissions budget if permit prices reach a pre-determined level – are meant to address the US concern that costs under the Kyoto system could be unacceptably high. Varied, domestically determined price caps would preclude an internationally efficient system and lead to a race to the bottom. Attempts to implement an international price at which unlimited additional emission permits are available would have to resolve difficulties of comparison and equitable access (due to differences between exchange rates and purchase power parities); of deferment (price caps would have to be increased over time to avoid buying spikes at the end of a commitment period); and banking (which would have to be curtailed if higher market prices are expected for subsequent periods).

The crucial feature of a price cap regulation is the level of the cap. A low-level cap would amount to an international greenhouse gas emissions tax and can seriously harm the environmental effectiveness of a regime. Both domestic action and investment flows via the Kyoto Mechanisms would be considerably reduced. Model studies made under the assumption that the U.S. participates in an international regime show that for price cap levels below \$20/tCO_2 (\$75/tC) the amount of additional permits created is likely to be several percentage points of Annex B emissions budgets. The ensuing trade off between increased damages primarily in developing countries –due to a reduced effectiveness of the regime– and cost reduction for the parties responsible is inequitable and contrary to the general principles adopted under Article 3 of the Framework Convention.

On the other side, a high-level cap that never binds would avoid weakening the environmental integrity of the Kyoto regime and give an ex-ante security that costs will not pass a certain level. Such a cap would thus be an appealing policy instrument. The challenge would be to decide a sufficiently high cap on the international level under uncertainties about abatement cost levels and business-as-usual paths. The price levels and options most discussed in the US debate would certainly not be high enough. Intermediate-level price caps that bind from time to time can also be reconciled with overall environmental integrity of the regime, if revenues are recycled into abatement project categories that are not part of the Kyoto Mechanisms (e.g. avoided deforestation) and thus offer reductions at costs below the price cap.

For future commitment periods, price caps may allow to negotiate stronger targets, especially if experience from the first commitment period gives some indications about abatement cost levels.

(C) Deferred abatement and technology-focused approaches. Because climate change is a long term problem and improved technologies undoubtedly will play a key role in long-term solutions, some analysts suggest that emission constraints should either be delayed until better technologies become available, giving time for the international community to ‘regroup’, or abandoned altogether in favour of an approach focused upon technology development and standards.

The economic arguments over timing in fact point to the need for balance in the degree and rate of abatement, not its deferral: as well as increasing the rate of climatic change over coming decades, deferring abatement would both undermine incentives for technology development and risk entrenching additional investment in carbon-intensive capital stock.

Furthermore, the complexity of the climate change problem renders an approach focused purely upon technology development and standards inefficient and probably ineffective. No specific approaches have been proposed which would yield credible paths and incentives to mitigation across the diversity of sources contributing to climate change, and history cautions against government-led R&D programmes as a *primary* driver of technological change in the absence of market incentives. In addition, technology standards have long been recognised as an inefficient approach to broad-based environmental policy, as well as potentially inequitable in the international context. At the same time, the debates on technology do help to highlight its importance and technology policies could have an important complementary role in facilitating stronger and cheaper abatement action over time, a role which is underdeveloped in the Kyoto system to date.

Thus, whilst elements of all these proposals may contain ideas for, say, the future development of the Kyoto system, none of them offers a credible replacement, and we find no grounds for believing that a concrete, credible and fair alternative, acceptable to the international community as a basis for negotiation, is likely to emerge.

1. INTRODUCTION

Proposals for alternative approaches to structuring an international agreement fall into several categories. One approach suggested has been to focus upon coordinating policies and measures, rather than establishing emission targets. In fact, early in the Kyoto negotiation process, considerable time and energy was expended upon trying to negotiate coordinated policies and measures. The approach was led by the EU and very strongly resisted by the US, and other countries. These countries argued that coordinating policies and measures would be inefficient because it would not adequately reflect national diversities, and would infringe upon national sovereignty regarding the appropriate choice of policy instruments. The very limited scope of policies and measures proposed in the US Cabinet Initial Report does not give any indication that such an approach could prove any more effective as a primary focus of negotiations than it did in the past. The Protocol does contain an Article that could form a basis for coordinating policies and measures, in the context of the quantitative emission targets, and the debate is not revisited in this report. Nor does this report address proposals to adopt indicative, non-binding targets, such as those established in the UN Framework Convention and already accepted as inadequate.

Some commentators more favourable to the general framework of emission cap targets have proposed alternative specific approaches to targets. Many US commentators suggest that the main problem with the Protocol is that its first-period targets are too soon, and too tight, to be realistic for the US. Other commentators set out other visions, such as proposals for per-capita convergence of global emission allowances over longer periods.[1] As explained in our companion report, these proposals are not necessarily inconsistent with 'Keeping Kyoto', but rather imply starting debate upon approaches to second and subsequent commitment periods. Hence they also are not considered in this report.

In pursuing the issue of what the US administration might propose as a 'global alternative' to the Kyoto Protocol, this study follows up some tentative indications in the Initial Report[2] and recent statements by US officials. It focuses on three prominent alternatives which have featured in the American debate for some time, namely targets framed in terms of *emission intensities* (Chapter 3), targets made flexible through *caps on the price of emission permits* (Chapter 4), and technology-oriented approaches which it is considered could either defer the need for quantified emission limits or replace them entirely. (Chapter 5).

To begin with, however, the study addresses in Chapter 2 one of the most prominent stated reasons why the Kyoto Protocol was rejected: its *unfairness* to the US due to the exclusion of developing countries in general, and China, in particular.

Having rejected the Kyoto Protocol as 'fatally flawed' for its failure 'to include key developing countries,' the Bush administration has left no doubt that a redress of this 'lack of meaningful global participation' is one of the key elements in their promised Kyoto alternative:

> Climate change is an issue that must be addressed by the world. Even with the best science, even with the best technology, we all know the United States cannot solve this global problem alone. We are building partnerships within the Western Hemisphere and with other like-minded countries.

[1] This is also an extremely complex debate in which there are several options even concerning the basic structure that might form a negotiating agenda (Philibert and Pershing, 2001). The complexities of finding an alternative to Kyoto are such that some leading analysts consider the most likely scenario for some years to be national actions without a significant global agreement (Jacoby and Reiner, 2001).

[2] United States government climate change programs are achieving real results, helping to reduce greenhouse gas emissions by 66 million metric tons of carbon equivalent in 2000. United States carbon intensity declined 15% from 1990 to 1999

The NEPD Group recommended that the President direct the Secretary of Energy to establish a national priority for improving energy efficiency. The priority would be to improve the energy intensity of the U.S. economy as measured by the amount of energy required for each dollar of economic productivity. This increased efficiency should be pursued through the combined efforts of industry, consumers, and federal, state, and local governments

> The President has directed the Cabinet-level climate change working group to press forward and develop innovative approaches in accordance with several basic principles. These approaches should … be based on global participation, including developing countries.

However, apart from these programmatic statements, there is very little in the recently published initial report of the US Cabinet Climate Change Policy (the 'Initial Report') on how the current US administration envisages to engage developing countries in such a global participation. The issue of 'meaningful participation' by developing countries –to use American political jargon– is, of course, not new at all and will presently be discussed in some detail (Chapter 2). The overriding question here has to be what exactly can the international community expect to be proposed as a Kyoto alternative by the US administration?

The Initial Report does contain a section dedicated to international actions, entitled 'Promoting Cooperation in the Western Hemisphere and Beyond.' However, the actions proposed are essentially focused on a hemispheric Pan American perspective ('Promoting Cooperation in the Western Hemisphere').[3] As concerns the 'And Beyond', the key recommendations are

- Revitalize U.S. efforts to assist developing countries to acquire the tools and expertise needed to measure and monitor emissions.
- *Promote the export* of climate-friendly, clean energy technology.

One of the few other concrete recommendations concerning international collaboration is included in the proposed Climate Change Research Initiative, which:

- Challenges the major greenhouse gas emitting countries to increase significantly their investments in high priority areas of climate change research

This could be significant for the developing world as the demand for increased spending is not limited to OECD or indeed to Annex I countries, but covers –according to an Initial Report table– China, Russia, India, South Korea, Mexico, South Africa, and Indonesia.[4]

The bulk of the Initial Report is dedicated to domestic policies and measures based on voluntary public private partnerships, a National Climate Change Technology Initiative (NCCTI) and an initiative to promote climate science.

The policies and measures put forward in the NCCTI and the National Energy Policy are estimated to achieve less than 0.5 percent reduction of carbon dioxide emissions by the end of the current decade while, at the same time, US emission levels in 2020 may actually increase by up to 5 percent over current 'business-as-usual' projections if the administration's National Energy Policy proposals for the power sector are implemented. It is unlikely that the proposed domestic programme will be able to stabilise the American greenhouse gas emissions in decades to come, let alone return them to 1990 levels, as already required under the Framework Convention on Climate Change.

[3] The Initial Report is actually quite modest in its recommended climate change actions even within the Western Hemisphere, namely 'Build on the recently signed CONCAUSA declaration with Central America', and 'Strengthen and expand scientific research within the Western Hemisphere'
'EPA Administrator Christie Whitman proposed holding talks with Mexico and Canada on greenhouse gas emissions, following criticism of U.S. rejection of the Kyoto accords on the same issue. … she said the three countries will ``look at what kind of market-based approaches we can undertake to address the greenhouse gas issue."'[*New York Times*, 29 June 2001]

[4] 'President Bush … wants to cut U.S. aid for Third World countries' global warming efforts, according to a White House report. While asking Congress for nearly $4 billion to address climate change, roughly the same as last year, Bush proposes reducing assistance to other countries by $41 million from last year's $165 million. He calls for shifting more responsibility to private industry.'[*Washington Post*, July 7, 2001; Page A05]

2. FATALLY FLAWED INEQUITY[1]

2.1 Introduction

From the very beginning, American policy debate on the Kyoto Protocol has been dominated by persistent accusations of unfairness to the United States and its citizens. In his opening statement of a hearing by the US House of Representatives Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs[2] –'The Kyoto Protocol: Is the Clinton-Gore Administration Selling Out Americans? Part III', 20 May 1998– Chairman David M. McIntosh, for example, declared that the Kyoto Protocol…

> is also patently unfair because it exempts 77 percent of all countries from any obligations. China, India, Mexico, and Brazil, just to name a few, are completely unfettered by the Treaty – these countries already have the competitive advantages of cheap labor, lower production costs, and lower environmental, health, and safety standards. If President Clinton has his way, now these countries will be free to develop and pollute all they want, while the U.S. economy goes into a deep freeze.

Exactly a year later, before the same body, a fellow Michigan Republican House member –Rep. Joe Knollenberg, by then well-known in climate change circles for 'the amendment'[3]– reiterated this sentiment:

> This fatally-flawed agreement [the Kyoto Protocol] is blatantly unfair because it exempts developing nations from making any commitment to reduce their emissions of greenhouse gases. As a result, nations like China, India, Mexico, and Brazil, [...] will be given a free pass while the United States is forced to struggle with the Kyoto treaty's stringent mandates.

On 13 of March, president Bush reiterated:

> As you know, I oppose the Kyoto Protocol because it exempts 80 percent of the world, including major population centers such as China and India, from compliance, and would cause serious harm to the U.S. economy. … there is a clear consensus that the Kyoto Protocol is an unfair and ineffective means of addressing global climate change concerns.[4]

These charges of inequity have to be taken seriously, for there is arguably nothing more discrediting to any piece of legislation than to be perceived as being unfair. Indeed, the president's remarks heralded the withdrawal of the US from the Kyoto Protocol.

2.2. A Variety of Arguments

Various arguments have been advanced as to why the Kyoto Protocol is to be branded as 'unfair' towards the US but, as witnessed above, they all seem to reduce to what in the jargon has become known as 'the lack of meaningful participation' of developing countries – their not being subject to emission reduction targets. The argument that this 'lack' creates an unfair situation rests on two presuppositions:

Claim 1. In the near future, main developing countries are going to be worse emitters than the US.

Claim 2. Under the Protocol, the US will be ruined while developing countries get away scot-free, if not better off.

Indeed, in some circles of the American policy debate, these positions have practically become a matter of orthodoxy. The injustice is taken to arise from the lack of 'meaningful participation' because America is being punished while others, who, it is claimed, will be much worse offenders are not –

[1] This part is based on a paper by Müller first presented at the World Bank Climate Change Day, Washington D.C., June 2001.

[2] http://www.house.gov/reform/neg/hearings/

[3] Popularly referred to as "the Knollenberg Amendment", this provision in the 1999 VA-HUD Appropriations Bill prohibits the appropriation of funds 'for the purpose of implementation, or in preparation for implementation, of the Kyoto Protocol'.

[4] 13 March 2001; http://www.whitehouse.gov/news/releases/2001/03/20010314.html

indeed, may even benefit. Or, paraphrased from the US perspective, 'we are going to be punished for becoming more virtuous'. The inequity felt will be particularly strong if, as implied by the second claim, the punishment is seen to be disproportionately large. But are these two key premises of the US Kyoto rejection actually defensible or do they belong to the realm of politicised myth?

Ignoring the Past. The differentiation between countries with and those without targets in Kyoto's first commitment period essentially reflects the 'Annex I' classification of the Framework Convention, which, in turn, relies on the principles of *historic responsibility* and *ability to pay.* The two orthodox claims put into question, or neglect, these very principles. Part of the orthodox argument from 'lack of meaningful participation' to inequity is the presupposition that –in assigning emission caps (= potential economic burdens)– it is unfair to differentiate between past and future responsibilities for the problem. Indeed, in light of past ignorance concerning the adverse effects of the emissions in question, the orthodox line can even go as far as demanding that, in fairness, *only* future performance should be taken into consideration. While fundamentally disagreeing with this view, let us for argument's sake suggest we concede the point and analyse the two claims from within their own framework, as it were. In other words, let us for argument's sake disregard the past and begin by comparing projected American and developing country behaviour as carbon emitters, in order to see for ourselves who is actually going to emit the most carbon.

2.3 Per Capita Methodologies

The use of per capita figures has led to some controversy in the climate change debate, but there seems to be little doubt that national wealth or welfare comparisons ought to be carried out in per capita terms. No one in their right mind would argue that Switzerland is a much poorer nation than the US because of the fact that American GDP is almost fifty times larger than the Swiss one. And it is difficult to see how any comparison other than in per capita terms could be appropriate in this context.

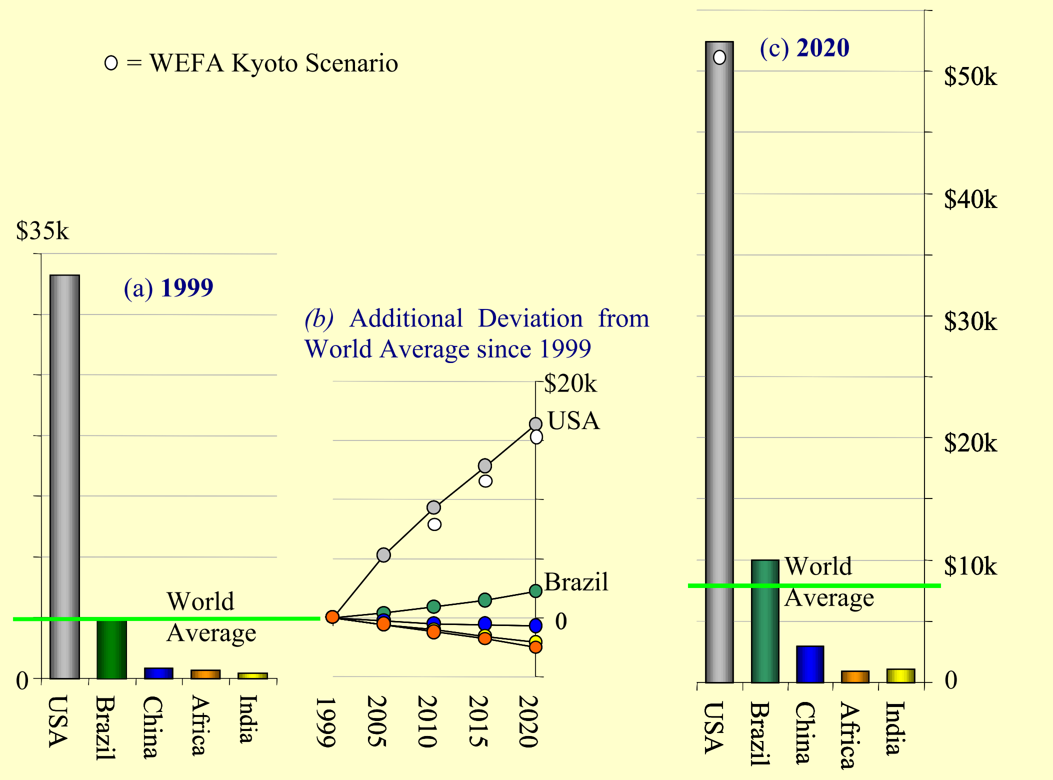


Figure 2.1: Per Capita GDP Projections. 1999-2020 ('000 US 1997 $)

Source: EIA *IEO*01, WEFA 1997

Many developing countries are currently experiencing –and are projected to experience– GDP growth rates significantly higher than those of the industrialised world. Does this mean that over the time-horizon, it would be unfair if they were not to carry an increasing share of some 'common but differentiated' burden? To give a reasoned answer we need to consider not only the size of burdens relative to the wealth levels but also the proportions of the latter to one another.

Consider, again, the US and the main developing countries (with Africa representing least developed nations). Given the current wealth polarisation –reflected in Figure 2.1.a– it would be difficult to argue for a 'North-South transfer' of anything but a truly crippling American burden, even if the relative difference in GDP growth rates would imply that developing countries are 'catching up' with the US.

And yet, to be quite sure, no such catching up is projected to happen. Figure 2.1.b depicts the evolution of the wealth gap between the US and the key developing countries/regions over the next two decades –as projected by the EIA.[5] Industrialised countries are projected to become much wealthier, not merely in absolute terms (57 per cent increase in real GDP/cap) but in terms relative to the rest of the world. In light of this projection, the only hope for the orthodox view that developing countries are not carrying their fair share of the burden under the Kyoto Protocol must be the claim that somehow they better themselves unfairly because 'the U.S. economy goes into a deep freeze'. But what could that possibly mean?

Given the existing wealth differences, it is difficult to see how any of the main developing countries could actually surpass the US in GDP/capita terms within the next 20 years, Kyoto or no Kyoto. The orthodox argument may thus have to rely on the rather dubious premise that the burden distribution of Kyoto would be unfair if Kyoto were to allow developing countries to gain on the US. Unfortunately for the orthodox view, not even this can be upheld (see also the Appendix).

The fact is that even under the highest cost estimates –such as the ones of the 1998 'WEFA Kyoto Scenario' (WEFA 1998)– US per capita welfare is still projected to grow at significantly above-average rates (Figure 2.1) without a reversal in the widening welfare gap. Indeed, the projected 'deep freeze'[6] amounts *at worst* to nothing more than foregoing about a year's economic growth. Such estimates however are in themselves substantially exaggerated (see Section 2.4)

Interestingly, this line of argument has a lesser-known 'cousin'[7] concerning CO_2 emission, bringing us back to the orthodox emissions claim (Claim 1), which we have so far considered in national aggregate terms.[8] And it stands to reason that in this context, aggregate figures are not appropriate.

For one, if aggregate emission figures of country groupings were taken to be decisive as to who had to take remedial action first, then it would not take a lot of ingenuity for countries to figure out that –as long as their own emissions do not amount to more than half of the world's total– they could always point at others with the justification that 'the rest of the world emits more than our country does.' But why should any of these other countries assume 'first-actor-responsibility' just because it was artificially grouped together with other countries over whose emission policies it has had no control? Why should Belize (74MtC in 1999) have an obligation to start mitigating actions at the same time as –or, strictly speaking, even prior to– the US, just because it belongs to a collection of independent

[5] It must be emphasised that the numbers represented in Figure 2.5.b exclude current inequalities; they merely reflect future projected increments on top of them. For example, in 2020, the USA is projected to have a per capita GDP $44.5k above the 2020 world average of $7.8k–$28k (current difference, Fig. 2.3.a) + $16.5k (projected increment, Fig. 2.3.b) – while Africa is projected to slip further from its current $4.5k to $7k below average. Indeed not even China, with its very impressive aggregate growth rates will be able to keep pace with world average wealth: it is estimated to slip a further $680 from its current $4,200 below global average by 2020.
[6] Rep. McIntosh was indeed referring to the WEFA figures.
[7] Related by way of energy use in fossil fuel economies.
[8] 'Aggregate' is used here to refer to measures pertaining to countries as a whole, as opposed to per capita measures that pertain, as it were, to their average citizen. Naturally, all the distinctions made in the context of aggregate measures (absolute, relative, increment and cumulative) can equally be applied to per capita measures.

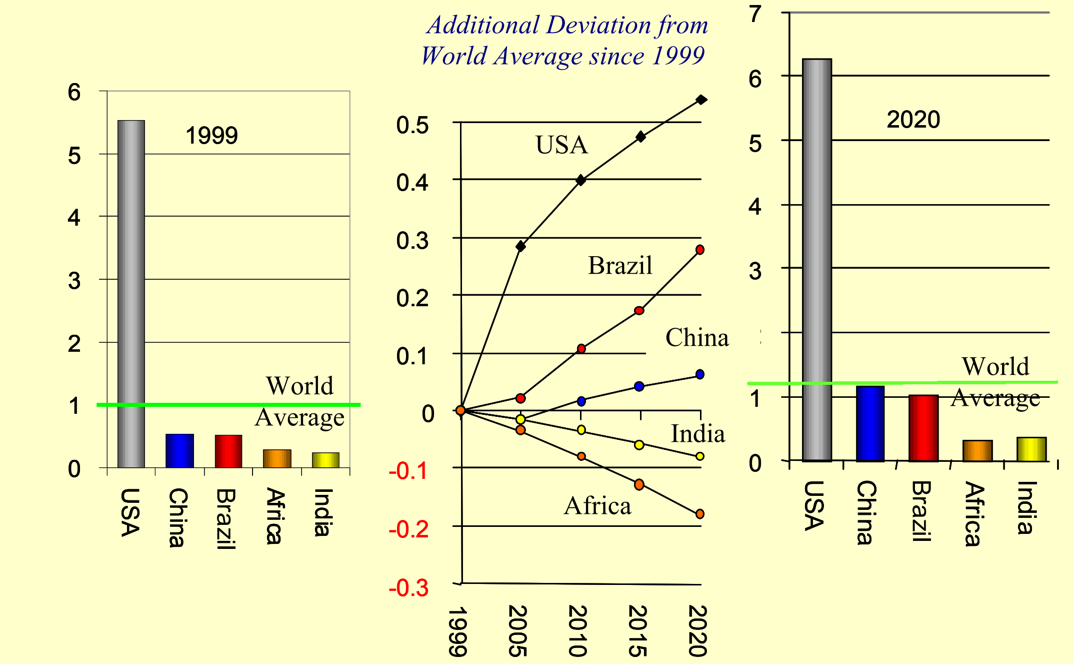


Figure 2.2: Per Capita Carbon Emission Projections. 1999-2020 (tCe)

Sources: China = Sinton and Fridley 2001, Others = *IEO*01

sovereign countries which collectively just happen to emit more than the US? Clearly such reasoning would have to be rejected.

In the absence of having available some grouping with higher aggregate emissions than oneself to justify a refusal to provide mitigation leadership, large emitting countries might be tempted, as mentioned above, to bring into play other large emitters who are either close second to their own aggregate emissions, or are seen as becoming the lead emitters in the near future. However, for reasons similar to the 'Sending-Aid-To-Switzerland' example mentioned above, such a comparison is only legitimate under *ceteris paribus* conditions. Should these not apply, then there is one equitable way to judge national emission behaviour, namely in terms of the average inhabitant's emissions.

Figure 2.2 shows US *per capita* emissions continue their substantial rise relative to the global average by adding on an increment of almost half a ton of carbon equivalent, rising from 4.5tCe (1999) to 5tCe (2020) above average. It is difficult to see how this sort of emission behaviour could possibly be described as 'restrained' in comparison with developing countries, in order to justify the orthodox emission claim.

If anyone can be said to have 'restrained' relative emission trends it would have to be India and the least developed countries of Africa with per capita emissions which continue to fall further and further below the global average. The CO_2 emission gap between least developed countries and Annex I parties in general, and the US in particular, is not only projected to grow considerably over the time horizon, but the growth is in opposite directions from the world average.

The point of this description is not to argue that the projected business-as-usual world averages are somehow setting a standard that is to be aspired to. Far from it, as they are clearly not sustainable and have to be revised downwards. The point is simply to highlight the fact that there is a natural criterion as to who ought to take precedence in bringing about such a revision –namely, whoever displays more profligacy in their projected emission pattern– which makes the American claim for simultaneous developing country mitigation commitments indefensible even if one chooses to ignore historic responsibilities.

Box 2.1. The Energy Information Administration GDP Cost Estimates Cited in the Cabinet Review

The EIA study was made at the request of the US House of Representatives' Committee on Science to analyse the impacts of the Kyoto Protocol on the U.S. economy. This contained various scenarios and costs that vary widely, of which the US Cabinet Review cites a 4% The high-cost result was acknowledged in the EIA report to be an effect of both high short-term adjustment costs and how the money flows are represented. To meet the target, a reduction in total US CO_2 emissions of over 30% is required over the 3-year period 2005-2008 because of two factors:

- the high baseline growth of CO2 emissions from 1990 to 2005 and
- the (assumed) delay in taking action until 2005

The 30% cut starting in 2005 requires a massive and sudden adjustment in energy structures. Using the same model, the EIA reported that if the economy is allowed much longer to adjust, the costs fall from 4.2% of GDP in 2010 to 0.8% in 2020 given other assumptions the same. The period from the agreement on Kyoto in 1997 to the end of the first commitment period is in fact 15 years, and the agreement contains numerous other flexibilities including multiple gases, carbon sinks, and the international mechanisms.

Furthermore, even with modelling the sharp 2005-2008 reduction for CO2 alone, the scale of the adjustment costs depend critically on the form in which the revenues are recycled: the cited costs in the EIA report for this shock treatment are themselves reduced from 4.2% to 1.9% of GDP simply by recycling the revenues through reductions in social security tax rebates. It is also clear from the detailed macroeconomic results that the increase in costs is associated with a large increase in overall consumer prices, as a result of the increases in costs of energy. An alternative way of recycling revenues may be even less costly, e.g. the revenues could be used to reduce sales taxes, thereby reducing consumer prices and offsetting the energy-price increases.

2.4 Economic Appraisals[9]

Concern about the high costs for the US economy of reducing emissions was one of the reasons given by the Bush administration for rejecting US ratification of the Kyoto Protocol. One of the highest estimates in the literature, a 4.2% reduction in US GDP for the 'Kyoto target', was included as a sensitivity study in a 1998 by the US Energy Information Administration (EIA) and cited in the US Cabinet Review. Similarly high estimates by industry consultants WEFA gained press prominence in 1998 (WEFA, 1998). Such estimates are more than twice the highest estimate of 1.9% of GDP in the 16 studies organised by the Energy Modelling Forum (EMF-16) on the costs of Kyoto (Weyant & Hill (1999)).

The assumptions that lead to figures as high as a 4% GDP loss in fact have no connection to the real Kyoto commitment: they are purely artificial constructs designed to generate high costs or to test assumptions on implementation that bear no relation to the agreement as signed (see Box 2.1). The EMF-16 estimates of about 2% GDP loss are also implausibly high, mainly because of the assumptions adopted. All the studies use carbon emission permits as the instrument for mitigation and therefore yield implicit carbon tax rates to achieve the targets, yet none reflects the gains available from efficient use of these revenues, and all set aside any environmental benefits. Even revenue recycling alone has been shown to substantially reduce costs.[10]

Furthermore, the higher cited results do not make allowances for the various hard-won flexibilities in the Kyoto Treaty. The international trading of emissions permits is shown by the EMF-16 studies to reduce costs by about half, with the highest costs with full Annex I trading falling to about 1% of GDP. In addition in all the studies there is only a very limited and stylised treatment of the other flexible mechanisms JI and CDM, of the non-CO2 greenhouse gases, and of carbon sinks, all of which can further reduce costs. The economic modelling community has responded to the challenge of assessing the economic effects of complying with Kyoto targets in two ways. The first way has been to

[9] This section owes substantially to Dr Terry Barker, Cambridge University Department of Applied Economics.
[10] If revenues are used instead to reduce some distortionary tax, then costs may also go down, as in the EIA study. Another example of such a tax switch is given in the Jorgenson & Wilcoxen 1993 study in which a 1.7% GDP loss under lump-sum redistribution is converted to a 0.7% loss by reducing labour taxes or to a 1.1% gain by reducing capital taxes.

see Kyoto targets for mitigation as an opportunity for beneficial change. It has sought out various low cost opportunities and potential benefits, aside from the primary benefit of mitigating climate change.

The second way of responding has been essentially to see Kyoto as a threat. The starting point of much of the theoretical and empirical work has been the belief that the economy is at an optimised equilibrium. Global warming is not accepted as an externality, so that any carbon tax becomes an economic distortion to the equilibrium and is inevitably costly. Opportunities for cost reductions and the hard-won flexibilities in the Kyoto agreement are often poorly modelled – albeit sometimes because they are genuinely difficult to model realistically – and commentators draw on the model runs that omit the flexibilities altogether. This latter approach has sought to examine the costs, usually in terms of loss of GDP or “welfare”, but has rarely sought to explore any benefits with the exception of emission-permit trading.

Much of the EU modelling has adopted the first approach, encouraged by the European Commission’s requirements to use tax revenues to reduce employment taxes since many countries in Europe have experienced high unemployment rates in the 1990s. Many studies have reported benefits for EU GDP from reducing greenhouse emissions.

US modelling studies have tended to adopt the second approach, partly because the US economy has been much closer to full employment. They have reported much higher costs, choosing metrics such as trillions of dollars rather than percent of GDP or differences in growth rates of GDP that give the impression of large costs, as well as assumptions that sometimes inevitably lead to costs.

Such sustained differences in approaches, and their use by interest groups, have created hugely divergent perceptions. The treatment of cost analyses in the US debate, including frequent neglect of agreed cost-reducing measures, raises a possibility that the effort to accommodate US demands for cost reduction measures could be almost limitless, or might only be satisfied when an agreement is reached that would require virtually no action. An agreement that satisfied such US lobby interests and which appeased the most extreme analyses would be an agreement that resulted in negligible action. Ultimately the only way of proving that greenhouse gas limitation is not as expensive as some of these communities predict, and indeed that net gains are possible, is by going ahead and doing it – including both domestic implementation in Europe, and for example, by bringing Kyoto’s various mechanisms into force so that their operation can be developed, observed, and modelled more fully.

2.5 Conclusions

No developing country will surpass American carbon emissions in the next 20 years. As a matter of fact the average American’s emissions are projected to continue growing at a rate significantly above average, while those of the average Chinese and Indian will grow at the world average, if not substantially below it. Indeed, no traditional emission measure substantiates the claim that the main developing countries are going to be worse –let alone much worse– emitters than the United States by the time of the Kyoto Protocol commitment period (2010), or for that matter by 2020. This is not to say that developing country emissions will not have to be addressed at some point not too long from now. But it clearly exposes the fallacy in the orthodox argument for a rejection of the Kyoto Protocol according to which the US is unfairly being singled out for reform (or even punishment) while other offenders –who are as bad if not much worse– are let off the hook. This argument is plainly and simply no longer tenable, assuming it ever was in the first place.

The costs of implementing the Kyoto Protocol in the US might be considered politically inopportune, but no one can seriously claim that they are unfair, be it because of their magnitude or because of a lack of ‘meaningful developing country participation’. In short, even if we disregard the past, it is still not possible to justify the claim that America would be unfairly treated by the Kyoto Protocol ‘because it exempts 80 percent of the world’. Developing country emissions will have to be addressed at some point in the not too distant future, but it is unfair and morally wrong to use them as a scapegoat here and now.

3. Intensity Targets[1]

3.1 Introduction

This chapter looks at *intensity targets*, that is targets formulated relative to economic output, usually in terms of 'per unit of gross domestic product' (GDP). Although targets of this kind have not officially been proposed as a general alternative to the Kyoto regime, non-binding intensity targets have been used in proposals to expand this regime (Argentina[2]), a step which was generally perceived to be supported by the then US administration in its quest for 'meaningful developing country participation'. Moreover, given the positive performance during the last decade, American intensity improvements were highlighted in the recent initial report of the current US Cabinet-level Climate Change Policy Review. We thus feel these targets deserve a closer scrutiny within the frame of this report.

The focus will be on intensity targets in the context of greenhouse gas mitigation regimes, where they usually take the form of 'emission intensities', i.e. emissions per unit of GDP. However, many of the results in the initial general discussion are applicable to any form of intensities-of-economic-output. Section 3.2 deals both with some practical (including moral) issues and with some serious theoretical problems concerning the soundness of aggregate intensities. Section 3.3 then turns to empirical matters –in particular the performance of emission intensities under conditions of economic collapse– by looking at different country data for the last decade. Finally, section 3.4 looks at projected intensity performances and the issue of equitable differentiation.

3.2 General Considerations

- ***Intensity Targets and Emission Caps***

The Kyoto Protocol's mitigation regime relies on an *ex ante* specification of caps ('assigned amounts') on national greenhouse gas emissions during a pre-determined commitment period (2008-12). In light of the fact that historically, growing economic output tended to go hand-in-hand with increasing emissions, the fear has been voiced that –unexpectedly high– economic growth would inevitably run foul of such emission caps. Indeed, if the relation between emissions and economic growth were one of simple and immutable proportionality, then there would only be one way to remain below an emission cap once it is reached, namely to stifle growth. But, as shall be discussed in time, the relation between economic activity and emissions is neither simple nor immutable, which is why emission caps should not be dismissed out of hand on this premise.

Emission intensity[3] measures the relation between emissions and economic activity. When applied to countries, intensity is usually defined as national emissions per unit of gross domestic product (GDP). In the context of greenhouse gas mitigation regimes, intensity targets have been proposed as an alternative to *ex ante* emission caps with a view to avoid the latter's potential to stifle (unexpected) economic growth. These intensity-based mitigation regimes generally involve an *ex ante* specification of a target intensity for a commitment period, usually defined relative to the intensity of a (past or present) base-period.[4] To be quite clear, intensity targets *do* impose a cap on permitted emissions

[1] This chapter has greatly profited from critical feedback received from Kevin Baumert, John Mitchell, Cedric Philibert, and Asbjørn Torvanger.

[2] '[...] the decision has been made [by Argentina] to establish a dynamic target based on the relation between emissions and GDP. The emission target will be expressed as $E = I \cdot \sqrt{P}$. where emissions (*E*) are measured in tons of carbon equivalent and GDP (*P*) in 1993 Argentine pesos. The value chosen for the index *I* (151.5) tends to guarantee an effective GHG emission reduction for Argentina, for most of the likely scenarios.'[Argentine Republic, (1999):p.4]

[3] Much of what is going to be said in this section will be true for any measure per unit of economic output, which is why we shall often just use the term 'intensity,' relying on the context to make sure which particular type of intensity is referred to, if any.

[4] Indeed, the idea usually is that the target intensity should involve some (percentage) reduction from the baseline intensity, but an increase is by no means precluded.

during the commitment period in question, but the size of these 'implied assigned amounts', as it were, depends on the level of economic activity during the commitment period, and is thus only determined *ex post*. As such, intensity targets are obviously more flexible in the way they react to economic growth than *ex ante* emission caps, even if this flexibility is bought at the price of potentially increased emission levels in high-growth situations. Moreover, there are situations in which such a trade-off between the risk of dampening growth and the risk of diminished mitigation are morally justifiable.

But before turning to discuss these situations, an illustration of the relations between emissions, economic activity, intensity targets and their implied assigned amounts may be of use. Consider the situation of Russia in 1995: With a GDP (in 1995 roubles) of R1540bn,[5] and CO_2 combustion emissions of 444MtC,[6] it had a 'carbon intensity' of 444MtC : R1540bn = 288gC/R. Assuming, for illustration's sake, that Russia had agreed not to increase its carbon intensity beyond this 1995 base-level by the end of the decade – as opposed to, say, signing on to a 'return-to-1995-emissions' regime – what would have been the consequences of such an agreement?

At the end of that decade, Russia found itself with a GDP which, in real (1995 rouble) terms, was cut by 4 percent to R1474bn. In order to keep its assumed obligations, Russia would have had to cap its 1999 carbon emissions to the implied assigned amount of R1474bn ×288gC/R = 425MtC. Given that its actual 1999 emission level was 400MtC, Russia would thus have an implicitly assigned surplus of 25MtC, as opposed to the 44MtC of the 'return-to-1995-emissions' regime.[7]

• *The Moral Justification for Economic Safety Valves*

As mentioned, there can be situations where an economic safety valve of the sort provided by intensity targets can be argued for on moral grounds, even if it involves an increase in uncertainty about (commitment period) emission levels. It would simply not be right to stifle –if not stop– the much-needed economic growth of countries at the bottom of the wealth ladder, particularly if that growth is achieved in an environmentally promising manner. Put differently, if economic growth is a matter of moral obligation, then there can be situations where it is right to trade-in risk to poverty eradication for risk to emission mitigation. And such a trade-off will be all the more warranted in the context of economic activities that can in some sense be regarded as being 'on the right environmental track.'

If, for example, the bicycle-manufacturing sector of a country demonstrates that it will be able to produce a bicycle with decreasing collateral emissions, then growth in this sector may be deemed acceptable even if it were to lead to increased sectoral emissions. This example actually illustrates nicely the way in which intensity targets –properly operationalised– could provide for such a trade-off. Regrettably, the proviso concerning a proper operationalisation turns out to be more problematic than our example might suggest. But before turning to these issues of implementation, two caveats:

First, the fact that intensity targets may be able to introduce this sort of economic safety valve does not imply that other types of targets might not be able to serve the same purpose. Indeed, even emission cap regimes can be made to provide such a safety valve –at least to some degree– in a very simple manner: after all, if one were worried about a morally unjustifiable growth constraint by an *ex ante* emission cap for a sector or country, all one would need to do is to differentiate and raise the cap accordingly.

Second, the trade-off between risks to economic growth and mitigation risks can only be morally justified in terms of poverty eradication. While safeguarding economic growth is undoubtedly a political priority in all countries – rich and poor alike – morally, this trade-off can only be justified in the context of growth which is deemed to be necessary for the purpose of eradicating poverty. The

[5] Source: IMF, *World Economic Outlook 2001*.
[6] Source: EIA, International Emission Statistics.
[7] It appears that the situation would likely have involved a deficit of permits, and not merely a reduction in surplus, had one chosen a 1990 baseline. The reason for not doing so in this context is simply a matter of data reliability: although the *WEO 2001* does provide a rouble figure for Russia's 1990 GDP, at R0.65bn it does seem to be excessively small.

need to increase wealth at the top end of the ladder simply does not have the moral force required to justify such a trade-off. This has been rightly acknowledged in the research community (in particular, in Baumert *et al*. 1999),[8] but it needs to be re-emphasised in light of certain remarks made in the Bush administration's recently published initial findings of the Cabinet-level Climate Policy Review:

'United States government climate change programs are achieving real results, …. United States carbon intensity – the amount of CO2 emitted per unit of GDP – declined 15% from 1990 to 1999.'

The performance of American and other countries intensities over the last decade will be discussed in some detail in Section 3.3., while the 'reality' of such aggregate national intensity figures will be the focus of the second half of this Section. But first, some practical considerations.

• *Some Practical Considerations*

Emission Levels. As indicated above, emission levels in the commitment period cannot be guaranteed with intensity targets. Unexpected economic growth would generate more allowances, admittedly less than expected growth would reduce allowed emission levels. However, in order to stabilise greenhouse gas concentrations in the atmosphere, the goal of the Framework Convention on Climate Change, global emissions will need to be reduced to far below today's levels. Intensity targets would only be able to deliver such emission reductions if the required reduction of intensity is greater than the output growth. Such tough targets, however, lose their comparative attractiveness compared with Kyoto-type (fixed cap) targets.

All three scenarios of the EIA's *International Energy Outlook 2001*, for example, project business as usual intensity improvements at around 0.5% per percentage of GDP growth, although developing countries often have slightly lower rates of improvements. However, unless intensity targets demanded improvement of more than 1% per percentage of GDP growth (thus stepping up intensity improvements to double the current rates), emissions would always increase and the regime would never reach its goals.

These concerns can be mitigated by more elaborate emission intensity targets that, for example, cap total growth, or are differentiated according to GDP growth. However, these targets would become more complicated, so that they would lose their attractiveness for an internationally negotiated regime. Additional flexibility can also be given within a framework of absolute caps for particularly strong economic growth or population changes.

Target setting. Business-as-usual trends in emission intensities are very diverse. Target setting is therefore little easier than absolute caps, although the politically attractive 'growth sweetener' (Section 3.4) could tempt negotiators. But intensity targets are much more difficult to understand for the negotiators (of other countries) than absolute caps.

Flexibility. The targeted emission levels, target setting and the above-mentioned difficulty of only know the target levels ex-post make the use of intensity targets difficult. Moreover, the Kyoto flexibilities add several dimensions of difficulty.

The UK industry's emissions trading proposal recognised that intensity targets could pose a problem for the cross sectoral trading system: "Open trading would mean that the number of permits between the two sectors would grow as output grows and therefore the ability of the trading scheme as a whole to demonstrate that it was reducing overall emissions would be compromised"[9]. Indeed, emissions trading and the other flexible mechanisms are designed to reduce costs; with intensity targets emissions trading, reducing costs and increasing revenue for participants, would therefore automatically inflate allowed emission levels. Within an international climate regime based on

[8] Baumert *et al.* (1999).
[9] Some of the sectors involved in the UK emissions trading scheme have negotiated intensity targets (mostly energy-intensity targets) with government under the climate change levy agreements. Emissions Trading Group proposal, 21 March 2000, see www.uketg.com.

absolute caps, an intensity target trading scheme would lose its credibility towards an international emissions market. However, emission trades – even under an intensity target regime – will need to take place in absolute emissions. Although translation of trades in absolute emissions (tonnes rather than tonnes per dollar) is not difficult, it might increase transaction costs.

The use of some other flexibilities that are part of the international climate change regime, such as the other greenhouse gases, sinks, and banking, would also become more complicated. Additionally, the emissions of the other gases are not as much correlated to economic output. Indeed, much of the methane emissions, a substantial share in many national inventories, stems from the agricultural sector, which has a small role in the economy. Similarly, emissions from forestry or absorptions by sinks are not very closely related to economic output. If, indeed, the carbon mitigation sector substantiates its growth, this would lead to negative emissions.

One of the Kyoto mechanisms in particular, 'bubbling' under Article 4 of the Protocol, is particularly troublesome with intensity targets. Intensity targets are not additive. The whole of Annex I for example improved its intensity by 20% over the last decade, while neither Annex II, nor Economies in Transition improved by much over 10% (12 and 11 percent respectively). Of course, the bubbling agreement is of particular interest to the European Union. However, intensity targets for the EU as a whole and the 15 EU Member States separately would lead to different allowed emission levels in the commitment period. Indeed, in theory, unless either base line intensities are exactly the same for all Parties in the bubble, or growth rates are exactly the same (or both), the bubble target is different from the aggregate target of the Parties. The same theory holds for sectors 'bubbled' within one national economy.

- ***The Potential for Inflationary Distortions***

Returning to our bicycle-manufacturing example, it will not be difficult to see how an emission-per-bicycle target could provide precisely the sort of safety valve against an undue constraint on the presumed environmentally acceptable growth of the bicycle sector in question. And in theory at least, it might be possible to apply similar 'physical' intensity targets to other economic activities, particularly in the manufacturing sector. In practice, however, a 'monetisation' of such targets – i.e. a translation into 'emissions per monetary magnitude' seems unavoidable, if only to allow for both inter-temporal as well as inter-sectoral comparisons and assessments.[10] The 'monetary magnitude' used most frequently is, as indicated before, the value added of the physical units produced. This arguably inevitable transition from physical to monetized intensities, however, generates its own problems.

Take arguably the least of them, to do with the monetary phenomenon of inflation. If bicycle prices rise because of inflationary pressures, then so does the value added by the sector, at least when calculated in terms of the prices at the time ('nominal terms'). This means that the derived monetised intensity of the sector has the potential to improve (i.e. decrease) – and to deteriorate, for that matter – in the absence of any changes in the associated physical intensity, i.e. the emissions generated per bicycle. There seems to be little, if any, controversy that intensity changes due to inflationary pressures need to be discarded as unreal 'paper changes' which do not reflect any sort of environmental behaviour by the sectors involved. And there is, of course, a simple remedy for the problem: measurement of GDP in 'real terms' (fixed prices).

To see the potential magnitude of such inflationary distortions, consider again the case of Russia. The staggering inflationary pressures which led the (nominal) GDP figures[11] to shoot up from R1,540bn in

[10] Not only is there no way in which, say, '5kgC per bicycle' and '1kg per computer' could be meaningfully used to compare the efficiency of the relevant production lines, but either of these measures would probably have to be further specified as to the specific type of the physical unit in order to be acceptable even within sectors. Such a specification would in turn lead to unacceptable inter-temporal incommensurabilities as soon as the product ranges in question are discontinued, for clearly, changing the product range *per se* should not be sufficient for compliance.
[11] Source: Russian-European Centre for Economic Policy (2001).

1995 to R4,757bn in 1999 would have had the distorting effect of reducing Russia's intensity by over 70 percent from its base 1995 level of 288gC/R to 84gC/R, while the 'real' intensity –i.e. the one measured in terms of real GDP– would actually have decreased by only 6 percent. The unacceptable paper nature of these changes becomes even more apparent if one considers that with these distorted intensities, Russia would have received an implied surplus amount for 1999 of almost 1Gt under the above-mentioned hypothetical 1995-intensity target agreement – compared with the actual 1999 world level of approx 6GtC, this would indeed be a substantial amount of 'hot air'.

- ***Intensities versus Indices***

Unfortunately, the problems of aggregate intensity measures do not end with these inflationary distortions. Indeed, the sensitivity –or 'non-robustness'– of aggregate intensities to be addressed in this section are arguably much more serious for their theoretical soundness –or, 'reality' for that matter– than anything else.

In the preceding section variations of (aggregate) intensities generated by price fluctuations were found to be unacceptable because they were seen to present a distorted view of the 'real picture'. It was possible to rectify these distortions by using fixed prices for the whole duration, usually –but not necessarily– determined as the prices assigned by the market in a 'baseline period'. The problem to be discussed here is that – by not being *additive*[12] – aggregate intensities have growth-rates that are equally sensitive to the specific values of the chosen base-prices. The growth-rates of aggregate intensity figures, in other words, depend on the particular choice of (base-) prices, even when they are kept constant over time.

To be sure, the fact that intensity growth-rates can be sensitive to choices of economic measures is nothing new. It is well-known that GDP figures expressed in a numeraire currency will generally grow at different rates depending on whether the figures are arrived at by using market (official) exchange rates or purchasing power parity (PPP). The 'exchange rate' GDP figures (in 1990 prices) of Japan, for example, were $2967bn in 1990 and $3328bn in 1999, implying an increase of 12.2 percent, while the PPP figures (in 1990 prices), were $2528bn, $2697bn, and 6.7 percent, respectively.[13] Internationally comparable intensity figures will thus tend to grow at different rates, depending on which of these numeraire GDP measures is chosen to estimate economic output. In the absence of a consensus on which of them should be used,[14] some experts have come to the conclusion that 'the only sensible choice of GDP seems to be constant local currency,'[15] – a choice which does indeed avoid this sensitivity problem, but at the cost of abandoning the ability for international comparisons of absolute intensity levels. Having said this, it must be stressed that the apparently lesser-known base-price sensitivity at issue here is quite distinct and more fundamental a problem than these GDP-measure related issues.

The Central Problem. To see this, consider Scenario A (Table 3.1). In a baseline period (t = 0) a high-intensity sector (*HIS*) is assumed to produce 1 physical good with emissions of 5 carbon units and a value added of 1 monetary unit. Or, put differently, the baseline period *HIS*-production is characterised by a physical intensity *PI* = 5, and a unitary 'price' *P* = 1. The baseline production of the companion low-intensity sector (*LIS*) is unitary in both variables. Moreover, both sectors are assumed to produce exactly one unit in this baseline period. The scenario involves a second, subsequent period (t =1), which is precisely the same as the baseline with one exception: *LIS* increases its production by 20 percent. In other words, the physical intensities of both sectors remain unchanged over time, as do the prices (i.e. we are dealing with a 'fixed price' scenario). Given the unitary prices, the monetised

[12] A quantity is 'additive' ('extensive') in the measurement theoretic sense if the measure of two combined objects is equal to the sum of the measures of the individual objects taken separately.
[13] Sources: 'Exchange Rate' figures: EIA. PPP-figures: authors calculation using World Bank purchasing power parity conversion factors (see *WDI 2001*, pp. 290ff.), Local Currency Units: *WEO 2001*.
[14] For different views on this issue see, for example: Gulde and Schulze-Ghattas, (1993): 106-23; and Birol and Okogu, (1997):7-16.
[15] Kevin Baumert, personal communication, July 2001

Table 3.1: Base-Price Sensitivities

Scenario A

	Physical Intensity *PI* [kgC/u]	(Base-) Price *P* [€/u]	Physical Output *X* [u]	Emissions *E* [kgC]	Value Added *VA* [€]	Monetised Intensity *MI* [kgC/€]	Change from *BL*	*'BL – 8%'-Regime* Target Int.	IAA	% change from CP-Emissions
			Baseline BL ($t = 0$)							
HIS	5	**1**	1	5	1	5.0				
LIS	1	**1**	1	1	1	1.0				
AS				6	2	3.0				
			Commitment Period CP ($t = 1$)							
HIS	5	**1**	1	5	1	5.0	**±0%**			
LIS	1	**1**	1.2	1.2	1.2	1.0	**±0%**			
AS				6.2	2.2	2.8	**–7%**	2.8	6.1	–2.1%

Scenario B

	PI	*P*	*X*	*E*	*VA*	*MI*	Change from *BL*	*'BL – 8%'-Regime* Target Int.	IAA	% change from CP Emissions
			Baseline BL ($t = 0$)							
HIS	5	**0.5**	1	5	0.5	10.0				
LIS	1	**2**	1	1	2	0.5				
AS				6	2.5	2.4				
			Commitment Period CP ($t = 1$)							
HIS	5	**0.5**	1	5	0.5	10.0	**±0%**			
LIS	1	**2**	1.2	1.2	2.4	0.5	**±0%**			
AS				6.2	2.9	2.1	**–13%**	2.2	6.4	+3.3%

Scenario C

	PI	*P*	*X*	*E*	*VA*	*MI*	Change from *BL*	*'BL – 8%'-Regime* Target Int.	IAA	% change from CP-Emissions
			Baseline BL ($t = 0$)							
HIS	**5**	**5**	1	5	5	1.0				
LIS	**1**	**1**	1	1	1	1.0				
AS				6	6	1.0				
			Commitment Period CP ($t = 1$)							
	5	5	1	5	5	1.0	**±0%**			
LIS	1	1	1.2	1.2	1.2	1.0	**±0%**			
AS				6.2	6.2	1.0	**±0%**	0.92	5.7	–8.0%

HIS, LIS, AS : high-intensity-, low-intensity-, and aggregate sector; $E \equiv PI \times X$; $VA \equiv P \times X$; $MI \equiv E/VA$; *TI* : *AS target-*intensity ≡ baseline *AS-MI* – 8%; *IAA* : implied assigned amount : *Target Intensity* × *CP-Value Added.*

sectoral intensities (*MI*) are actually numerically of the same value as their physical counterparts, and do not change over time. The aggregate intensity, however, diminishes by 7 percent from 3 to 2.8.

Before rushing to a conclusion based on this mathematical fact, consider the alternative Scenario B, again listed in Table 3.1. Like Scenario A, this alternative is quasi-static in being based on fixed physical intensities and fixed prices. Indeed the values of the physical intensities and the production figures in the two scenarios are exactly the same, the only difference being the values of the assumed base-prices. While the numerical values of the monetized sectoral intensities are no longer identical with their physical counterparts, their growth-rates are, i.e. the sectoral intensities –physical or monetised– do not change over time. And again there is a drop in aggregate intensity, but this time of 13 percent.

In short, the growth-rate of aggregate intensities is sensitive to variations in the choice of the underlying base-prices, even though *nothing changes in any of the real* (physical) *intensities*. Indeed, an analysis of 100,000 expanded (100-sector-) versions of these quasi-static two-period scenarios with randomly chosen base-parameters –baseline intensities, prices and production figures, as well as production growth figures– reveals (see Figure 3.1) aggregate intensity growth variations of ±25% due solely to the choice of baseline period prices. Moreover, a simple frequency count shows that while the chance of a growth variation between –1 and +1 percent is about 11 percent, chances for a price induced increase in aggregate intensity of more than 5 and more than 10 percent are not negligible, namely around 30 and 11 percent, respectively.

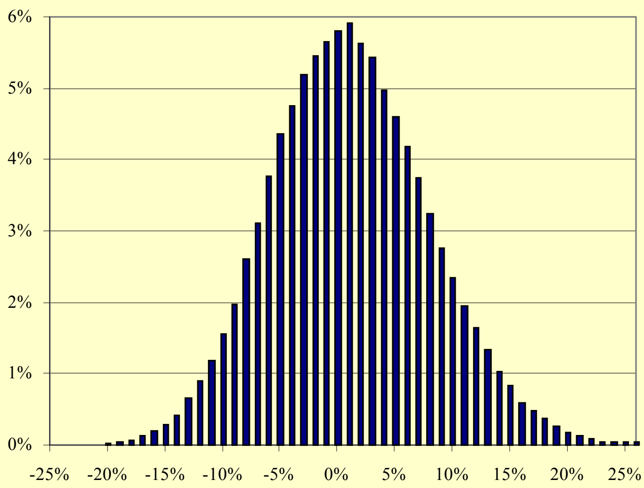


Figure 3.1: Frequencies of Base-Price induced Aggregate Intensity Growth Changes

On their own, these base-price induced growth variations may well be of merely theoretical interest. However, it is not difficult to see that they become rather less academic in the context of an intensity-target mitigation regime. Consider again Scenarios A and B, and compare them against a mitigation regime based on a reduction of the aggregate intensity of, say, 8 percent below the prevailing aggregate baseline intensity. In the case of Scenario A, such a regime amounts to an implied assigned amount (*IAA*) of 6.1, i.e. 2.1 percent less than the total 'commitment period' (t = 1) emissions of 6.2, while in Scenario B, the *IIA* turns out to be 3.3 percent larger than the emissions in the commitment period. In other words, the difference in base-period prices between the two scenarios is tantamount to the difference between non-compliance and compliance (with surplus permits!).

There is, of course, no need to choose prices at random, particularly in the context of these quasi-static scenarios. In light of the fact that none of the underlying sectoral intensities –either physical or translated into monetary terms– is changing over time, it would not seem to be unreasonable to expect the aggregate figure to remain equally constant. Indeed, one might feel inclined to adopt the 'reality criterion' that if a variable portrays to measure a change where nothing happens, then this measure cannot be of anything real. Our frequency analysis would then imply the unreality of aggregate intensities, at least for almost all base-prices.

A Potential Solution. However, Scenario C (Table 3.1) shows that it is possible for aggregate intensities to meet this reality criterion, simply by 'carbonising' the prices, in the sense of, roughly speaking, 'equating' them with the value of the corresponding physical baseline intensities. Having said this, it must be emphasised that talk of such an 'equation' is just metaphorical and has to be taken with a pinch of salt, for strictly speaking one cannot identify an amount of money (per output unit) with an amount of carbon (per output unit). The only reason why the base-prices chosen in Scenario C are special is that their purely numerical figures ensure the 'reality' of the resulting aggregate intensities. Yet this is simply a mathematical fact and has nothing to do what prices are meant to be, namely expressions of value per unit of output.

The only meaningful way of interpreting the mathematical correlation exhibited in Scenario C is to abandon the idea of using monetary amounts to translate physical intensities into commensurable fractions, and instead use the physical baseline intensities (*PBI*s) to translate themselves and those of any subsequent period into the common currency of dimensionless (carbon) index numbers (*C*s).

Table 3.2: Carbon Indices

Scenario D

	Physical Intensity *PI*	*Physical Base Int.* *PBI*	*Physical Output* *X*	*Emissions* *E*	*Domestic Carbon Product* *DCP*	*Carbon Index* *C*	
	[kgC/u]		[u]	[kgC]	[kgC]	[ ]	
			Baseline BL (t = 0)				
HIS	**5**	5	1	5	5	1.0	
LIS	**1**	1	0.83	0.83	0.83	1.0	
AS	(6)			5.83	5.83	1.0	Change from *BL*
			Commitment Period CP (t = 1)				
HIS	**2**	5	1	2	5	0.4	–60%
LIS	**1**	1	1	1	1	1.0	±0%
AS	(3 = *BL* – **50%)**			3	6	0.5	**–50%**

Scenario E

	PI	*PBI*	*X*	*E*	*DCP*	*C*		*Target Index*	*IAA*	% change from *CP-Emissions*
			Baseline BL (t = 0)							
HIS	**5**	**5**	1	5	5	1				
LIS	**1**	**1**	1	1	1	1				
AS				6	6	1	Change from *BL*:	‘*Baseline – 8%*’*-Regime*		
			Commitment Period CP (t = 1)							
HIS	4.60	5	2	9.2	10	0.92	–8%			
LIS	0.92	1	2	1.8	2	0.92	–8%			
AS				11.0	12	0.92	–8%	0.92	11.0	0.0%

$E \equiv PI \times X$; $DCP \equiv PBI \times X$; $C \equiv E/DCP$.

Take Scenario D in Table 3.2, with the high-intensity sector *HIS* producing, say bicycles. Instead of ‘translating’ the commitment period physical intensity *PI* = 2kgC/bicycle of *HIS* into a monetised intensity through dividing it by the (baseline period) bicycle price, it is transformed into a dimensionless carbon index of C = 0.4 through dividing it by the relevant physical baseline intensity *PBI* = 5kgC/bicycle. The scenario also shows that, by normalising production figures relative to the final period the growth of the aggregate carbon index becomes identical to the growth-rate of the average physical intensity.[16]

This is not to say that these carbon indices will not exhibit any of the other drawbacks or advantages of intensity targets identified in this chapter. Indeed, Scenario E clearly shows that ‘carbon index targets’ can serve precisely the sort of safety valve purpose (with precisely the same trade-offs) discussed earlier with reference to intensity targets. All this means is that intensity targets are really not a sound option for this purpose and need to be replaced –if one wishes to pursue this line– by something like these carbon indices.

In spite of this, Parties may nonetheless feel fatalistic or even lucky about the ‘price hand’ dealt to them by the market in a proposed baseline year – after all, chances are that they may find themselves on the left-hand side of Figure 3.1. This is why it may be useful to consider some of the other potential impacts of the market once the hand is dealt, as it were, and the game is being played.

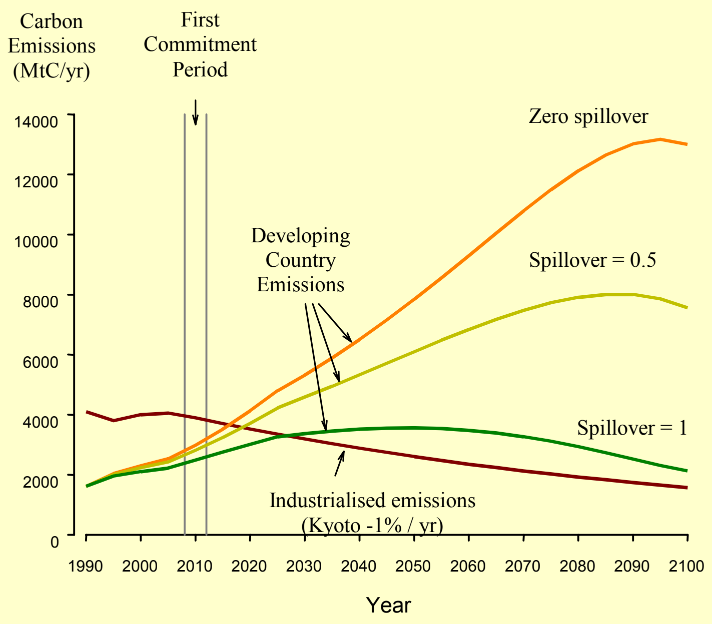
[16] Strictly speaking it is, of course, the growth of the sum of the emissions involved.

3.3 The Problem of Economic Collapse

Theory and modelling suggest that in the medium to long term, the effects of a cap-and-trade mitigation regime within the industrialised world are not confined to a potential for 'carbon leakage' – the southerly migration of carbon intensive industries– but also include North-South technology 'spill-overs', ultimately contributing to significant reductions in emission intensities in the developing world. Michael Grubb, Chris Hope and Roger Fouquet have convincingly argued for the importance of the spillover effect on intensities and emissions of developing countries in their article on 'The Climatic Implications of the Kyoto Protocol.' They develop a scenario with annual 1 percent emission target reductions after the Kyoto commitment period for Annex I countries alone, leaving developing countries uncapped for the whole of the 21st century (Box 3.1). Without the international technology spillover, 2100 greenhouse gas concentrations are estimated at around 750ppm, much higher than the maximum allowed concentrations now talked about. A North-South transfer of efficient technology is projected to lead to substantially lower atmospheric concentrations of around 600ppm, and to bring developing country emission intensities in line with those of Annex I countries.

Box 3.1 The Grubb-Hope Spill-Over Scenarios

The reference case: IPPC SRES A2 scenario, modified by the Kyoto targets for industrialised country emissions, followed a decline by 1%/yr thereafter. Emissions from developing countries are not curtailed. The spillover parameter comprises three broad components: $\sigma = \sigma_s + \sigma_t + \sigma_p$, where σ_s is the spillover due to economic *substitution* effects; σ_t is the spillover due to the diffusion of *technological* improvements; σ_p is the spillover due to *policy and political* influence of industrialized country action upon developing country actions. The spillover parameter $\sigma = 0$ represents the simplified case in which intensities in one region are completely independent of those in another (there is no spillover or other effect), whilst $\sigma = 1$ represents a case in which aggregate emission intensity in the developing world converges to the same level as in the Annex I countries by the end of the century. The projected global emission trajectories from the different spillover scenarios are depicted in the following figure:



These findings like these could be taken to suggest that –given a suitably effective Annex I regime– intensity targets would actually put minimal burden on developing countries. Bracketing the theoretical problems discussed in the preceding section, it may in this context be instructive to leave the realms of theory and modelling and instead consider some examples of the way actual national intensity figures have tended to behave historically.

For this purpose, we shall consider national carbon intensity evolutions over the past decade (1990 to 1998, to be precise) for examples from both the North and the South. To avoid discussions about correct cross-country measures, we shall use real GDP figures in billions of *local currency units* (LCUs) and *constant* prices as supplied by the IMF *World Economic Outlook 2001*. Emission figures used in this exercise are fossil fuel emission data provided by the Carbon Dioxide Information Analysis Center (CDIAC) at the US Oak Ridge National Laboratory, measured in thousand metric tons of carbon (ktC).[17] In order to judge the predictability of these intensity variations, we shall also make use of certain hypothetical projections of the 1998 values based on knowledge available –in principle– in 1990 (see Box 3.2).

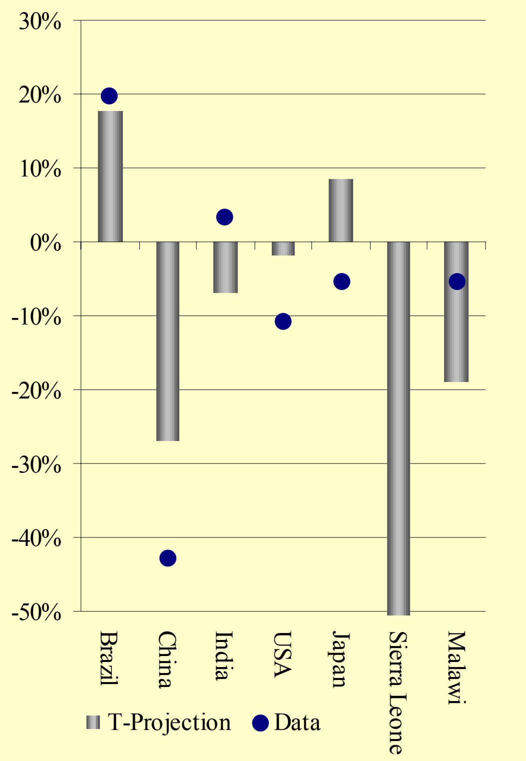
Box 3.2. The '1990 Projections'

In order to get an idea of how the emission intensities measured in 1998 compare to what might have been expected at the beginning of the decade, we have used two elementary forecast methodologies to generate 'projections' of the 1998 intensities based on data up to the year 1990.

- In analogy to an IEA *World Economic Outlook* (WEO) methodology, the 'simple' ('S-') projections are based on the average annual growth over the preceding 8-year period (1983-90). In other words, the 'S-projection' is given by adding 8 times this average percentage to the 1990 value.
- The 'trend' ('T'-) projections, by contrast, are based on the sequence of 8-year averages prior to 1983, 84, …to 90 (= the T-projection base), and on a linear trend line extrapolated to 1998.

Average Annual Change 91-98. Projections and Data.

	GDP				*Intensities*		
.	*S-Proj*	*T-Proj*	*WEO factor*	*Data*	*S-Proj.*	*T-Proj.*	*Data*
Brazil	3.2%	4.1%	+0.4%	2.8%	–0.1%	2.2%	1.8%
China	11.4%	17.3%	+0.4%	13.4%	–3.0%	–3.4%	–5.1%
India	6.2%	9.3%	+0.5%	6.2%	0.6%	–0.9%	–0.3%
Japan	4.7%	5.7%	–1.3%	1.1%	–1.3%	1.1%	–0.5%
Malawi	2.9%	2.9%	+0.2%	2.6%	–1.9%	–2.4%	–0.6%
S-Leone	0.7%	-0.6%	+0.2%	-6.0%	–6.7%	–20.6%	18.6%
USA	3.8%	6.0%	–0.2%	3.4%	–1.7%	–0.2%	–1.5%



- ***The Case of Annex II***

The 24 original OECD members plus the European Union are listed in Annex II of the Framework Convention as countries sufficiently rich to take on special obligations to help developing countries with financial and technological resources. This, by itself, is no reason why they should be grouped together for the purpose of the present analysis. Yet, as it happens, there is actually a degree of similarity between the intensity performances of these rich countries that does warrant them being discussed together in this context.

Figure 3.2 depicts the cumulative intensity changes since 1990, together with the annual growth changes of emissions and GDP for four of the main countries in this grouping: Germany, Japan, the United Kingdom, and the United States. The common feature between these pictures is quite apparent: their trend of substantial cumulative intensity improvements.

Mathematically, the driving force behind the intensity changes is the *difference* between emission- and GDP-growth (see Box 3.3). But this should not detract from the fact that one and the same intensity change can arise in a variety of substantively different ways.

[17] Gregg Marland *et al.* (2001).

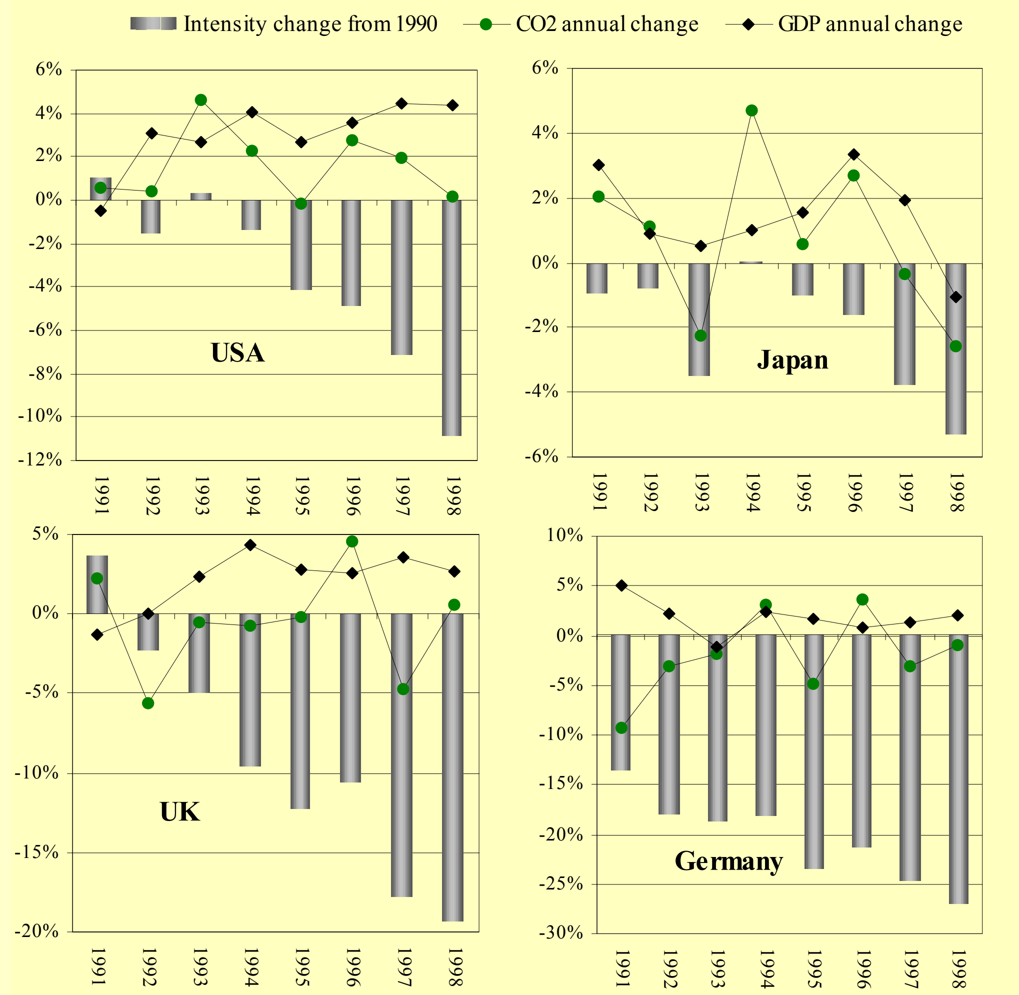


Figure 3.2. Annex II Intensities. Annual CO_2 and GDP Growth. 1990-98

For example, in 1998 Japan experienced an intensity reduction of 1.5 percent in the context of a recession (negative GDP growth: –1.1%). The UK was less fortunate in a similar macro-economic situation (1991: GDP growth –1.3 percent), as it failed to keep the emission growth-rate below the GDP one, thus being left with an intensity increase of close to 4 percent. In general, the examples show that it was possible to keep the growth of emissions below that of GDP, indeed, Germany and the UK managed to do so in the best possible way, namely with positive figures for GDP and negative ones for emission growth.

US performance over the eight years between 1990 and 98 may not have been of the same ilk, but it too performed rather better than our hypothetical trend projection would have predicted: while the projection estimates a modest improvement of –2 percent, in reality US emission intensity improved by more than –11 percent over the past decade, due to the economy out-growing the nonetheless increasing emissions.

Judging from these examples, Annex II economic structures seem to be performing rather well with respect to decreasing intensity objectives, both in situation of economic growth and recession. Without further analysis, this will, of course, have to remain in the realm of conjecture and hypothesis. However, one thing that it is not meant to do is imply that similar performances could not or did not happen outside Annex II.

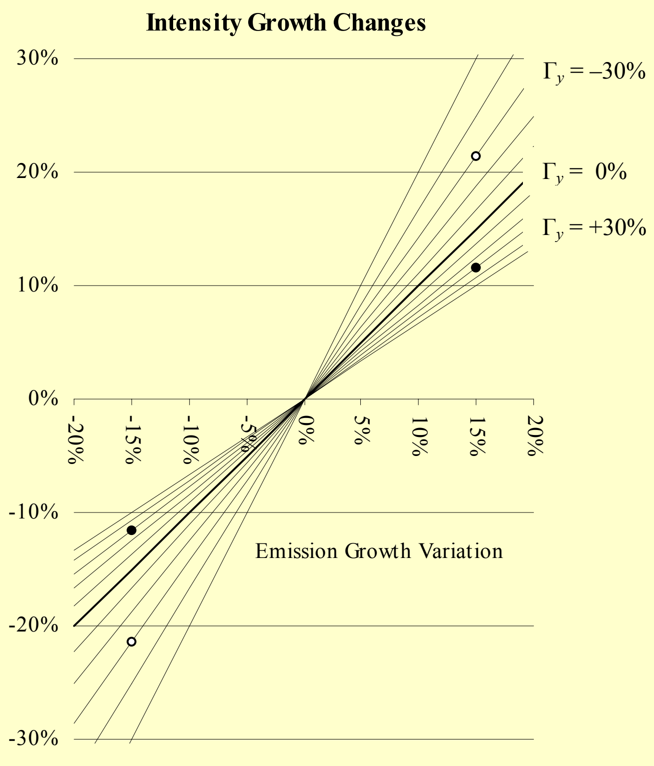
Box 3.3: Intensity Growth Rates. Asymmetries between High- and Low-GDP Growth Situations

If $e(t)$, $y(t)$, and $i(t) := e(t)/y(t)$ denote a country's emissions, gross domestic product (GDP), and emissions intensity (in period *t*), respectively, then there is a simple analytic relation between the growth rates –

$$\Gamma_e(t) := \frac{e(t)-e(t-1)}{e(t-1)}, \quad \Gamma_y(t) := \frac{y(t)-y(t-1)}{y(t-1)}, \quad \Gamma_i(t) := \frac{i(t)-i(t-1)}{i(t-1)}$$

– of these variables, namely: The intensity growth rate is proportional to the difference between the emission and the GDP growth rates, modified by a factor inversely dependent on the GDP growth rate

$$\Gamma_i(t) = \frac{\Gamma_e(t) - \Gamma_y(t)}{1 + \Gamma_y(t)}.$$



Intensity growth changes due to variations in emission growth-rates are *in*dependent of the point of departure of these variations (the base level around which the variations are centred), but they *do* depend on the prevailing level of GDP growth.

A variation in emission growth level of, say, ±15% generates –regardless of the base level relative to which it is measured– an intensity growth variation of ±12% (see figure: black points) in the context of a GDP growth rate of +30%, or of ±21% (white points), in the context of a GDP growth rate of –30%. In short, the same percentage variation in the presupposed emission growth rates has significantly different impacts on intensity growth, depending on the assumed level of economic growth.

The GDP growth rates mentioned are, of course, at the extreme end of the feasible spectrum, although not quite symmetrically so: it would seem that a decline of 30% is a much more likely possibility than an increase of the same magnitude. But the key conclusion is that the risk of errors in predicting intensity growth is greater in the context of recessions than in periods of rapid growth.

- ***The Case of non-Annex II*: *Economies in Transition and Developing Countries***

In the past decade, the People's Republic of China has consistently 'out-performed' the United States –by up to 10 percentage points[18]– in keeping economic growth on top of emission growth. In recent years, China has even had the distinction of joining our Leibnizian best-of-all-possible-intensity-worlds. Indeed, in 1998 China managed to reduce emissions by almost 6 percent while simultaneously expanding its GDP by close to 8 percent. Unfortunately, this is not where the 'non-Annex II story' ends.

The 1990s saw a spectacular collapse of what have since become known as 'economies in transition,' the countries with formerly centrally planned economies. The Russian Federation, as indicated in Figure 3.3, was clearly a case in point: in the first half of the period –between 1990 and 1994– Russian real GDP went into free-fall, dropping by a staggering 40 percent. In the second half, the decline continued, but at a much reduced rate, leaving the Russian economy in 1998 at 53 percent of its 1990 value. Unlike Japan's slipping into recession at the end of the decade, Russia was unable to keep its emissions dropping faster than its GDP, with the result of an 18 percent intensity increase during the collapse.

[18] The maximum difference between US emissions- and GDP-growth in the period in question is 2.8%, is exactly the minimum figure for China (both, incidentally reached in 1995), whose maximum is an impressive 14 percent in 1998.

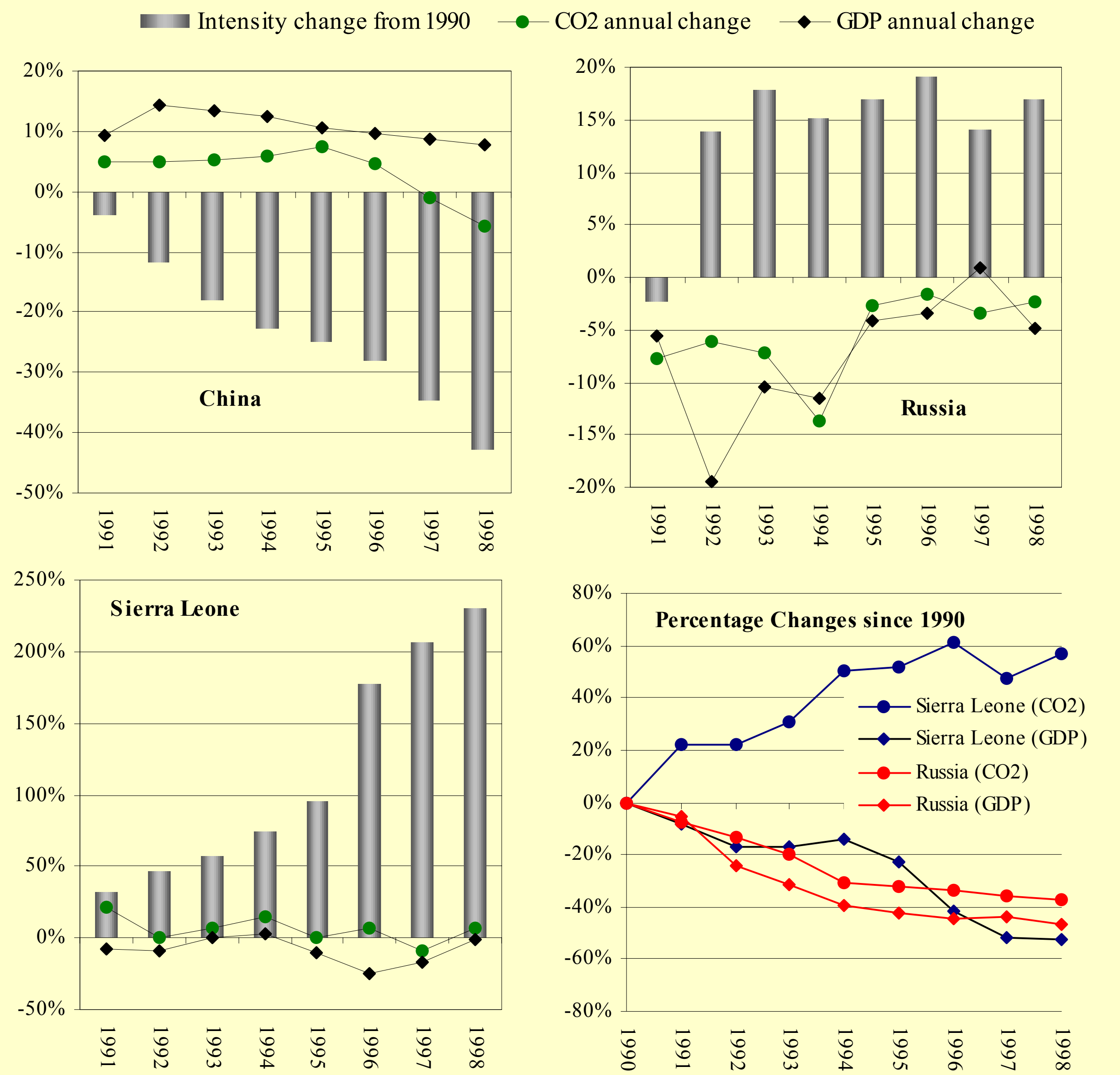


Figure 3.3: Non-Annex II. Intensity-, CO_2- and GDP-Growth. 1990-98

Yet even with this course of events, we have not exhausted the spectrum of (non-Annex II) intensity performances over the last decade. While both India and Brazil saw their intensities grow by 3 and 20 percent, respectively, there have been cases, such as that of Sierra Leone, of truly ‘anti-Leibnizian’ proportions, characterised by a GDP decline –indeed collapse– coupled with an *increase* in emissions, leading to a staggering intensity increase of over 230 percent from the 1990 level.[19]

Before jumping to conclusions about the acceptability or not of such a performance, it may be useful to consider some cross-country comparisons. The tragic events of the recent war-torn history that led to the collapse of the Sierra Leonean economy are well-known. While these events are clearly quite different from the causes of the Russian breakdown, the fact nonetheless is that the two collapses are quite similar in relative magnitude (Russia: –46%; Sierra Leone: –52%; Figure 3.3), thus raising the question as to what would have been responsible for the enormous difference in intensity changes.

[19] Given its tragic recent history, Sierra Leone, of course, is not an average representative of the group of least developed countries for the period in question. Malawi managed to decrease its intensity by 5% (but even this performance did not live up to what might have been expected at the outset of the decade, see Box 3.2).

While this is not the place to investigate this in any detail, a look at some of the relevant country specific parameters may give some idea about where an answer might lie.

Table 3.3: Cross-Country Comparisons

	GDP/cap 1990 $	1990 CO_2/cap kgC	Intensity gC/$	1998 Intensity gC/$
China	341	577	1,690	967
Russia	6,922	4,362	630	737
Sierra Leone	224	23	101	335
USA	22,838	5,173	226	202
Japan	24,702	2,365	96	91
Germany	18,919	3,372	178	130
UK	17,192	2,700	157	127
Source	IMF	CDIAC		(1990 $)

As shown in Table 3.3, Sierra Leone –apart from being the poorest of the countries– has one outstanding characteristic that sets it apart not only from Russia: its per capita emissions. At 24kgC –24 times smaller than the Chinese, 182 times smaller than the Russian, and 215 times smaller than the American ones– the1990 (per capita) emissions of Sierra Leone cannot be far off the minimum needed for mere survival. And it is not difficult to imagine that, at this subsistence level, emissions are very easily de-coupled from GDP, in particular in the case of negative growth or collapse: when emission levels reach the subsistence floor, then they will not and should not be expected to follow GDP growth in economic recessions just to safeguard emission intensity. As it happens, Sierra Leone's 1990 emission intensity of 101gC/$ were as good or better than any other around the world, Annex II and not alike (Table 3.3). Even at its 1998 level of 335gC/(1990)$, it was still only 2/3 higher than that of the US and still only a third of the Chinese level.

The discussion in this section highlights at least two things: for one –while industrialisation is no safeguard against rocketing intensities in times of recession– countries at the bottom end of the wealth ladder are more vulnerable in this respect than most. Secondly, shunning the use of internationally comparable GDP figures may overcome some of the unsatisfactory characteristics of (national) emission intensities, but at a price. The implied inability to compare absolute intensity levels between countries poses serious problems for an equitable differentiation of targets in an intensity-based mitigation regime. Equitable differentiation is indeed a key issue for any mitigation regime, reaching beyond the principle of common but differentiated responsibility enshrined in the Framework Convention. For this reason it is of importance to consider also the implications of differentiations in intensity targets.

3.4 Equity and the Differentiation of Intensity Targets

- ***The Allocation of Implied Assigned Amounts***

It is in the nature of quantitative targets to allow for differentiation, and it is in the nature of differentiation to raise the issue of distributive justice or equity. Differentiation in intensity target regimes is most likely to take the form of differentiated target percentage changes from the relevant base-period intensities.[20] There may well be general differentiation criteria that refer explicitly to

Box 3.4: The Emission Intensity (EI) and Global Compromise (GC) Scenarios

I. EI-Scenario Specifications

- Targets are given in terms of improvements (percentage reduction) of a Party's baseline CO_2 emission intensity (amount of CO_2 emitted per unit of GDP).
- Targets are universal (all Parties) and undifferentiated - namely 70 percent of baseline intensity (i.e. a 30% reduction). The reduction rate of 30 percent, in turn, was chosen to achieve a commitment period reduction of global emissions by 14.5 percent from Business-as-Usual (BaU), in order to enable a comparison of the implications of this scenario with the 'Global Compromise' (GC) Scenario
- A single baseline 1999 (EIA data) is used, and the commitment period is centred around 2020 (2018-2022)
- The intensities involved are measured in CO2 emissions per unit of GDP (1997 US$) and (largely) based on projections carried out by the US Energy Information Agency in their latest *International Energy Outlook*.
- Implied Assigned Amounts under Emission-Intensity Reduction:

(a) $$Assigned\ Amount_{2020} = GDP_{2020} \times \left(\frac{GHG\ emissions_{1999}}{GDP_{1999}} \times (100 - R)\% \right) =$$

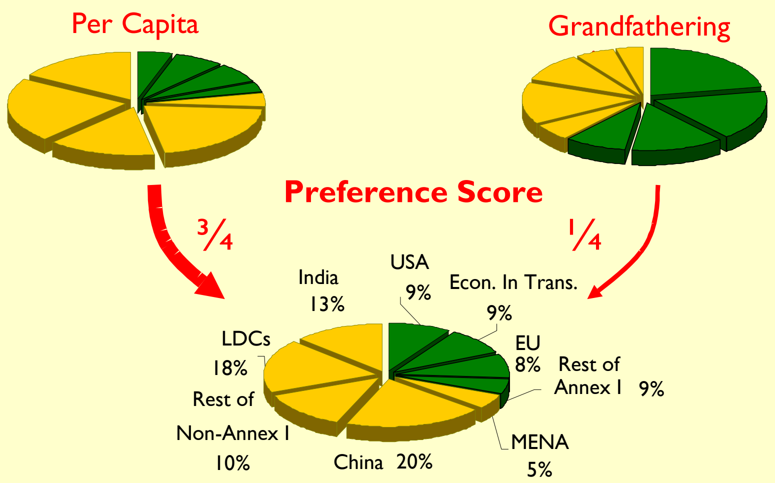
$$= \frac{GDP_{2020}}{GDP_{1999}} \times GHG\ emissions_{1999} \times (100 - R)\%$$

(b) R = Intensity Reduction Target (= 30%)

(c) Hence ***Assigned Amount$_{2020}$* = '*Growth-sweetener*'** × ***Grandfathering*** × **70%**

II. GC-Scenario Specifications (Bartsch and Müller, 2000)

Commitment period = 2018–22; Global emission reduction = 14.5 percent of BaU emissions; Assigned Amounts = ¾ Per Capita + ¼ Grandfathering. This 'preference score' mixture (see Bartsch and Müller 2000, Chapter 13) and resulting shares in the global 'emission cake' (=BaU – 14.5%) are represented in the following figure:



[20] There are, obviously, other ways in which an intesity regime could be differentiated, e.g. by adopting different baseline periods, or simply by using absolute intensity targets (i.e. unrelated to a base year).

intensities that could be used to establish equitable percentage changes, but they are not the concern of the present analysis. Instead we shall focus on an issue of distributive justice which only arises by implication, namely the question of equity in the distribution of (implied) assigned amounts, and, in turn, in the distribution of implied mitigation burdens.

At first sight, it may well seem that neither of these issues could be dealt with in the absence of some estimates of economic activity and emissions in the relevant commitment period. Indeed, this first sight appears to be quite correct with respect to mitigation burdens, which is why we will have to make use of some modelling results in the discussion of these issues below. However, as concerns the fairness of allocating (implied) assigned amounts, the first sight was at least partially blind, as it were, for there are circumstances under which it is possible to give an informative description of the proportions between these implied assigned amounts without a need for modelling. The fact is that for Parties with the same base year and the same percentage change, the implied assignment of assigned amounts under intensity targets – and carbon indices, for that matter[21]– is tantamount *to grandfathering with a* '*growth sweetener*' (see Box 3.4).

Admittedly, this characterisation of the assigned amount allocation implied by intensity target regimes is strictly speaking only true for groupings of Parties with uniform intensity targets. Nonetheless, the characterisation must be taken seriously. For one it is highly likely that there would be such groupings along similarities in economic structure and wealth. Secondly, it does give a rough idea of where assignments of implied amounts are likely to fall with respect to proposals put forward in the context of an *ex ante* assigned amount allocation (e.g. grandfathering and per capita).

- ***Intensity Targets and Burden Sharing***

As indicated earlier, analysing 'mitigation burdens' –i.e. changes from Business-as-Usual (BaU) emissions imposed by a mitigation regime– does require some assumptions (usually based on modelling) as to what this BaU would have been. In the following assessment, we shall make use of EIA projections for this purpose. We will begin with assessing the burdens imposed on different countries and regions by a simple 'Emission Intensity' (EI-) scenario. These 'simple' intensity burdens will be compared with the relevant burdens of a 'Global Compromise' (GC-) scenario (modelled in Bartsch and Müller, 2000) with *ex ante* emission caps, as described Box 3.4. The final part of the section will be about the effects of intensity target differentiation on the 'burden sharing patterns' arising from uniform targets.

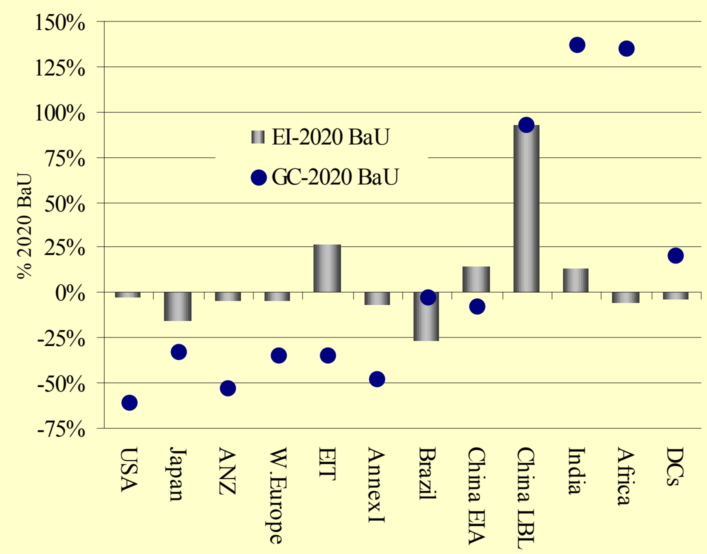


Figure 3.4: EI and GC, Scenarios. Targets relative to BaU.
'–' = Reduction Requirement, '+' = Surplus Permits

EIA = US Energy Information Administration CO_2 projections
LBL = Lawrence Berkeley National Laboratory CO_2 projections

The Uniform Case. The initial target assumption in our EI-scenario is a uniform 2020 target of 30 percent intensity reduction from the base-year 1999 (Box 3.4). The figure of 30 percent was chosen simply for comparative purposes, in order to achieve an overall emissions reduction of the same

[21] Instead of GDP growth, assigned amounts implied by (uniform) carbon index targets will be proportional to grandfathering modified with a DCP ('domestic carbon product', see Table 3.2) growth sweetener.

size as that achieved under the Global Compromise scenario. The percentage figures depicted in Figure 3.4 correspond to the burden (negative percentage figures = requirement of reduction from BaU emissions in the commitment period) or benefit (positive figures = surplus permits) under the EI uniform intensity targets and the GC 'preference score' emission caps (with their substantial per capita component).

Annex I. At 2 percentage points below BaU, the USA has to exert the least effort amongst all the Parties and regions with reduction requirements – followed in Annex I (in order of increasing 'severity') by Australia and New Zealand (BaU–4%), Western Europe (BaU–5%) and Japan (BaU–16%). Economies in Transition, by contrast, are allocated surplus emissions (+26%), which leaves a reduction requirement of 6% below BaU for Annex I overall.

Under the 'preference score' targets of the GC-scenario the US, by contrast, faces the toughest target of BaU–60%. Indeed, all Annex I Parties face more stringent reduction requirements than under intensity targets. From the point of view of narrow 'economic rationality,' no one in Annex I would hence have reasons to choose the Preference Score targets over the much more favourable emission intensity ones.

Non-Annex I. Assuming that a proposed inclusion of 'key developing countries' – Brazil, China, and India – the potential reaction of G77+China to this sort of intensity regime will be crucial to its overall acceptability. And here there might be some mixed signals.

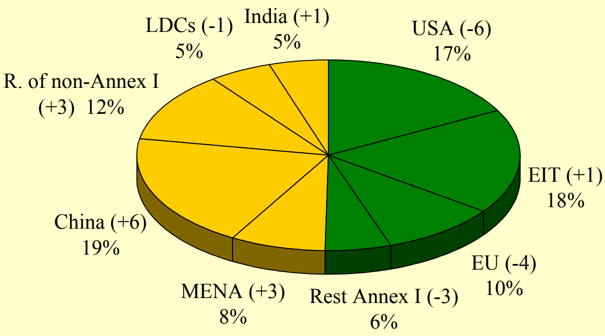
Considering the intensity regime in isolation, it is clear that some Parties will not be happy with the distribution of mitigation requirements arising from the intensity targets. Brazil, for example, would have by far the most severe mitigation burden (BaU–27%) of all Parties, including Annex I. Least developed countries, here represented by 'Africa' may also find it rather curious that with –5%, they are expected to mitigate as much as or more than any Annex I Party (bar Japan). Indeed, similar sentiments might prevail amongst developing countries in general, given that overall they are meant to put in twice the mitigation effort (BaU–4%) demanded of the US under such an intensity regime.

A country's emissions intensity target allocation depends both on the current and projected future fuel mix in addition to current and future projections of GDP. Changes to either the fuel mix or to GDP will thus have an effect upon emissions intensity. This point can be illustrated by considering the cases of Brazil, China and the US, and the additional effort they will have to put in to meet the overall 30% reduction target.

Brazil. Brazil's current energy mix consists of a high proportion of hydropower and biomass. Future energy supply projections suggest that there is little opportunity to increase hydro capacity and that the trend for switching from biomass to commercial fuels will continue. Growth in demand will therefore need to be met by the increased use of fossil fuels and this in turn will lead to an increase in emissions. Over the same period GDP is projected to increase but at a slower rate than the expected increase in emissions. The overall consequence for Brazil is that it is allocated its tough target of -27% extra effort compared to the business-as-usual case.

China. China in contrast is expected to increase the proportion of hydro electricity in its energy mix on completion of the Three Gorges Dam, and has greater potential to increase the efficiency of industrial processes which, unlike Brazil's, are already heavily reliant upon fossil fuel. Over the same period GDP is also expected to increase rapidly. The allocation of effort for China is less than for Brazil because it is already expected to achieve a decrease in emission intensity under the business as usual case of greater than 30%. If China exceeds 30% under the business-a- usual case, it would be able to sell the surplus emissions intensity credits.

Target Differentiation. It may well be objected that the EI-scenario is not just simple, but simplistic in its assumption of a global undifferentiated intensity target. And clearly it would not be reasonable to propose such a regime. However, as shown in the right-hand figure of Box 3.5, a differentiation of



Implied Assigned Amounts

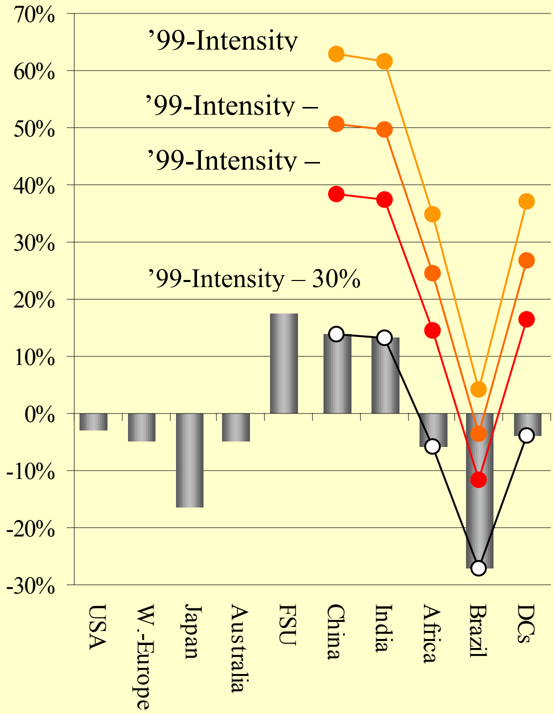
% of Total. Changes from Grandfathering (in brackets)

Source: OIES; 'MENA' = Middle East & North Africa

If R and R' designate different target intensity reduction percentages (e.g., to keep with the examples illustrated in the left-hand figure, $R = -30$, and $R' = -15$) and if M and M' represent a Party's mitigation figures (in % of BaU) due to these intensity reduction targets (e.g. –27 and –11.5 for Brazil), then the following relationship holds:

$$M' + 100 = (100 + R'/100 + R) \times (M + 100)$$

Box 3.5: The Emission Intensity (EI) Scenario



Differentiation of 2020 Targets.

Implied Assigned Amounts as Percentage Changes from BaU

intensity targets –in the case shown between Annex I (–30%) and non-Annex I (–30%, –15%, –7.5%, and ±0%, respectively) will essentially retain the relative proportions of mitigation burdens (the 'equity pattern') established in our simple EI-scenario within the grouping treated the same.

Thus even if one were to avoid North-South inequities by introducing a differentiation of intensity reduction targets, it is unlikely that *intra* developing country equity could be achieved under an emission intensity regime, short of assigning individual ('ad hoc') targets to the developing world Parties – at least it is difficult to see how say Brazil could be made to accept its target level being between 40 to 100 percent below that of China (depending on the chosen projections for Chinese emissions).

Per Capita Components. The reaction of G77+China to the EI regime on its own might also be mixed simply because India and China –as opposed to Brazil– would actually be receiving a certain number of surplus permits, which is not surprising given that intensity targets are essentially grandfathering with an economic 'growth sweetener'(Box 3.4).[22] However, compared to the surplus permits allocated under the GC regime, these EI surpluses are trifling. This is particularly true for least developed countries which, instead of receiving a much-needed asset, are actually required to impose emission restrictions. Indeed, one of the fundamental shortcomings of intensity targets –and carbon indices, for that matter– for anyone who believes that assigned amounts (whether ex ante or implied) should fairly be allocated on a per capita or a historic responsibility basis, is the essential 'family-tie' of these targets to grandfathering proposals. It might be possible to overcome this proximity to grandfathering by adopting individual country by country targets so as to obtain implied assigned amounts proportional to populations, but it is unlikely that proponents of intensity targets would support such an 'artificial' differentiation.

[22] The shares of the global 'cake' allocated under an emission intensity regime (Figure Box 3.5) are closer to grandfathering than to say a per capita allocation (cf. Box 3.4.)

3.5 Conclusions

Intensity targets focus upon emissions per unit GDP and thus allow emissions to expand with economic growth. However, they have a number of important drawbacks:

- They cannot guarantee the *environmental effectiveness* of the regime, even under global compliance;
- They pose much greater problems to running *efficient flexibility mechanisms* such as international emissions trading;
- Intensity growth rates are highly sensitive to the choice of *economic output measure* (such as exchange rate or purchasing power parity measures), and other problematic variables.
- While providing some measure of protection against curtailment of above-average economic growth, they can be *catastrophic in the context of economic recession;*
- If applied uniformly across a group of countries, they are tantamount to 'grandfathering allocations with growth';
- Given the current differences between the world's economies, they would almost inevitably be *regressive* in the North-South context and also could lead to considerable inequities between developing countries.

It may be possible to address some of these points by turning to some form of carbon indices (as mentioned in section 3.2). A global regime based on legally binding intensity targets, however, is unlikely to be either fair, effective, or find sufficient international approval to replace or succeed the Kyoto Protocol.

4. CAPPING THE PRICE OF EMISSION PERMITS[1]

4.1. Introduction

A greenhouse gas mitigation regime can in principle take two forms: a quantitative one, limiting emissions or a price-based one, defining a tax per emission unit. Obviously, in the first case, abatement costs will be uncertain whereas in the second one, overall emissions levels are not defined. Environmental economists have early come up with recommendations based on the relation between the slopes of the marginal abatement cost curve and the marginal benefit function (Weitzman 1974, for climate change taken up by Pizer 1999). If the marginal benefit curve is thought to be steeper than the marginal cost curve, quantity instruments are better. If, on the contrary, the marginal cost curve is steeper than the marginal benefit curve, then price instruments have an advantage. However, concrete application of this result in climate policy is hampered by the fact that the shape of the benefit curve is extremely uncertain due to the potential of climate "surprises" leading to sudden jumps in damages. The abatement costs also are uncertain but the shape of the cost curve is unlikely to exhibit comparable peculiarities. While most economists argue that the abatement cost curve is steep and the damage curve very flat, other researchers see a flat abatement cost curve containing a lot of no-regret options and a steep damage curve, especially if lives in developing countries are valued as highly as those in industrialised countries. Apart from this controversy, shapes of the curves can change over time. Newell and Pizer (2000) argue that the slope of the cost curve is likely to decline while the benefit curve becomes steeper.

The international climate policy regime started from a quantity-based approach due to the preponderance of scientists and NGO representatives who felt that emission targets would be easy to understand and administer. Another reason for not looking at price instruments was the reluctance of the U.S. to commit itself to anything looking like an emissions tax. Only when it became clear that the Kyoto targets would create problems in terms of domestic politics and the opponents of any climate policy voiced concerns about crippling costs, price instruments were revived. Their proponents argued that in the short term there was no risk of crossing a threshold of greenhouse gas concentration beyond which damages increase non-linearly. However, currently nobody dares to suggest a pure global emission tax due to several obstacles. First, developing countries would not be willing to submit themselves to such a tax given their high emissions intensity per unit of output. To differentiate net burdens, industrialised countries would have to make side payments to developing countries, but the distribution of such payments would create political problems. Moreover, a quantitative regime only creates a net burden at the margin whereas the tax creates a burden for all emissions unless the revenue is distributed back.

Pizer (1999) has thus argued for a hybrid approach linking quantitative targets with a price on emissions via a "price cap". This approach has become quite fashionable and deserves a detailed discussion.

4.2 Price Caps as 'Safety Valves'

The idea behind the price cap is simple. There is a regime with quantitative greenhouse gas emissions targets. A transparent national/world market for emissions permits exists, leading to a common market price. If the market price rises above a predetermined threshold, additional permits are issued at the threshold price. Depending on the level of the price cap, the regime has more features of a quantitative or a price regime but this will not be known *ex ante*. The proponents of the price cap argue that the cost of climate policy will be limited ex ante, addressing President Bush´s first concern.

[1] We thank Cedric Philibert for helpful comments on an earlier draft.

In practice, a price cap has already been used in the Danish CO_2 trading system for the electricity sector since January 2001. The price cap lies at 40 Danish Crowns (about $5) per tonne of CO_2. This level has been set to avoid Danish coal-fired power stations becoming uncompetitive within the fully liberalised *Nordpool* electricity market.

4.3. Simulation of Price Caps for International Climate Policy

Hourcade and Ghersi (2001) have developed a meta-model (SAP 12) evaluating 12 current economic models of international greenhouse gas abatement. They calculate the effect of price caps. The model assumes relatively high transaction costs of at least $2.7/t$CO_2$ and overall limits the CDM to 25% of its potential while allowing 66% of the JI potential to be used. Under a price cap of $13.6/t$CO_2$, ($50/tC) domestic abatement in OECD countries falls by about 20 percentage points; for a cap of $27.2/t$CO_2$ ($100/tC) the difference is reduced to around 10 points. If the revenues from sales at the price cap are not recycled domestically but used to finance abatement projects abroad, domestic abatement increases by 3 to 10 percentage points due to the assumption that there is a political cost to spending money abroad (they use a multiplier of 1.3 and 1.5). The volume of additional permits issued is shown in Figure 4.1. Caps at this level roughly lead to an emissions increase of 5 to 10% compared to the Kyoto targets; emissions remain about 10–15% below business as usual.

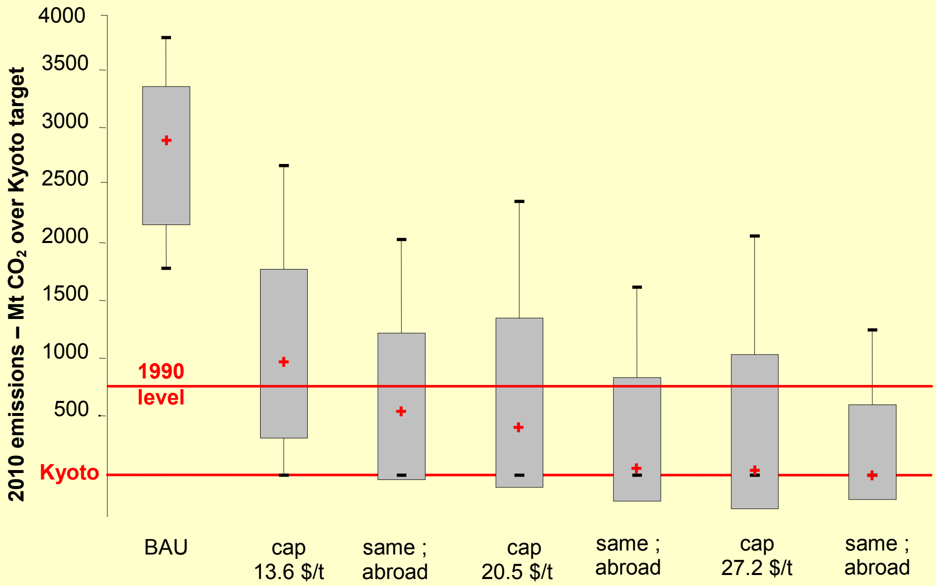


Figure 4.1: Effect of Price Caps on Annex I Emissions

Source: Hourcade and Ghersi (2001)

The likelihood interval (the average of the 12 model results minus and plus the standard deviation) is shown by the shaded boxes in Figure 4.1; extreme bounds and median value are represented by the lines and crosses.

Table 4.1: Probabilities of staying below Kyoto target and 1990 emissions levels (5.2% additional permits)

Cap level		*Normal*		*Optimistic*	
$/t$CO_2$	($/tC)	Kyoto target	1990 level	Kyoto target	1990 level
9.5	(35)	8%	50%	17%	67%
13.6	(50)	25%	75%	50%	83%
20.5	(75)	50%	83%	67%	92%
27.2	(100)	75%	83%	83%	92%

Weighing models results in the following factors: one for the four most pessimistic, two for the four medium and three for the optimistic, Hourcade and Ghersi take an ‘optimistic’ worldview. Probabilities of creation of additional permits for four different cap levels differ considerably, as shown in Table 4.1.

At price caps below \$20/t CO_2, there is thus a considerable probability that additional permits amounting to several percentage points of emissions budgets will be created. The environmental integrity of the Protocol would thus be jeopardised unless it is possible to recycle the revenues in a way that allows reducing/sequestering emissions of a similar amount (see discussion below).

4.4 Drawbacks of Price Caps

The seemingly simple idea of a price cap has a number of drawbacks that will be discussed in the following chapter.

- ***Elimination of incentives for R&D in technology with costs above the price cap***

Depending on the level of the price cap, there will be a threshold effect crowding out technologies with costs slightly above the price cap. The effect is much stronger than in the case of a world market for permits since the world market price varies and there is a chance that the price will rise above the value that makes a currently uneconomic technology economic.

The probability that the price stays below the threshold is 100%, at least for the duration for which the price cap is fixed, whereas in the world market case, there is a probability distribution around the current market price.

Research incentives will be concentrated in technologies whose costs are somewhat higher than the cap. Those technologies with a huge cost gap will not attract any interest.

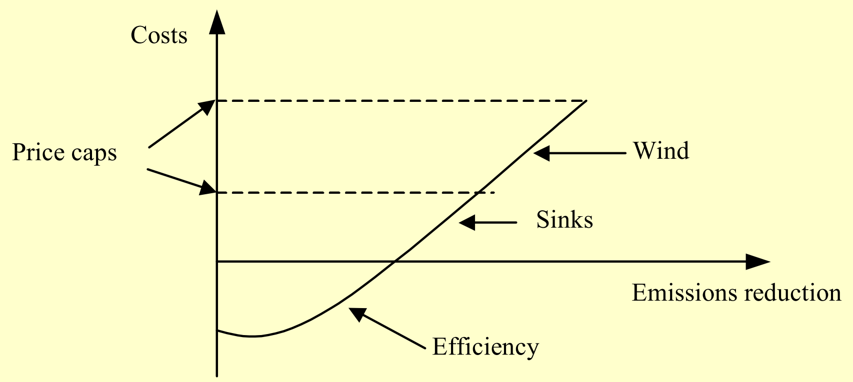


Figure 4.2: Threshold Effects

Under the lower price cap, wind will never be implemented

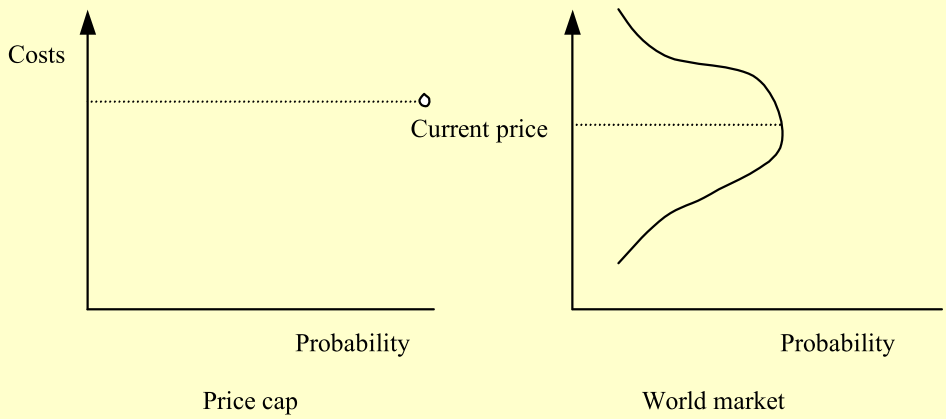


Figure 4.3: Probability Distribution of Price Per Tonne under a Price Cap Compared to a World Market

- ***Setting the price cap: who does it and what are the rules for change?***

A price cap can be set on either a national or an international level. The former would mean that emissions trading between countries would become impossible due to arbitrage – all permits would flow out from the country with the lowest price cap as long as the cap was binding. The country would earn rents from the printing of permits. The international permit price would decline to this value – bad money drives out the good – and a larger number of additional permits would enter circulation. Pizer (1999: 9) therefore suggested forbidding permit sales from countries with lower threshold prices. He is right because otherwise the incentive for rent seeking cannot be removed. However, this would mean that the price cap would have to be harmonised or we get an inefficient international regime. Still some efficiency increase could be achieved if national governments with lower price caps had the international obligation to buy up permits from those countries that have not reached their (higher) price caps. The buying governments would face a budget problem due to the domestic sale of permits at a lower price than the acquisition price. National price caps therefore make no sense if international flexibility is to be retained.

Setting the price cap on an international level would be a political nightmare, especially under the consensus principle. Negotiating floor prices in the context of international commodity agreements has been very difficult and agreement could not be sustained for longer periods (ODI 1995).

A great problem relates to the difference between expected and real abatement costs. If the price cap was too high, it would never bind and the situation would be comparable to that under the Kyoto Protocol. Still under such a situation, the cap would give some reassurance to those fearing extremely high costs and thus would have a positive impact. It could for example lead to more stringent targets for subsequent commitment periods. If abatement costs turned out to be lower than expected, the targets would be kept. However, given the political bargaining situation in international climate negotiations, it is likely that the cap level would be very low, thus not giving a credible incentive for greenhouse gas reduction. Then it would always be binding and amount to a low-level harmonised GHG tax – a policy instrument that was previously rejected in the early stages of the international climate negotiations. McKibbin and Wilcoxen (1997) have even suggested setting the trigger price low enough to avoid the need for international GHG trades. However, due to the existence of 'hot air' and cheap CDM projects, this price would have to be very low, presumably only at the level of transaction costs. This would mean that emission reduction activities would be negligible.

Of course, one could raise a price cap that is found to be too low or lower a non-binding one. However, this conflicts with the aim of giving long-term security for planning. Thus there should be predefined rules for changes in the price cap. The possibilities range from once per commitment period to every MOP. If it could be changed at discretion, the uncertainties for economic actors would become as big or even bigger as in the case for a fixed quantity without price caps.

If the price cap is set on an international level, the question remains as to who controls the allocation of permits if the price reaches the threshold. Central issuance by the UNFCCC secretariat would guarantee that there be a common procedure and currency used. If allocation is left to the discretion of governments, the question arises as to how the cap would be converted into national currencies. Some countries would use exchange rates, others would argue for purchasing power parities. In case of exchange rate fluctuations arbitrage possibilities would arise.

With a price cap, market participants would be likely to wait until the last moment (i.e., the end of the first commitment period) until they bought permits at the ceiling price. This is to be expected because (1) there is a chance that credits could still be obtained at a price lower than the ceiling price, and (2) in terms of net present value it would be economical to purchase the permits as late as possible. Therefore, the cap would have to be inflated over time to make early purchasing of the permits more attractive (Schlamadinger et al., 2001). The rate of increase should be at least equal to the market interest rate.

Under a price cap regime, countries may actually *reduce* their climate policy activities, if they converted existing GHG taxes into permit systems. In some European countries, carbon taxes amount to more than \$30/t CO_2 for households. Usually industry is exempt or pays much lower rates, but under a very low price cap it would have good reason to press for a reduction of the tax level to the price cap. Equally, also under a price cap regime, governments could still use higher price policies, if they thought their electorate would accept these.

- ***Limiting of banking and the need for open market policy***

Under a low price cap, banking of permits would have to be limited as observed by Pizer (1999: 9). Otherwise, under the expectation of a rising threshold price, there would be an incentive to buy large volumes of cheap permits in order to sell them at high prices in the future. A possible solution would be to limit banking to the duration of the period during which the price cap had been fixed. Limitation of banking, however, means that hedging strategies would become more difficult since economic actors always have to use derivatives, leading to transaction costs. On the other hand, market liquidity would grow. However, limiting banking again would reduce the flexibility, and therefore the overall efficiency, of the market.

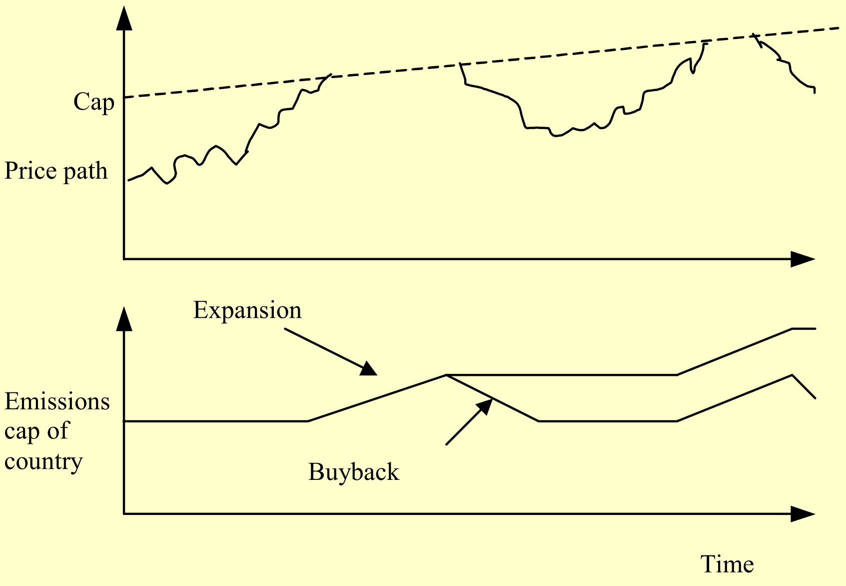


Figure 4.4: Expansion of emission budgets and buyback

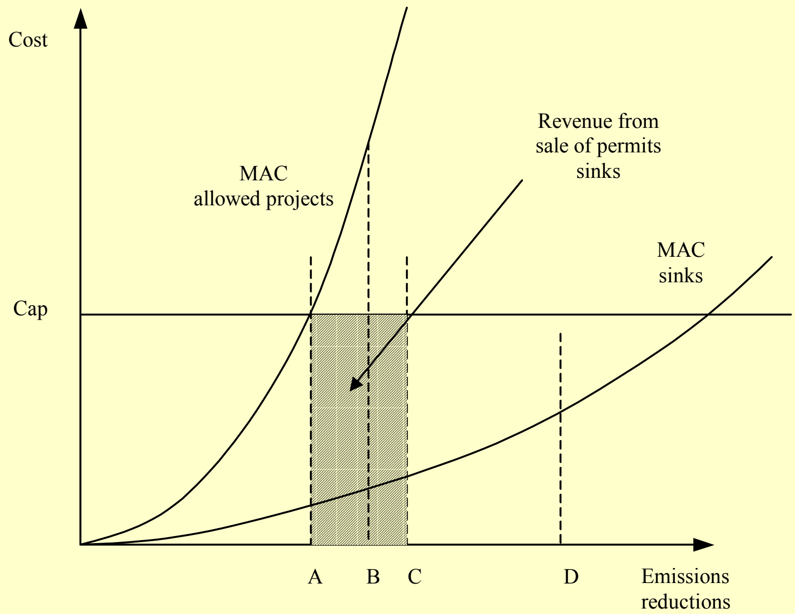
A situation where the price cap had been set at a level where it is not binding, would require rules as to what happens if the price were to fall again after the cap had been reached (see Figure 4.4). If the emissions target was felt to be the guiding principle, there should be a rule calling for the UNFCCC secretariat/governments to buy back the supplementary permits.

Obviously, even under this rule the question arises as to how quickly a buyback should be made. Moreover, such a rule would mean that revenue from permit sales would have to be earmarked for later buyback. Under an international regime for permit sales, this might be easier than if the revenue were to accrue to governments. Instead of compulsory buyback rules, the international regime could also use revenues for investment in additional emission reduction projects. Under normal assumptions this would not allow for fully compensating for the emissions increase, since the reductions would have already been done when the permit price had been below the cap (see Figure 4.5). An intriguing proposal[2] suggests to allow investment in cheap project categories that are otherwise excluded from

[2] Schlamadinger *et al.*, (2001).

the CDM, such as avoided deforestation or land use-related sinks in general This could even achieve a reduction greater than the Kyoto target if the price were sufficiently low (see Box 4.1).

Box 4.1: Reinvestment of permit sales revenues



A government sells permits of the amount C-A and thus gets a revenue of the amount of the shaded rectangle. If this revenue is reinvested in allowed project, only an emission reduction of B-A is achieved (the area from A- B until the MAC is equal to the shaded rectangle). If now cheaper sinks are allowed for reinvestment, the amount buys a reduction D-A.

4.5. Evaluation of the RFF and McKibbin-Wilcoxen Proposals

There are two proposals from US researchers that include the idea of a price cap. The simpler one has been advocated by the think tank Resources for the Future (Kopp et al., 1999). It refers primarily to domestic US climate policy and suggests a domestic emissions trading system with a price cap of $6.8/tCO_2$ rising by 7% p.a. Validity of permits bought at the cap level is restricted to one year, other permits are only valid for two years. Kopp et al. (2000) transfer the price cap idea to the international level and link it to the issue of compliance. They suggest that Annex B countries in non-compliance should pay a ‘penalty’ of $13.6/tCO_2$ for their surplus. The revenues would then be collected in a ‘compliance fund’ and used to tender emission reduction projects.

A problem with this proposal is that these payments would only be made by states and would have to be translated into domestic penalties. If domestic penalties were higher, private actors could not cap their costs. The cap of the world market price would be the discounted value of the ‘penalty’, thus considerably lower. The volume of payments could only be known after the end of the commitment period and may be difficult to raise in one payment under the restrictions of public budgets.

NGOs who had initially supported the compliance fund assuming that the penalty would be the highest market price during the commitment period times a multiplier, became opposed to it at COP 6a in The Hague because they felt that the penalty would become a low-level price cap (Wiser, 2001).

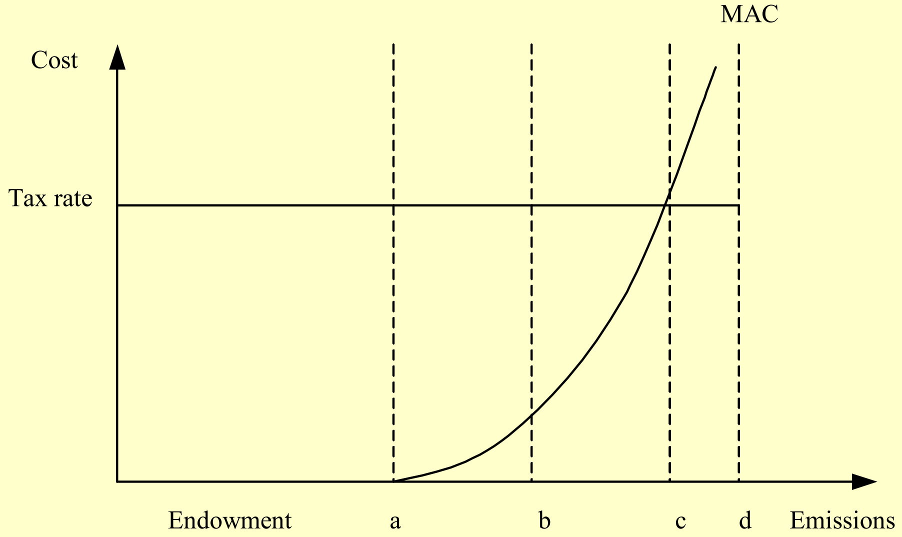
McKibbin and Wilcoxen (2000, 1997) suggest a combination of two permit systems – one system would allocate permits that are valid forever (‘endowments’) on the basis of Kyoto targets for Annex

B and growth targets for Non-Annex B. They would be complemented by permits valid for one year issued at 2.7 $/ t CO_2 in Annex B. There would be no international trading.

The latter type of permit acts essentially as a carbon tax and not as a price cap. The tax level is fixed once per decade. The endowments are nothing other than a perpetual tax exemption. Tax would only be paid if the emissions were to rise above the endowment level. The value of endowments would be equal to net present value of tax payments for the rest of the decade plus expected net present value of tax payments beyond. To strengthen targets, governments would have to buy back endowments. In Non-Annex B countries, the tax level would be zero until the emissions exceeded the endowment. The endowment would have a price above zero due to expectations about emissions growth. The same situation would exist in Annex B countries with regard to hot air.

The main problem with the McKibbin-Wilcoxen proposal is that there would be no incentive to equalise marginal abatement costs globally so long as the tax was not binding (see Box 4.2). This would depend crucially on endowment levels.

Box 4.2: Emission reduction costs under McKibbin/Wilcoxen



As long as emissions are below a (=endowment), there is no abatement action and marginal costs are zero. If emissions rise beyond a to point b, marginal costs are well below the tax rate. They only equal the tax rate beyond c. Companies would thus abate a-c before paying the tax. While the value of endowments rises as emissions grow beyond a, their overall number remains constant and thus does not influence the abatement cost curve

Moreover, governments would lose their freedom to strengthen targets without serious budgetary implications since they would have to buy back the endowments. Flexibility is thus much *lower* than in the Kyoto regime.

If the emissions level were to rise quickly above the endowments, expectations would form that tax levels will be increased in the following decade. Thus endowment prices would rise.

4.6 Conclusions

There is a long-standing discussion between economists whether quantity or price-based regimes are preferable in international climate policy. While economists often prefer price instruments, there are also many reasons for quantity rules. Price caps try to get the best of both worlds by combining a quantity regime with a price-based approach.

Price caps at which additional emission permits would be issued would have to be internationally harmonised to avoid free riding by countries that would issue permits at very low prices and thus try to reap revenues. This harmonisation would create difficulties related to the differences between exchange rates and purchase power parities. Caps would have to be continually increased to avoid buying spikes at the end of a commitment period. Banking would have to be limited under a price cap, as otherwise it becomes attractive to bank under an expectation of rising cap-levels. This is particularly relevant if the initial price cap were low as would be likely under a U.S. proposal.

A high price cap could give some *ex ante* certainty that costs would not be crippling and thus help to allow more stringent targets in subsequent commitment periods. If it never bound, it would be equal to a pure quantity regime. However, political pressure is likely to exert a downward influence on the cap level. If its level was very low, it would be tantamount to a low-level international greenhouse gas tax. Both domestic action and investment flows via the Kyoto Mechanisms would be reduced and Kyoto target levels would be overshot by a large margin. Model studies show that for price cap levels below \$20/t CO_2 (\$75/tC) the amount of additional permits created is likely to be several percentage points of Annex B emissions budgets. The ensuing trade-off between increased damages -– primarily in developing countries – relating to a reduced effectiveness of the regime, and cost reduction for the parties responsible, is morally wrong and contrary to the general principles adopted under Article 3 of the Framework Convention.

An intermediate level cap would be binding from time to time. If its revenues were earmarked for reinvestment in abatement project categories not covered under the current Kyoto Mechanisms, it could even enhance the environmental effectiveness of the regime.

5. Timing and Technology-oriented Approaches

5.1 Introduction

Faced with the difficulties of designing an alternative international regime, but nevertheless opposing Kyoto, some analysts argue that the global community could afford to take 'time out' to start exploring all possible options, in the hope that something will emerge – if not a global agreement, then perhaps a mix of unilateral actions and regional agreements. Such analysts tend to start from the belief that Kyoto is just too ambitious – and in particular that its targets are too much, too soon – and they point to a strand of economics literature that argues that it might be cheaper to defer abatement, partly to await improved technologies. Some go further, and argue that focusing explicitly on CO2-avoiding technologies could obviate the need for either quantity targets such as those embodied in the Kyoto Protocol, or for price-based agreements that raise the price of carbon (as discussed in Chapters 3 & 4 of this report respectively). This chapter briefly considers these arguments.

Four main issues affect the estimated costs of meeting a fixed target for stabilising CO2 concentrations in the atmosphere (Wigley *et al.,* 1997*:* the 'WRE' analysis; Grubb, 1997):

- *discounting* would reduce the 'present value' of abatement costs if deferred (or, would require less resources to be used now to finance it); but would, by the same token, increase the 'present value' of the greater near-term climatic damages arising from higher near-term emissions.
- *carbon cycle absorption* of CO_2 means that higher earlier emissions (deferred abatement) allow greater *cumulative* emissions before a given concentration ceiling is reached; but such higher earlier emissions also increase the *rate of climatic change*, and potentially the risk of crossing rate-dependent climate system thresholds leading to irreversible effects.
- prematurely retiring existing *capital stock* could make rapid change costly; but the ongoing retirement, replacement and construction of new capital stock provides opportunities for low-cost abatement starting now, and construction of new carbon-intensive stock could risk 'locking in' systems to higher future emissions (or increase the cost of subsequent reductions).
- *technical progress* in low carbon technologies would reduce the costs of abatement in the future; on the other hand, near-term abatement may stimulate the development of improved technologies.

This chapter considers each of these issues briefly, and then discusses proposals for technology-oriented approaches to the international system. As noted in the introduction to this report, the claim that the US target *per se* is too strong – or at least, cannot now realistically be achieved given the lack of effective abatement to date and the political difficulty of getting action through the US legislature – need not destroy the basic Kyoto agreement. If the US remains unwilling to honour its Kyoto 1st period commitment, the rest of the international community does still have the option of implementing Kyoto as agreed, and then turning attention towards the negotiation of second and later period commitments, as discussed in our *Keeping Kyoto* report. The focus of this chapter is whether timing-related arguments could justify a general abandonment of the Kyoto framework, and whether technology-related approaches offer a credible alternative.

5.2 Discounting and Carbon Cycle Effects

Deferring emissions abatement lowers the *present-value discounted costs* of mitigation, but conversely it would bring impacts nearer. So even neglecting all other considerations, the implications of time discounting for the overall policy problem are not as clear-cut as implied in studies that considered only the question of stabilization without reference to damages (so that discounting applies only to abatement costs).[1] Even for models which maximise the supposed economic benefits of delay,

[1] WRE were in fact careful to note that the time paths of impacts would differ according to the time path of emissions, and presented calculations of how global average temperature and sea-level change varies between scenarios (though it did not (cont.)

tentative economic studies suggest indeed that the monetary estimate of additional climate damage from ‘delay’ scenarios might be comparable with the supposed economic benefits of deferring abatement, with wide margins of uncertainty.[2]

Additionally, although carbon emitted earlier has more time to be ‘reabsorbed’ before hitting a concentration ceiling, it also means greater overall peak rates of change in the atmosphere, with more rapid change and more cumulative heat trapped over coming decades. Since human societies are likely to have greater difficulty in adapting to rapid climate changes than to slow and smooth changes, this is an important consideration. Furthermore, a more rapid rate of change enhances the risk of (inadvertently) crossing thresholds of the climate system, leading to abrupt and irreversible effects being increased at any point in the future.

In addition, these observations point to important issues of equity. Whilst richer countries account for most of the emissions (Chapter 1) and are expected to bear most abatement costs in the near term, developing countries are expected to bear a disproportionate degree of climatic damages. Thus, deferring action, in the absence of compensating international transfers, also involves shifting costs on to poorer countries that are both less able to cope and share little responsibility for the problem in the first place.

5.3 Capital Stock Turnover and Inertia

The observation that ‘time is needed to re-optimize the capital stock’ has been widely used as an argument for deferring abatement. However, it is double-edged as an argument since capital stock is continually being refurbished, retired or restructured and additional new investment is required to meet demand growth.[3] A key to economically efficient abatement is to make new, less carbon-intensive capital stock than it otherwise would be. This will mean a steady reduction of emissions from the business-as-usual trajectory, starting as soon as climate change is recognized to be a potentially serious problem.[4]

Especially when coupled with uncertainties about the actual objective (see below), this has powerful industrial implications. Inappropriate delay in constraining emissions is not necessarily in the interests of industry and could backfire: it could increase the exposure of industry to the risk that new, carbon-intensive investments will have to be prematurely retired at large cost compared with the costs of avoiding such investments in the first place (e.g. coal-powered plants or mines left ‘stranded’, or frontier oil exploration and development left without sufficient high-price markets when they mature). Moreover, emitting companies think they may be able to prevent GHG reducing policies completely if they are relegated to the future and thus have an incentive to continue to invest in emissions-intensive

note the link with discounting). For estimates of climate change damage costs, see, for example, Fankhauser (1993), or Ridley (1998).

[2] For WRE’s central case, averaged over the next 50 years, the rate of temperature change appears to be more than 20% higher than is the case without deferral of emissions abatement. The Dutch IMAGE model has also been used to explore the implications of deferred abatement under a 450 ppm ceiling. Compared to the IPCC 450 ppm scenario, the scenario in which abatement is delayed until 2025 (followed by rapid reductions) leads to a 40% higher rate of global average temperature change over the first half of the next century, and a higher overall peak temperature later in the century; other indicators that are substantially affected throughout the next century by delayed action include maize yields and natural vegetation change (Alcamo, 1996). Quantitative analysis of the effects of deferring abatement on climate change shows these impacts to be significant (e.g. Tol, 1997).

[3] Frequently the oldest capital stock is also the least efficient, with rising maintenance costs. The net costs of retiring such stock rather than refurbishing it for a longer (polluting) life may be small and may indeed result in net gain when other factors are considered. When the costs are finely balanced the economic issues are similar to those involved in new investment to meet demand growth.

[4] The economic importance of getting this right was itself apparent from the scenarios in the WRE analysis. In their central case, their ‘deferred abatement’ trajectory showed emissions rising by more than 50% over the next 40 years, before dropping steadily. Thus the delay scenario involved constructing an *additional* 4 GtC per year of capital stock over and above that anyway required for replacement. The scenario would mean investing in at least as much new CO_2-based capital stock over the next few decades as is embodied in the world’s entire energy systems today, and then dismantling it over the subsequent decades.

projects, entering into a vicious circle of postponement of climate policy action and climate-unfriendly investment. In general, economic modelling studies do not capture these complex inertial effects well, and an analysis which sought to focus explicitly upon these inertial effects argues that given a quantitatively more realistic value for inertia in the global energy system, deferring abatement until 2020 could prove very costly for stabilization levels significantly below about 550 ppm (Figure 5.1).

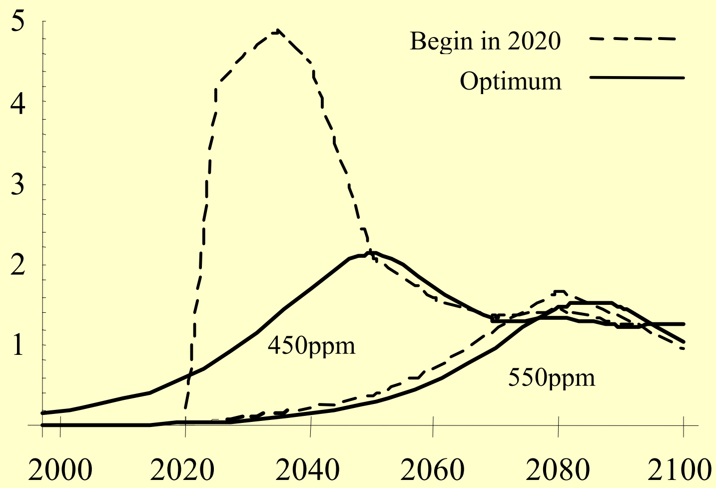


Figure 5.1: Costs of Abatement after Delay. 450 ppm and 550 ppm CO_2-only Concentrations

Source: HaDuong *et al.* 1997

Uncertainty is a key consideration here. If we delay action in the belief that we are aiming to stabilize concentrations at 550 ppm, for example, then after a couple of decades it may simply be too late to be able to stabilize at 450 ppm, however urgent the problem then turns out to be; and even stabilization at 500 ppm might by then involve radical changes of direction that could prove economically very disruptive. Also after such a delay, stabilization at a lower-than-expected level would require not only faster, but much deeper action – car-free cities, for example, rather than the low-emission, high-efficiency vehicles that might be consistent with a smoother abatement trajectory. Steady sustained pressure to limit emissions cannot expose us either economically or environmentally to the scale of risks that may be incurred by a long delay.

For the US, this issue assumes particular importance in the context of the Administration's proposed energy strategy. This plan envisages a substantial investment in new carbon-emitting capital stock that would be designed to last for decades. In effect, this would represent a gamble – by the US as a nation, and by the companies involved - on the hope that climate change will not turn out to be such a serious problem, and that serious constraints on US emissions can be avoided for decades. Certainly, the view that abatement action can be deferred with little consequence contrasts with the conclusions of the industry-led World Energy Council, which back in 1997 observed that 'action postponed will be opportunity lost, guaranteeing that when action can no longer be avoided the ensuing costs will be higher; dislocations more severe; and the effects much less predictable, than if appropriate actions are taken today'.[5]

The long-run consequences of the US energy plans and the carbon-intensive capital stock they would embed are hard to envisage in full. One preliminary estimate is that cumulative US emissions could increase over the *century* by up to 50%, if subsequent abatement were constrained to avoid prematurely retiring any of the additional stock constructed, as compared to a scenario in which emissions are reduced broadly in line with capital stock turnover starting immediately. Depending upon how the spillover affects policies, energy choices and technology choices elsewhere, the resulting increase in cumulative global emissions could be twice that – perhaps up to c. 100 billion tonnes of carbon over the century (Grubb, 2001).

[5] World Energy Council, *Energy for our Common World – What Will the Future Ask of Us?* Conclusions and Recommendations of the 16th WEC Congress, Tokyo and London: WEC, 1995.

5.4 Technology Development

The argument for deferring action that has gained most hold in US discourse is that technology development would reduce abatement costs in the future, hence it would be cheaper to defer abatement and invest in R&D instead[6].

Even in less extreme forms, there are two major complications regarding the use of technology arguments to defer emissions abatement. First, not all abatement requires advanced technologies (at currently high but declining costs); for example, improved building insulation, waste heat recovery and lighting controls can be cheap and simple. In reality there is a whole continuum of abatement options. It is clearly a *non sequitur* to imply that cheap abatement should be deferred on the grounds that the costs of more expensive action might decline in the future.

Box 5.1: The Conflicting Messages of Technical Change Modelling

All economic models applied to climate change mitigation underline the importance of technology development in lowering the cost of long-run, deep emission reductions (Edmonds, Roop and Scott, 2000). Most of these models still characterise technological development as 'autonomous': the costs of renewable energy in 2050, for example, are projected by the modeller and do not depend upon the capacity of, and market investment in, renewable energy in the intervening decades. Not surprisingly, these models generally suggest that it is cheaper to wait until the costs of low-CO2 technologies 'come down'.

In reality the costs of technologies generally decline as the market share increases, due to corporate R&D investment and learning-by-doing. Recent models that incorporate this show different behaviour to the classical models, but vary considerably in the strength of the observed effects. Technology-oriented models in which costs depend explicitly upon investment or installed capacity, to a degree that is consistent with historical experience, generally show a strong effect. In such models, these effects greatly strengthen the appropriate abatement over the coming years, so as to stimulate the market-based learning that is required to lower long-run costs (Anderson, 2000; Criqui, 2000): there is a high 'innovation externality' benefit from policies that limit emissions and thereby encourage innovation in low-carbon technologies.

More aggregated models, that have less empirical engineering basis but which seek to model the whole economy, emphasise that such induced innovation in the energy sector may be at the expense of drawing 'innovation resources' from elsewhere in the economy; these models generally show a weaker effect, though all generate greater long-term abatement than the case without any learning-by-doing (Goulder and Matthei, 2000; Nordhaus, 2000). In response to this however, it has also been pointed out that there is considerable potential to shift the innovation effort within the energy sector: at present, much energy investment is still directed to making fossil fuel extraction and conversion cheaper, and efficient abatement is likely to involve redirecting much of this effort towards low-carbon resources, thus reducing abatement costs without drawing 'innovation resources' from outside the energy sector (Grubb, 2001). None of the aggregated models incorporate this factor.

Second, this line of thinking assumes that all technological development would occur independently of emission abatement efforts. This envisages technology development as an 'autonomous' process occurring independently of market conditions. This may be true to the extent that technology development represents an automatic accumulation of knowledge, or is fostered primarily by government R&D. But the idea that new technologies develop autonomously, or arise primarily because governments pay to develop them, was abandoned decades ago by economists working on technology issues.[7] Government R&D can help, but much effective technology development and dissemination is done by the private sector in pursuit of markets. In other words, much technology development is *induced* by market circumstances: market experience leads to cost reductions, and expectations about future market opportunities determine how industries deploy their R&D efforts. This is not surprising, since in fact corporate R&D exceeds government R&D. The energy sector

[6] The argument reached its zenith with a proposal that emissions should be essentially unconstrained for the next 20 years, then be capped, and should then be cut back at unprecedented rates towards zero once the 'required technologies had been developed'

[7] K. Arrow, 'The Economic Implications of Learning-by-Doing', *Review of Economic Studies*, Vol. 29, 1962, pp. 155–73. The standard reference on induced technical change has become W.B. Arthur, 'Increasing Returns and Path Dependence in the Economy', Ann Arbour: University of Michigan Press, 1995.

itself, ranging from oil platforms to wind energy, has provided powerful examples of the fact that technology development depends strongly upon market conditions.

Induced technology development implies that the *act* of abatement would generate market opportunities, cash flows and expectations that enable industries to orient their efforts and learning in the direction of lower carbon technologies. Hence, action itself generates cheaper technological options arising out of accumulating experience. In this case, deferring emission reductions simply delays the generation of options that can address the problem at low cost.[8] Though modelling studies characterise the problem in different ways and differ greatly as regards the numerical importance of this issue of 'induced technical change' (see Box 5.1) it generally does increase the economic benefits of early action, as compared to the notion that better, cheaper technologies will arrive like manna from heaven, or purely through government-directed R&D programmes.

To an important degree, therefore, the use of economic arguments to justify deferring abatement has led to the opposite conclusion, and has clarified the economic case for acting now. Analyses based on less overtly economic approaches, exploring 'tolerable windows' for emission trajectories towards certain climate-related goals, have tended to reinforce views that the problem calls for urgent action (Alcomo and Kreilman; Alcomo, Rlleemans, and Kreileman (1998)). The appropriate degree of action, of course, depends upon the objective and framing of the problem. Atmospheric concentrations exceeding about 550ppm could be achieved with relatively gradual emissions abatement even if such action were largely deferred for the first decade or two of this century. Such deferral would become increasingly costly for stabilisation levels below this (Azar (1998)). Another key consideration is thus uncertainty – since we do not know what might be a 'safe' atmospheric level, a failure to start limiting emissions now would preclude very low stabilisation levels (e.g. below 450ppm), and would rapidly start to raise the costs of achieving levels in the region 450-550ppm should these prove necessary (HaDuong *et al*). More generally, focusing just upon stabilisation levels misses a large part of the overall objective, namely that higher rates and levels of atmospheric change, arising from deferring emission reductions, would almost inevitably increase the risks and costs associated with climate change as well as tending to impact the more vulnerable regions), even if the exact nature and degree of risks and impacts cannot be quantified. It is an inescapable conclusion that substantially higher near-term emissions mean greater climatic change for all over the coming decades, and probably irreversible commitments to greater long-term warming as well.

5.5 Technology-led Regimes

Notwithstanding the dubious use of technology-related arguments to try and justify weak abatement efforts, there is no doubt that technology and technology development has a very important role to play in solving the long-term climate change problem. Some analysts have suggested that a global response could just focus on technology, without recourse either to quantified emission constraints or a price-based agreement (Edmonds, 2001; Barret, 2001). The suggestion is that solutions could be found either (a) through a concerted global R&D effort that yields such dramatic success that the world adopts these technologies as a matter of course, or (b) through a technology-based standards approach in which countries – proponents tend to assume, all countries – would agree to pass laws mandating that certain low-carbon technologies had to be used.

The first of these approaches is, obviously, a huge gamble with little real plausibility. Certain forms of renewable energy, for example, might well become cheaper than fossil fuels for some applications (some already are, mostly in the context of market incentives). But the idea that a government-led R&D programme, without the market incentives associated with CO2 constraints, could lead to a

[8] e.g. The Tokyo World Energy Congress urged 'governments, business decision-makers and energy consumers' to 'start taking action now to adapt to the needs of our long term future ... the next two or three decades represent the key period of opportunity for a transition to a more sustainable path of development for the long term. Research done and action taken now will begin the shift of direction required of "minimum regrets" action'. World Energy Council, *Energy for our Common World*.

global industry displacing the entrenched fossil fuel business, lies in the realm of fantasy.[9] History also shows the repeated failures that have arisen from governments fundamentally choosing which technologies to sponsor on a massive scale: the danger of trying to 'pick winners' (Cowan 1991, David and Bunn 1988, Alic and Mowery, 2001).

Could such developments be achieved however through a standards-based approach? Edmonds (2001) argues that the plausibility of this is increased by the fact that most energy goes through two channels, namely power production and refining, and that technology standards could be applied to these. Unfortunately this could not address the non-CO2 and non-energy-sector gases, non-commercial energy, and most heating supplies. Furthermore, focusing only on the energy conversion part of the chain would give no incentive for tackling emissions elsewhere – for example, it would give no incentive to improve the efficiency of energy use (other than indirectly, through the sledgehammer consequences of raising the costs of energy conversion).

In addition, it is far from clear how such standards might be applied in practice – an edict banning all carbon-based power production from some year in the future? A requirement that all refineries must accept only biomass-based source material or non-fossil fuel derived hydrogen? What about petrochemicals? What about the use of natural-based combined heat and power production, at three times the efficiency of coal-based power generation – should this equally be banned? What about countries that do not have the vast land area of the US with which to develop large-scale biomass fuels? Should crowded developing countries such as Bangladesh be required to buy imported, expensive biofuels?

These considerations suggest that an approach based *purely* on technology standards may be unworkable, and at best that it would be a poor and ineffective – and potentially highly inequitable - substitute for an international regime that focuses upon the actual problem, namely greenhouse gas emissions. Nevertheless, given the acknowledged importance of technology, useful ideas could emerge from such discussions. A stronger explicit technology-based component could usefully complement an emissions-constraint-based regime, helping for example to lower the costs of future period commitments. Although in classical economic theory, emission constraints should themselves provide incentives for the required innovation, the reality is far more complex.

5.6 Integrating Technology, Timing and Emission Limits

In combination with an incentive structure that leads companies and households to value carbon abatement, appropriate policy can do much to ensure an adequate technological supply to meet both existing and likely longer-term emission constraints. Government R&D, judicious use of technology standards - perhaps in some cases internationally agreed – and novel ideas for encouraging corporate investment in new technologies, could all have a useful role to play.

Indeed, the concept of technological change is commonly protrayed as a series of unique, albeit interlinked stages – invention, innovation, niche market commercialisation, diffusion (e.g. Gr-Ler et al (1999)). Different types of policy instruments (sticks, carrots and sermons) are likely to provide differenct incentives for the individual stages of technological change. Hence, a portfolio of carefully selected policy instruments is most likely needed to promote each stage, and secure incentives throughout the technology development cycle.

Alongside the basic economic incentive structure, governments could try and balance the diffusion of technology with the growth of the economy by seeking to coordinate technology development and investment with business cycles. The fact that most investment in new technology takes place in the growth phase of a business cycle offsets the fear that absolute emission caps might prove particularly

[9] Indeed, one of the major technologies advocated in many 'technology fix' scenarios involves direct CO2 stripping and sequestration. Obviously, this adds considerably to the cost of power stations and would only be adopted under regulatory pressures.

costly in times of rapid economic growth. In addition, rapid expansion of new technologies is least costly to companies – and has greatest potential benefit – when associated with an economic upswing. Despite forecasting difficulties, policymakers could usefully consider the duration and timing of technological diffusion processes in the context of business cycles.

Building for the longer term, addressing climate change is likely to require large-scale transformations of the energy system. Many believe that we are already moving towards an 'energy revolution' in both structures and technology, for example with demand for small, decentralised electricity generating units (Flavin and Lensen 1995, Patterson 1999). Competitively priced technology that can meet such a demand can accelerate such a transformation, providing massive opportunity for low carbon technology (Fouquet 2001). To catch the 'big wave' of such a transformation, related factors such as both hard and soft infrastructure (e.g. network structures, and a tradable emission permit scheme) need to be implemented in advance, to provide both means and incentives. Policies will probably include a combination of 'command and control' regulation, market-based incentives and information campaigns, and will be particularly valuable in the early phases of technological diffusion.

To the extent that such policies may benefit from international cooperation, they could either be negotiated through the relevant, under-developed provisions of the Kyoto Protocol[10], or through other channels including the parent UN Framework Convention on Climate Change. The emerging US-led debate on technology and technology approaches could thus provide an important input to the long-run global effort. Nevertheless, it does not offer a credible alternative to the basic architecture of emission cap-and-trade embodied in the Kyoto system – which can provide the underlying incentive for countries to implement serious technology-oriented policies. What matters is to build upon what has been achieved, and to supplement the demand-side incentives of Kyoto-type constraints with focused policies to accelerate the development and supply of appropriate technologies. Technology policies, in both national and international contexts, could be a very important part of the route to a low carbon future. Yet neither they, nor the economic debates surrounding technology and timing, offer plausible grounds or alternatives from which to 'Reject Kyoto'.

[10] Article 2 of the Kyoto Protocol, on Policies and Measures, makes explicit reference to cooperation on technology research and development; article 11 addresses cooperation in technology transfer.

REFERENCES

Alcamo J., (1996) results presented at 3rd International Workshop on the IMAGE 2 Model, Delft, The Netherlands, 15-16 February 1996.

Alic J. and D.C.Mowery (2001), 'US Technology and innovation policies: lessons for climate change', draft presented to the Pew Centre conference on timing, October 2001, Washington DC.

Argentine Republic (1999), Revision of the first National Communication, Buenos Aires, October 1999

Arrow K. (1962), The economic implications of learning-by-doing, Review of Economic Studies, June.

Baumert, K.A., R. Bhandari, and N. Kete (1999), 'What Might A Developing Country Climate Commitment Look Like?' Washington DC: WRI.

Birol, Fatih and Bright E. Okogu (1997), 'Purchasing-Power-Parity (PPP) Approach to Energy-Efficiency Measurement: Implications for Energy and Environmental Policy,' Energy, Vol. 22, No. 1.

Carraro C. (1998), 'Climate modelling and policy strategies. The role of technical change and uncertainty', Energy Economics, 20:463-471.

Cowan, R. (1991) 'Tortoises and hares: choice among technologies of unknown merit.' The Economic Journal 101 801-14.

David, P.A. and Bunn, J. (1988) 'The economics of gateway technologies and network evolution: lessons from electricity supply history.' Information Economics and Policy 3(1) 165-201.

Edmonds J., Roop, and Scott (2001) Technological change and its effects on mitigation costs, in E. Claussen (ed.): Climate change - science, strategies and solutions, Brill, p. 209-226

Fankhauser, S. (1993): Greenhouse Economics and the Costs of Global Warming, Ph.D thesis at Department of Economics, University College London, UK.

Flavin, C. and N. Lensen (1995) Power Surge: A Guide to the Coming Energy Revolution. Earthscan Publications. London.

Fouquet, R. (2001) The Importance of Timing. Report for Climate Strategies. Imperial College. London.

Goulder L. and K.Mathai (2000), 'Optimal CO2 abatement in the presence of induced technical change', J. Env Econ & Management, 39:1-38.

Grubb M, (1997) 'Technologies, Energy Systems and the Timing of CO2 Emissions Abatement: an Overview of Economic Issues', Energy Policy, Vol. 23, No. 2, 1997, pp. 159-72.

Grubb M. (2001), 'Who's afraid of atmospheric stabilisation? Making the link between energy resources and climate change', Energy Policy, Vol.29 no.11, September 2001.

Gulde, Anne Marie and Marianne Schulze-Ghattas (1993), 'Purchasing Power Parity Based Weights for the World Economic Outlook,' in Staff Studies for the World Economic Outlook, Washington: IMF, December.

HaDuong M., M. Grubb and J.C. Hourcade (1997), 'Influence of Socioeconomic Inertia and Uncertainty on Optimal CO2 Abatement', Nature, 390, 20 November 1997.

Hourcade, Jean-Charles; and Ghersi, Frédéric (2001): The economics of a lost deal, mimeo, Paris.

Kopp, Raymond; Morgenstern, Richard; and Pizer, William (2000): Limiting Cost, Assuring Effort, and Encouraging Ratification: Compliance under the Kyoto Protocol, http://www.weathervane.rff.org/features/parisconf0721/KMP-RFF-CIRED.pdf

Kopp, Raymond, Morgenstern, Richard, Pizer, William and Toman, Michael (1999): A Proposal for Credible Early Action in U.S. Climate Policy, Resources for the Future, Washington, http://www.weathervane.rff.org/features/feature060.html

Marland, Gregg, Tom Boden and Robert J. Andres (2001), 'National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-1998' Oak Ridge, Tennessee: 25 Juli.

McKibbin, Warwick (2000): Moving beyond Kyoto, Policy Brief 66, Brookings Institution, Washington, DC.

McKibbin, Warwick; and Wilcoxen, P (1997): A Better Way to Slow Climate Change, Brookings Policy Brief 17. Brookings Institution, Washington, DC. http://www.brookings.edu/comm/ PolicyBriefs/pb017/pb17.htm

Nordhaus W. (1999), 'Modeling induced innovation in climate-change policy', paper to International workshop on induced technological change and the environment, IIASA, Laxenberg, Austria, June 1999.

Overseas Development Institute (1995): Commodity markets: options for developing countries, ODI Briefing Paper 1995:5, London

Patterson, W. (1999) Transforming Electricity. Earthscan Publications. London.

Pizer, William (1999): Choosing price or quantity controls for greenhouse gases, Climate Issues Brief 17, Resources for the Future, Washington, DC.

Ridley, M.A. (1998): Joint Implementation in the Framework Convention on Climate Change and the Second Sulphur Protocol: an empirical and institutional analysis, Ph.D thesis at Department of Economics, University College London, UK.

Rotemberg, and Woodford (1996) 'Real Business Cycle Analysis and Forecastability.' American Economic Review 86.

Russian-European Centre for Economic Policy (2001) in cooperation with theWorking Centre for Economic Reform, Government of the Russian Federation, Russian Economic Trends Monthly, Moscow: 17 September.

Schlamadinger, Bernhard; Obersteiner, Michael; Michaelowa, Axel; Grubb, Michael; Azar, Christian; and Yamagata,Yoshiki (2001): A ceiling for the CO2 market price with revenue recycling into carbon sinks, mimeo, Graz.

Tol, R.S.J. 'On the Difference in Impact of Two Almost Identical Climate Change Scenarios', Energy Policy, Vol. 26, No. 1, pp. 13-20.

Weyant J. P. and Thomas Olavson, (2000), 'Issues in modeling induced technological change in energy, environment and climate policy', Environmental Modeling and Assessment,

Wigley T.M.L., R. Richels and J. Edmonds (1997), 'Economic and Environmental Choices in the Stabilisation of Atmospheric CO2 Concentrations', Nature, Vol. 379, 18 January 1997

Wiser, Glenn (2001): Kyoto, costs and compliance: a public interest lawyer's view of COP 6, Washington, DC.

Worcester, R. (1996) In the Aftermath of Brent Spar and BSE. Paper given at the Business & the Environment Programme. 16 September. University of Cambridge. Cambridge.

Data Sources

Energy Information Agency (US Dept of Energy)

ICDE *International Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels Information*, http://www.eia.doe.gov/emeu/international/environm.html#IntlCarbon
*IEO*01 *International Energy Outlook* 2001, http://www.eia.doe.gov/oiaf/ieo/

International Energy Agency (OECD)

*EFC*00 *CO_2 Emission from Fuel Combustion 1971 – 1998* (2000 edition), OECD/IEA 2000
*WEO*00 *World Energy Outlook 2000*, OECD/IEA 2000

International Monetary Fund (IMF)

*IMF*01 *World Economic Outlook 2001*,
http://www.imf.org/external/pubs/ft/weo/2001/01/data/index.htm

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