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The Business of Climate Change II

Policy is accelerating, with major implications
for companies and investors

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LEHMAN BROTHERS

FOREWORD

In February of this year, Lehman Brothers published *The Business of Climate Change: Challenges and Opportunities*. In the Foreword to that study, we wrote that we saw climate change as a slow but powerful force that, like globalisation, technological change, or population ageing, inexorably stands to shape, possibly quite fundamentally, the economic environment in which companies operate.

We also wrote that we viewed the publication as merely the first step in engaging our corporate and investing clients in what, we trusted, would over time become a deeper and progressively more informed dialogue on the subject. In the event, these expectations have been more than fulfilled: we have already had many thoughtful, and challenging, discussions with clients. The principal issue on their collective mind is what policies are likely to be enacted in the name of climate change. And this is appropriate: many businesses, as well as a range of asset prices, will be importantly affected by policies, made in the name of climate change, long before they are affected by climate change itself.

However, so far there is little hard information for many parts of the world on what the policies that stand to be enacted will actually look like. Accordingly, most of the questions that have been put to us thus far have concerned what policies *ought* to be put in place; and hence, in turn, what the consequences of such policies might be for business. And, for this reason, the bulk of the questions that have been put to us have been firmly rooted in the economics of the matter.

There is, in our view, a particular sense in this. Until recently, many – and in some countries most – climate change policy proposals have originated mainly outside government. Today, however, governments themselves are increasingly becoming directly involved in policy proposal and design. Thus far, in most national administrations, responsibility has come in as far as ministries of environment, technology, energy, and industry. However, we judge that ultimately the nexus of responsibility, at least for key climate change policies, will move inwards still further – into treasuries and ministries of finance. And when these ministries take over responsibility, policymaking will acquire a harder edge: the objective of policy design will be not only to reduce greenhouse gas emissions, but to reduce them at the lowest possible cost.

Thus economic considerations are poised to assume their greatest weight yet in policy debate and design. A year or two from now, of course, the debate will have moved on: client concern will likely be with analysing the consequences of actual policies, or at least of more concrete policy proposals. But that is for tomorrow.

We trust that this volume will be a constructive sequel to *The Business of Climate Change: Challenges and Opportunities*, for clients and others who seek clues about how policy may look, a year or two from now, and about what some of the implications may be for business. ■

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ACKNOWLEDGEMENTS

The inspiration for this follow-on publication to our earlier *The Business of Climate Change: Challenges and Opportunities* owes principally to our clients. Climate change, and climate change policy, is firmly on many of their minds. We are grateful to those many – too numerous to mention, but they know who they are – who have obliged us to delve further into such a range of questions.

Important encouragement came also from Theodore Roosevelt IV who, as Chairman of Lehman Brothers' recently established Council on Climate Change, has from the outset been keen to make these issues as accessible as possible to clients at the Council's forthcoming meetings in New York, London, and Tokyo.

We were also encouraged importantly by Lord Turnbull who, with his deep experience of government, emphasised to us both the importance that climate change issues stand to assume in policymaking, and the role that economics stands to play in policy design. And we benefited from a number of discussions with John Ashton, Special Representative of the United Kingdom Foreign Secretary.

On the scientific side, we are grateful to Dr. James Hansen, Director of the NASA Goddard Institute for Space Studies, who, at the end of a particularly informative dinner hosted by Ben Cotton of the Man Group, gave generously of his time to clear up a number of scientific questions that had been niggling us. Dr. Peter Collins and Richard Heap of the Royal Society provided valuable input and brought us up to date on the more controversial areas of scientific developments in the domain of global climate change.

This report is, however, principally about the economic, policy, and thereby business implications of climate change; and here we have been helped by many people. A meeting with Simon Thomas, CEO of Trucost Plc, and his Advisory Panel, gave us a unique opportunity to participate in discussions about how the emissions of companies could be measured and valued. We have also benefited, as we did when writing our earlier study, from discussions with Tom Burke and Nick Mabey of E3G.

Then, at the drafting stage, we were honoured to receive detailed, penetrating, and constructive comments on all of the chapters from Jorgen Elmeskov, Director of the Policy Studies Branch of the Economics Department of the OECD. Vicki Arroyo, Dr. Janet Peace and Dr. Jay Gullede of the Pew Center on Global Climate Change also went through all the draft chapters, and gave us many helpful comments and suggestions. We received helpful comments, too, from Francis Breedon of Imperial College London; Lord Turnbull; and Dr. Donald Verry of University College London.

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Alastair Newton was particularly helpful to us throughout, as always, drawing our attention to a range of material that we would otherwise have missed, and but for which this study would have been the poorer.

Melanie Saint Cyr went carefully through the entire report, editing and checking everything from the drafting to the logic, as indeed she did with the earlier publication too. And we are obliged also to Joan Male and Ruth Llewellyn, both of whom read the final, final version with great care.

Inevitably, however, errors will remain: and for those we ourselves are solely responsible. ■

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MOTIVATION: WHY CLIMATE CHANGE MATTERS TO BUSINESS

Summary

Many clients have asked for our view on the argument that, even assuming that scientists' projections of the likely effects of climate change are broadly correct, the effects will be felt only slowly, with little effect on asset prices over most investors' time horizons.

We judge this argument as flawed, for three, linked, reasons. First, markets anticipate even slow-moving variables, such as climate change. Second, policy made in the name of climate change could have an almost immediate, up-front effect on asset prices. And third, markets anticipate policy itself. In this way, expected future effects of climate change become brought right forward to the present.

Fundamentally, the economic case for considering climate change ultimately depends on the science. Our judgement is that the science will increasingly be seen as broadly correct; that this view will be progressively accepted by the weight of market opinion; and that, while the adjustment of asset prices has begun, full adjustment will take years, rather than months.

The adjustment of asset prices will depend on the evolution of the science

Proceeding from the science

Everything flows from the science. If the science is (broadly) right, then:

- There will be **temperature consequences**. The Intergovernmental Panel on Climate Change's (IPCC) low scenario for global average surface air warming by the end of the 21st century is 1.8°C, and its high scenario is 4°C¹;
- There will be **climatic consequences**. The IPCC judges it as *very likely* (i.e. with a more than a 90% probability) that hot extremes, heat waves and heavy precipitation events will become more frequent, as may tropical cyclones²;
- There will be **economic costs**. The impact of climate change will vary by region but, aggregated and discounted to the present, is *very likely* to impose net annual costs that will increase as global temperatures increase³. Even conservative estimates have economic costs building up to 3% of global GDP annually by the time that temperatures have risen by 3°C;
- There will be an **international policy response**. Cost-benefit analysis indicates that abatement policies will have a clear economic payoff, providing a rational basis for some sort of international agreement.

If, however, the scientific consensus is wrong, or even seriously misleading, that will progressively become clear. And that would lessen the likelihood of a continuing policy response and reduce the consequential effects, including on asset prices.

The first step, therefore, in deciding on the likely implications for asset prices, has to be to decide on the probability that the science is basically correct. Here there is a considerable range of opinion – not among scientists, in the main, but among the non-scientific public, the actions of which do most to determine the course of asset prices.

A broad spectrum of beliefs

While there is a scientific near-consensus...

A scientific near-consensus. Scientists today agree, rather overwhelmingly, that the world is warming, and that this is the result of man-made (anthropogenic) emissions of greenhouse gases. In 2005, the national science academies of the G8 nations, including the United States National Academy of Sciences, and science academies of Brazil, China and India, called on world leaders "... to acknowledge that the threat of climate change

¹ Intergovernmental Panel for Climate Change (2007), vol.I, Technical Summary.

² IPCC (2007), vol.I, Technical Summary.

³ IPCC (2007), vol.II, Technical Summary.

is clear and increasing” and declared that the “scientific understanding of climate change is now sufficiently clear to justify nations taking prompt action.”⁴

More recently, the first volume of the Intergovernmental Panel on Climate Change’s Fourth Assessment Report⁵, *The Physical Science Basis*, was produced by more than 150 coordinating lead authors from over 30 countries and reviewed by 600 experts. Their conclusions about mankind’s role in climate change include:

“(…) it is *very likely* [our emphasis] that anthropogenic greenhouse gas increase caused most of the observed increase in global average temperature since the mid-20th century.” and

“(…) anthropogenic forcing, resulting in thermal expansion from ocean warming and glacier mass loss, has *very likely* [our emphasis] contributed to sea level rise during the latter half of the 20th century.”

Concerning temperature and climate projections, they conclude:

“Temperature averages over all habitable continents and over many sub-continental land regions will *very likely* [our emphasis] rise at greater than the global average rate in the next 50 years, and by an amount substantially in excess of natural variability.”

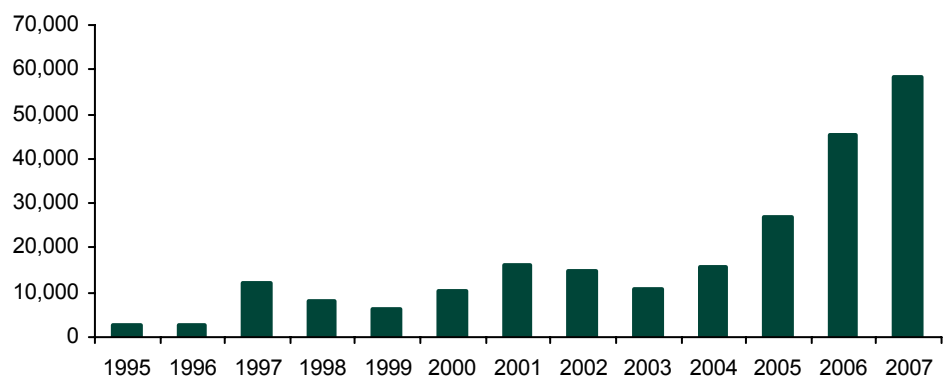
Gore (2006)⁶ reports a study published in *Science* of every peer-reviewed science journal article on global warming in the previous 10 years. Broad results show that virtually 100% of them agree with the consensus view enunciated above.

... public opinion is much more diverse

But public opinion is considerably more diverse. Although climate change has been an increasingly frequent topic in the headlines (Figure 1), generalist newspapers do not convey the same broad consensus as the scientific journal articles.

A study similar to that made of scientific articles was conducted of all articles on global warming published in 1988-2002 in the four newspapers considered the most influential in the United States (*The New York Times*, *The Washington Post*, *The Los Angeles Times* and *The Wall Street Journal*). Researchers found that, of the random sample of articles they took, more than half paid “roughly equal attention” to the view that humans were contributing to global warming on the one hand, and to the sceptical view on the other⁷.

Figure 1. Climate change headline hits⁸



Source: Lehman Brothers, Factiva.

⁴ National Academies website, www.nationalacademies.org/morenews/20050607.html, Joint Science Academies’ Statement: Global Response to Climate Change.

⁵ Intergovernmental Panel on Climate Change (2007), vol.1.

⁶ Gore, A. (2006).

⁷ Boykoff, M.T. and Boykoff, J.M. (2004).

⁸ This analysis counts the number of times the words “climate change” or “global warming” are found in the headlines and lead paragraphs of major newspapers.

In particular, climate change does not gather consensus among the business community

The business community, too, seems fairly distributed along the belief spectrum. A recent study by YouGov for KPMG found that around 20% of respondents think that climate change is “not a very important issue” for their business. Moreover, “86% of business leaders interviewed do not have a strategy in place for responding to climate change.”⁹

Another study, by HeadLand, a communications consultancy, reports findings from interviews with 19 mainstream UK fund management houses: “...there remains a clear disconnect between the apparent seriousness of this [climate change] issue and attitudes of institutional fund managers” and “respondents revealed very little evidence of investment firms incorporating climate change in top-down investment strategies.”¹⁰

However, both groups surveyed said they needed more clarity from politicians on what was required from business in the battle to halt global warming. They said that if the government created a stable legal framework, companies could plan ahead and investors could assess risks and opportunities.

“Ah yes! I remember it well ...”

This wide spectrum of opinion is reminiscent of the situation in the 1990s in respect of EMU

The next issue is how fast asset prices might be affected by the evolving view of the science.

This question is reminiscent of the situation that obtained in 1995 in respect of potential monetary union in Europe. At the time there was a wide range of public opinion. At one end of the spectrum were those who believed that French President François Mitterrand and German Chancellor Helmut Kohl were absolutely committed to European Monetary Union (EMU), would do everything they could to bring it about, and that they would succeed.

At the other end of the spectrum were people who thought that the idea of a monetary union was fantasy, that it would not work, that opposition would build against it even before it was created, and that it would therefore never happen. Public opinion about the likelihood of EMU was generally spread between the two extremes.

It is instructive to look at how the matter played out. The two extreme views had a very clear expression in the market in the differential rate of return of German Bunds, on the one hand, and Italian government bonds, on the other.

It took three years for opinions in the market to converge ...

In early 1995, the spread between the two bonds was approximately 500bp. Those who thought Monetary Union was going to take place believed in turn that this differential would be largely eliminated. On the other hand, those who believed that Monetary Union would never happen judged that this gap would remain wide. Hence traders who thought monetary union would happen expressed that belief by going long Italy and short Bunds. Conversely, traders who thought it would never happen went short Italy and long Bunds.

... and hence for asset prices to adjust

In the event, Monetary Union did take place, on 1 January 1999. The evolution of the overall judgement of investors can be seen in the spread between Bunds and Italian government bonds (Figure 2). It took fully three years for the gap to close, i.e. for opinion to move along the spectrum towards the (eventual) point of certainty.

The parallel with climate change is not perfect, of course. Whereas European Monetary Union was established on a precise date, there is no end point for a final judgement on the assessment of the science, the climatology, and hence of the economic cost of climate change. Nevertheless, the science will become clearer, one way or the other; and there will be policy milestones along the way. As investors become more certain in their judgement, asset prices are going to move accordingly.

⁹ KPMG (2007).

¹⁰ HeadLand Consultancy (2007).

Which direction will asset prices take?

There is virtual consensus among scientists that, even if all greenhouse gas emissions ceased immediately, the world’s mean temperature would nevertheless continue to increase, because of oceanic thermal inertia, by probably a further 1°C¹¹. This seems set to have a number of direct consequences, and hence direct impacts on some businesses.

Temperature increase will directly affect some businesses, such as the snow and ski industry

One direct consequence is the melting of snow and ice. The snow and ski industry is directly affected by weather conditions, particularly temperature. A recent study by the OECD¹² considers how temperature increases are already affecting Europe’s skiing industry, through the effects on snow reliability in alpine ski areas. A ski station’s value is a function of the number of people who go to the station and of the number of days of snow cover. And days of snow cover directly affect the reliability of slopes. If this reliability declines, then the value decreases too.

The OECD study estimates that a 1°C rise in temperature would imply a decrease of 18% in “snow-reliable” ski areas; a 2°C increase a decrease of 34%; and a 4°C increase a decrease of 67%. Presumably, this would affect some regions more than others, and therefore have an impact on relative values of different ski areas and villages. It could, for example, lower the value of low-altitude villages and businesses, yet raise the value of high-altitude villages.

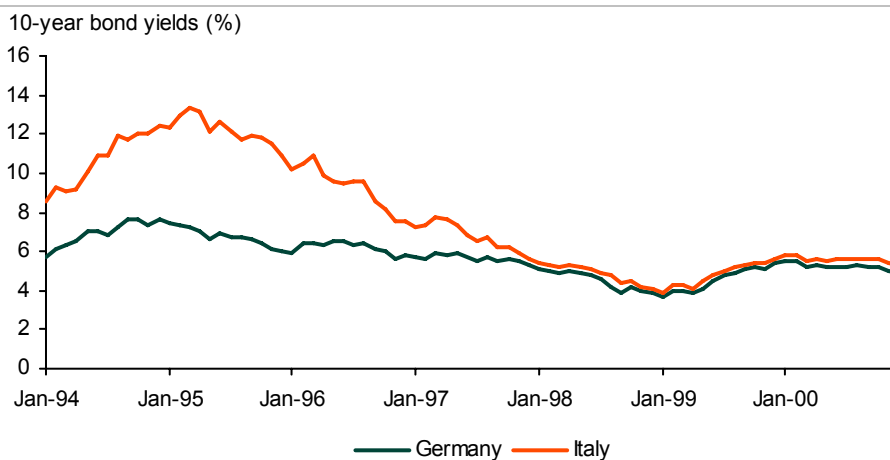
Sea level rise and increased storm damage could result in changing (relative) prices of land and buildings

A second direct effect of increase in average temperatures is sea level rise. The likely extent is still uncertain. However, according to the Intergovernmental Panel on Climate Change (2007), the average rate of sea level rise during the 21st century *very likely* exceeds the 1961-2003 average rate, i.e. 1.8 ± 0.5 mm per year. The Intergovernmental Panel on Climate Change suggests an average sea level rise by 2100 of between 0.18m and 0.59m. Other scientists, however, consider that the true figure could be much higher.

Such sea level rise, together with the associated risk of increased storm damage, could be expected to result in the prices of land and buildings on low-lying coasts falling relative to the prices of otherwise similar land and buildings higher above sea level. Certainly the insurance industry is starting to look at the matter in that way.

For example, the British insurance company Norwich Union developed in 2004 a map of the United Kingdom that enables homeowners and businesses to see whether their properties are at a low, moderate, or significant risk of flooding¹³. This map takes into account proximity to rivers and the coast, as well as the presence and protection afforded

Figure 2. 10-year German and Italian government bond yields



Source: Lehman Brothers.

¹¹ Wigley, T.M.L. (2005).

¹² See OECD website, www.oecd.org/document/. OECD Warns Climate Change is Threatening Europe’s Skiing Trade.

¹³ See Norwich Union Risk Services website, www.nu-riskservices.co.uk/news/.

by flood defences. It shows, in particular, that the number of properties at risk has increased by 300,000 from the former map, to 2.2m properties. Similarly, in the United States, the Flood Insurance Rate Map (FIRM) has been developed by the Federal Emergency Management Agency (FEMA) for the purpose of rating flood insurance policies sold through the National Flood Insurance Program.

As a result of the information conveyed by such maps, the relative value of properties shown not to be at risk is likely to rise, and conversely. Moreover, even if bodies such as the Association of British Insurers (ABI) commit to insure properties in at-risk areas, homeowners in such areas may find their insurance premiums rising, making their properties harder to sell. They may even become ineligible for insurance; indeed, the ABI recently warned that only with heavy spending on flood defences (£750m per year – \$1.5bn – by 2011) would flood insurance continue to remain widely available¹⁴.

Further climatic consequences imply a range of further implications for businesses and asset prices

Climate models offer richer detail. In practice, there are likely to be many more climatic consequences from global warming than simply the melting of snow and ice, and higher sea levels. Climatologists have constructed detailed models that incorporate everything that they have learned to date about climate formation, and use these models to make detailed projections of climatic impacts across global regions.

Projected impacts include: more frequent and longer-lasting heat waves; decreases in snow cover and the extent of sea ice, which in turn could contribute to higher sea level rise; more intense tropical cyclones, with higher peak wind speeds and heavier precipitation; changes in wind, precipitation and temperature patterns, as a result of extra tropical storm tracks moving poleward; increases in precipitation at high latitudes; and decreases in most subtropical land regions¹⁵.

As with all models, the projections of climate change models are unlikely to be completely accurate, especially given that the models are by necessity having to be used to make predictions outside the temperature range over which they were estimated.

Nevertheless, the models are unlikely to be completely misleading; and there is considerable interest in them because they offer a rich tapestry of detail, with an attendant wide range of implications for businesses and asset prices. Some examples:

- **Higher temperatures** may have direct impacts on regions which are expected to become too hot, and where, therefore, land and properties may lose relative value. The Mediterranean region is one case;
- **Winds** may change route. For example, the strong winds that blow across the Hebrides and northern Scotland are expected to shift further south, potentially causing increased damage to buildings in England and quite possibly northern France. To the extent that buildings and other structures in these areas have not been built to withstand such winds – although the technology exists – there stands to be a negative impact on ‘weak’ buildings and infrastructures, relative to ‘stronger’ ones;
- **Rainfall** may become heavier in South Asia, particularly in India. As a result, floods could become more extreme, and affect low-lying areas. Moreover, changes in the intensity of rainfall events, combined with an increased risk of critical temperatures being exceeded more frequently, could significantly change crop yields. This could well have a direct and substantial impact on relative land prices; and
- **Melting of the permanent sea ice and change in ice thickness** could open historically closed sea passages, thereby increasing access to shipping routes and resources in the Arctic. This could well increase the relative value of some regions, notably parts of Canada and Russia.

¹⁴ See the Association of British Insurers website, www.abi.org.uk/Newsreleases/viewNewsRelease.asp?nrId=14565.

¹⁵ Intergovernmental Panel on Climate Change (2007), vol.1, Summary for Policy Makers.

Businesses will be obliged to internalise the climate change externality

As the climate change externality is internalised, firms' valuations will be affected

The economics of climate change is fundamentally an 'externality' story. So far – or at least until recently – polluters, particularly emitters of greenhouse gases, have not had to pay for the damage they have caused. Hence, they have had no economic incentive to limit them. However, to the extent that the science of greenhouse gases comes to be accepted as broadly correct, social and political pressure will likely build to internalize this externality, one way or another.

If, for example, climate change comes to be seen as “the biggest market failure ever”¹⁶, as Stern has put it, then greenhouse gas emitters eventually will have to pay for the externality they are creating.

The economic, and thereby the market, issue is to value this externality, and establish how large it is in relation to each firm's value added. Strictly speaking, these externality considerations apply not only to greenhouse gases, but to all pollutants, ranging from smoke, through to emissions of heavy metals, and other pollutant chemical substances.

To the extent that society starts pricing these various externalities, that is a negative for the valuation of the polluting firm. There are already some examples.

Such policies already exist

Some such policies already exist, such as water control policy ...

In France, water control policy already makes use of effluent charges, known as pollution charges. Under this policy, firms pay differential taxes according to their use of water, and the quantity and types of effluents that they discharge. The control system also grants *discounts* for reducing pollutants through the installation of water treatment equipment. Investments in water pollution abatement equipment are also stimulated by government subsidies and tax reductions. Thus, water pollution control contains both *negative* and *positive* incentives, which imply differential value impacts on firms.

... carbon taxes ...

In Sweden, a carbon tax has been implemented. In January 1991, a tax of SEK0.25/kg CO₂ (\$40/tonne of CO₂) was imposed on the use of oil, coal, natural gas, liquefied petroleum gas, petrol, and aviation fuel used in domestic travel. Simultaneously, as the carbon tax was introduced, general energy taxes were reduced by 50%. Since 1991, the level of the carbon tax has been raised to SEK0.36/kg CO₂ (\$55/tonne of CO₂). While consumer users are responsible for paying the full tax, the industry rate has been reduced to 50% of this tax because of competitiveness concerns.

But taxes are not the only way to put a price on such externalities. Limiting permits to emit, for example by means of an emissions trading scheme, also puts a price on carbon emissions. Indeed, any scheme that limits emissions, relative to what they would be otherwise, raises the price of carbon.

... and emissions trading schemes

There are already a number of such emissions trading schemes. In Europe, the European Union Emissions Trading Scheme (EU ETS), launched in January 2005, is the world's largest multi-country and multi-sector emissions trading scheme, and currently covers around 45% of European emissions.

In the United States, the Regional Greenhouse Gas Initiative (RGGI) was established in December 2005 by the governors of seven north-eastern and Mid-Atlantic States¹⁷, and was recently joined by Massachusetts, Rhode Island, and Maryland. These states agreed to develop a multi-state cap-and-trade program covering greenhouse gas emissions. In 2006, the RGGI states and California agreed to coordinate market policies, and to explore linking western and eastern trading systems.

Most recently – June 2007 – a national cap-and-trade greenhouse emissions scheme was announced by the Australian Prime Minister. The trading scheme, which could be running by 2011, would cover about 55% of total Australian emissions¹⁸. The New

¹⁶ Stern, N. et al. (2006).

¹⁷ Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont.

¹⁸ See *New Scientist Environment*, 17 July 2007.

South Wales state government had already set up the NSW Greenhouse Gas Abatement Scheme, in January 2003. This mandatory trading scheme aims to reduce greenhouse gas emissions associated with the production and use of electricity. All these different trading schemes will ultimately lead to an increase in the (relative) price of carbon.

Impact of climate change policies on firms' value

Firms that emit relatively more carbon will be relatively more affected by policy

Such (relative) carbon price increases can be expected to have a relatively negative effect on firms that emit relatively more carbon dioxide into the atmosphere. However, measuring the values of these externalities is still at an early stage. Disclosure figures in annual statements are in most cases practically worthless. And this is for understandable reasons: the problems of gathering and processing high-quality data on a company-by-company basis are considerable. First, there are many pollutants, ranging from carbon emissions to heavy metals; and second, there are many methodological issues, including, for example, how to deal with vertically integrated companies vis-à-vis non-vertically integrated ones.

One source of data – the only one we have found so far – is from Trucost, an environmental research organisation. Trucost has generated environmental impact profiles for more than 130 different business activities. Using these profiles, along with financial and segmental analysis, Trucost produces an estimate of 3,200 companies' direct impacts; and in turn an input-output model is used to quantify the indirect impacts. By applying external prices to companies' emissions, a valuation of the environmental profile can be made. When taken in conjunction with an estimate of the firm's value added, this provides a basis for estimating the extent to which a firm's valuation stands to be affected once it is obliged to pay for its emissions.

Firms' environmental impacts differ considerably, not only between sectors, but within sectors

These data reveal major differences, not only between sectors, but also between apparently similar firms within a given sector. For example, by deducting the damage value of its emissions from its value added, one US power company was found to have a net annual value added of minus \$5bn.

More generally, across a sample of 33 US electricity companies¹⁹:

- whereas the return on capital ranged from 1.0% to 8.6%, the rate of return adjusted for the damage value of emissions ranged from -14.2% to 6.7%;
- the standard deviation of the adjusted series was six times that of the unadjusted series; and
- the two series were almost perfectly non-correlated (correlation coefficient: 0.003).

Similarly, an unpublished calculation of CO₂ emissions in relation to the turnover of a sample of European airlines revealed one company as being 64% above the average, while another was 20% below.

To the extent that policy in the future gets a better handle on these figures, and charges for them – through further taxes or extended carbon trade schemes – significant movements in relative asset prices can be expected.

Implication: asset prices are moving and will likely move further

The potential for asset price adjustment is considerable

Our overall judgement is that the potential for asset price adjustment is considerable, for several reasons:

- Markets anticipate even slow-moving forces, such as climate change;
- Asset prices stand to be affected markedly sooner by policy; and
- Markets anticipate, not only climate change itself, but policies to address it.

¹⁹ Repetto, R. and Dias, D. (2006).

*Price adjustment has likely
already begun and should
continue*

To the extent that the European Monetary Union analogy is valid, given that non-scientific opinion is apparently, at the moment, widely spread along a spectrum of beliefs, then it could be expected that:

1. Adjustment will take place over a run of years; and
2. This adjustment will likely have already started.

Furthermore, over time, it seems likely that investment managers, perhaps in increasing numbers, will direct their investments towards companies that are relatively 'carbon-light'.

For all these reasons, therefore, it is not perhaps surprising that markets are already edging their way towards such price adjustments. One piece of suggestive evidence comes from GLG Partners, which launched an Environment Fund, a long-only fund compiled by filtering the greenest companies from its \$1.5bn European Equity strategy. When it was launched, the objective was to pick stocks with a 30% lighter impact on the environment than the average, using Trucost data. Back-testing found that the 'child' fund would have produced higher returns than the 'parent' fund – 27.62% after fees in the past three years, versus a 26.44% annualised rise from the European Equity fund²⁰.

Conclusion

In our judgement, the science is no longer the central point of discussion. What concerns most businesses and investors now is how policies will evolve.

As responsibility for climate change policy starts to be assumed by finance ministries and treasuries, the cost of policies will become a primary preoccupation. Economics will increasingly become a central consideration in policy design. Hence, analysing the climate change policy issue in the way that we think treasuries and ministries of finance will increasingly come to do, should provide the best guide both to the types of policies that will be implemented and to their implications for asset prices.

Those investors and businesses that make the right predictions in terms of climate change policies may be able to anticipate the directions of asset prices and turn climate change and the evolution of climate change policy to their advantage. ■

²⁰ See *Financial Times*, 19 February 2007.

CHAPTER 1: WHY CLIMATE CHANGE IS A (COST-BENEFIT) ECONOMIC ISSUE

Summary

Many clients have appreciated that, while much of the public discussion of climate change is couched in *technological* and *regulatory* terms, in *The Business of Climate Change* we approached the matter first and foremost as an *economic* issue.

There is good reason for this. It takes resources – i.e. it costs money – to reduce emissions. Moreover, it would cost a great deal – much more than most societies would be prepared to pay – to reduce emissions to a minimal amount, let alone to eliminate them altogether. Society, therefore, has to decide on the balance it wants to strike between how much it wants to reduce emissions and how much it is prepared to pay. It is from this economic cost-benefit standpoint that we examine the matter of climate change.

Naturally, society could, if it wished, pay to reduce emissions more than would be implied by a purely economic, cost-benefit calculation. That however is conceptually a separate issue and we treat it as such later in this report.

The price mechanism will be at the core of climate change policies

Why attach a price to carbon?

There are many technologically feasible options for reducing greenhouse gas emissions, and more and more are being developed. But not all are cost-efficient. As one engineer who is also an economist put it to us: “The technology exists today to power automobiles by fuel cells: but they cost a million dollars per car, and the fuel costs the equivalent of 100 dollars per gallon.”

Such a ‘solution’, although technically feasible, is not economically efficient: it would not represent an allocation of resources consistent with reducing emissions in the least-cost way.

In all successful economies, the price mechanism is fundamental in allocating resources so as to match relative scarcities to relative demands, and thereby produce efficient, least-cost outcomes. The system is not perfect, and few economists would claim that it is: but, like democracy, the price mechanism is “the worst form [of government] except all those other forms that have been tried from time to time.”²¹ The only serious alternative, governmental central planning, has proved unequal to the task. Today, in the aftermath of the collapse of the Soviet Union, few economies, and certainly none of the developed economies, allocate resources by fiat.

That is not to say that the unfettered market always provides a desirable outcome; and pollution represents one such case. Under free market conditions, polluters do not pay for the damages – the ‘externalities’ – that they cause. Accordingly, a basic role of policy, recognised since Pigou²² in the 1920s, is to ‘internalise’ such costs into emitters’ cost structures – the ‘polluter pays’ principle.

Importantly, however, such a policy does not negate the price mechanism: it simply represents a correction of a (relative) price so that it thereby correctly reflects a resource cost – in this case, a damage cost to society. Thereafter, the price system is left to allocate resources, as before; but now in accordance with the (new, corrected) relative prices.

The (relative) price of carbon can be raised either by a tax, or by limiting permits to emit

The (relative) price of carbon can be raised in two basic ways: by directly imposing an increase in the price of carbon emissions, through a so-called ‘tax-based’ system, for example; or by limiting permits to emit, for example via an emissions trading scheme.

Strictly speaking, while the first of these two basic ways is commonly referred to as a ‘tax’, it is not, at least in the sense that the word is most commonly used. Insofar as the primary purpose is not to raise revenue, but simply to increase the relative price of

²¹ Churchill, W. (1947), *Speech in the House of Commons*, cited in *The Penguin Dictionary of Modern Humorous Quotations*, Guild Publishing London.

²² Pigou, A.C. (1920).

carbon, the policy can, and in principle should, be ‘revenue neutral’, i.e. the revenues raised by the policy should be rebated, preferably through the general tax system.

It is against this fundamental background that the economist, concerned to limit emissions in the least-cost way, typically is critical of policies that operate not through the price mechanism, but by such means as regulations or standards. Such policies generally do not explicitly attach a price to carbon. In some cases however it is possible, albeit with difficulty, to infer that price, i.e. evaluate the implicit cost per ton of carbon saved. And, while sometimes such calculations reveal a regulation as cost effective, in many other instances the (implicit) cost is revealed as high, and sometimes extremely so (see chapter *The implicit price of carbon in regulation-based policies*).

Regulatory and standards policies also imply an (implicit) carbon price

The role for non-price policies

None of this is to say that there should be no place in the policy armoury for regulatory policies, standards policies and, for that matter, publicly funded R&D. However, as climate change policy moves towards the centre stage of government policy, it will in many administrations progressively become the province of treasuries and ministries of finance. And they will tend, in the interests of economic efficiency, to favour policies that produce cost-efficient solutions by placing the price mechanism at, or at least near, their core.

Accordingly, the ‘social’ or ‘damage’ cost of carbon – i.e. that tax or other price that, if charged to those who emit greenhouse gases, would both raise the requisite revenue to compensate those damaged by the emissions, and encourage the reduction of emissions – should be the benchmark against which to assess every climate change policy that does not explicitly attach a price to carbon. Some administrations – Australia for example – now require that every non-price policy be evaluated in respect of its cost efficiency.

Conclusion

Two issues therefore follow:

- 1) By how much should the (relative) price of carbon be raised so as to ‘internalise the externality’; and
- 2) What instrument should be employed?

The first of these issues is the subject of the following chapter, *The measurement of the ‘social’ or ‘damage’ cost of carbon*; and the second is the subject of the chapter after that, *The choice of policy instrument: taxing vs trading*. ■

CHAPTER 2: THE MEASUREMENT OF THE ‘SOCIAL’ OR ‘DAMAGE’ COST OF CARBON

Summary

The theory of externalities, which is the intellectual foundation of economic policy to abate greenhouse gas emissions, is based on the recognition that polluters cause damages that they do not pay for, and that accordingly they should be charged a price – equal to the ‘social’, or ‘damage’, cost of carbon – that generates the revenue necessary to compensate those damaged by the emissions.

In practice, there are many uncertainties in calculating the ‘social’ cost of carbon. Moreover, the estimated cost will change as information accumulates about the various types, and hence costs, of damage. Nevertheless, it is useful to have an idea of the range in which the social cost is likely to lie, not least to serve as a benchmark against which to assess each proposal that is advanced to control emissions. For example, a proposal to limit greenhouse gases costing, say, five or 10 times the estimated social cost of carbon would *prima facie* be a reason to be hesitant about implementing the policy.

These considerations give rise to two issues:

1. What is the range of estimates of the ‘social’ cost of carbon? – the subject of this chapter; and
2. How far is the implicit price of carbon in some policies from the estimated ‘social’ cost? This is the subject of the chapter, *The implicit price of carbon in regulation-based policies*.

We take a value of \$50 per tonne of carbon as being a reasonable central value to use in climate change policy analysis and hence as a benchmark against which to assess non-price-based policies.

The ‘social’ cost of carbon is derived from a cost-benefit calculation

Definition and calculation of the ‘social’ cost of carbon

The calculated ‘social’ cost of carbon is the product of a cost-benefit analysis that has two elements. The first consists of a schedule of monetary valuations of the (global) damage caused by the emissions of each successive tonne of carbon. That valuation can also be construed as the financial value of the damage avoided by reducing each tonne of emissions of carbon. The second element consists of an evaluation of the cost of reducing – abating – each tonne of greenhouse gases.

Most empirical estimates indicate that:

- The incremental or ‘marginal’, cost of abatement *rises* with the scale of emission reduction, e.g. it costs more to reduce emissions by 1 giga tonne from a rate of 3 giga tonnes per year, than to reduce emissions by 1 giga tonne from a rate of 10 giga tonnes, i.e. the (marginal) cost curve of abatement is upward-sloping; and
- The incremental, or ‘marginal’ benefit resulting from reducing greenhouse gas emissions *falls* with the scale of abatement, e.g. the value of the damage avoided is greater when reducing greenhouse gas emissions by 1 giga tonne from a rate of 10 giga tonnes per year, than when reducing emissions by 1 giga tonne from a rate of 3 giga tonnes, i.e. the marginal benefit curve is downward-sloping.

From an economic standpoint, it is optimal to undertake expenditure on abatement up to the point at which the benefit from the reduction of the last, or ‘marginal’, tonne of carbon just equals the (marginal) value of the benefit obtained, i.e. the damage thereby avoided. The price at which this occurs is the so-called ‘social price’ of carbon. Above this, any additional expenditure on abatement would cost more than the incremental value of the damage avoided, and *vice versa*. In Figure 3, the optimal, or ‘social’, price of carbon is the point at which the two curves cross. Associated with this ‘optimal’, or ‘social’ price is an ‘optimal’, or ‘social’, volume.

The range of estimates is broad

A range of uncertainties ...

In practice, considerable uncertainties surround both the incremental costs and the incremental benefits, making it impossible at present to determine with certainty the

value of the ‘social’ cost of carbon – and hence what emission target represents the optimal abatement level. These uncertainties take various forms (for further analysis, see chapter *Uncertainty and risk: the case for paying a risk premium*):

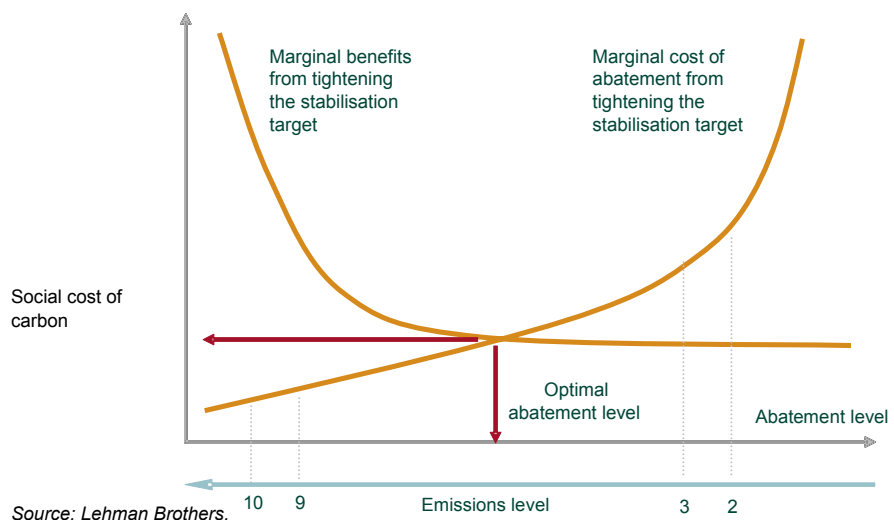
- 1) **Scientific uncertainties** about current and future levels of greenhouse gas emissions and about the future level of climate change impacts.
- 2) **Economic uncertainties** about the valuation of impacts, particularly in non-market sectors: for example, the impacts on biodiversity and amenity values of diminished glaciers and beaches, or even the ‘socially contingent’ effects of climate change, such as those associated with hunger, migration and conflict, are especially difficult to evaluate.
- 3) **Methodological uncertainties**, particularly concerning the extent to which it may be appropriate to discount expected damages – considered in the chapter *The discount rate controversy*. A further methodological issue arises over how to aggregate costs across geographical regions that show huge disparities in income.

... results in a broad range of estimates

They have resulted in a wide range of estimates of the ‘social’ cost of carbon:

- In 2002, DEFRA published a review based on nine major studies²³. It recommended a value of £70 (\$140)/tonne of carbon – with a range of £35-£140/tC – increasing by approximately £1 (\$2)/tC per year in real terms to account for increasing damage costs over time.
- Nordhaus (2007)²⁴, using a Dynamic Integrated model for Climate and Economy (DICE 2007), estimated the ‘social’ cost of carbon at around \$28/tC in 2005, rising to \$90/tC in 2050 and to \$200/tC in 2100, if the optimal policy is implemented.

Figure 3. Choosing the optimal abatement level



- Tol (2004)²⁵ combined 103 estimates to produce a probability-density function. He found the modal value to be \$2/tC, the median value to be \$14/tC, the mean to be \$93/tC, and the 95 percentile \$350/tC. Tol also showed that, as might be expected, studies that assume a low discount rate give higher estimates of the ‘social’ cost of carbon but lead to more uncertainties, as do studies using so-called ‘equity

²³ Clarkson, R. and Deyes, K. (2002).

²⁴ Nordhaus, W. (2007).

²⁵ Tol, R.S.J. (2004).

weighting²⁶. Tol concluded that marginal damage costs – i.e. the ‘social’ cost of carbon – “are unlikely to exceed \$50/tC.”

- The Intergovernmental Panel on Climate Change (IPCC)²⁷, recently judged that the ‘social’ cost of carbon that would be required to stabilise atmospheric greenhouse gas concentrations at around the presumed-critical level of 550ppm of CO₂, would lie between \$70 and \$290/tC by 2030, but perhaps between \$18 and \$240 were there to be significant “induced technological change”.

Our central working estimate is \$50 per tonne

Given these studies, we currently take as a central working estimate of the ‘social’ cost of carbon a figure of \$50 per tonne today (€40), rising to perhaps \$100 per tonne by 2050 (€80).

In addition to these basic uncertainties surrounding any calculation of the ‘social’ cost of carbon, there is a further difficulty, that the value is ‘path-dependent’. The marginal cost of carbon today depends on the stock of greenhouse gases in the future: but this depends on, *inter alia*, the policies adopted today. Thus, the ‘social’ cost of carbon that is to serve as a basis for designing and evaluating policies depends on the policies implemented.

Policy and the ‘social’ cost of carbon

Policy should seek to produce a carbon price as close as possible to the ‘social’ cost of carbon

Notwithstanding all these difficulties, however, the ‘social’ cost of carbon is a useful measure for governments when considering which policies to implement, and on what scale. While it would be a case of false precision to reject any policy with an implicit price of carbon that did not precisely match a government’s preferred estimate of the ‘social’ cost, a government would nevertheless have to think hard before deciding to implement a policy where the implicit price of carbon was, say, five or 10 times the ‘social’ cost. To implement such a policy would be to engage in an unduly expensive way of reducing greenhouse gas emissions.

Putting the issue the other way around, as estimates of the ‘social’ cost of carbon are refined over time, as they likely will be, governments should increasingly seek to implement measures that lead to a price of carbon that is as close as possible to that ‘social’ cost. This holds regardless of what form the policy takes, be it a price (tax)-based policy, or a volume-based policy, such as a cap-and-trade system – for more on this, see *The choice of policy instrument: taxing vs trading*, below. ■

²⁶ *Climate change would impact various countries differently, and different countries have different levels of development. Equity-weighted estimates of the damage cost of greenhouse gases reflect these differences: the same monetary damage causes more grief to a “poor” than a “rich” person.*

²⁷ *Intergovernmental Panel on Climate Change (2007), vol.III.*

CHAPTER 3: THE CHOICE OF POLICY INSTRUMENT: TAXING vs TRADING

Summary

Having addressed the question of how much policy should raise the relative price of carbon, the next issue is what policy instrument should be used to achieve such a price. As outlined in *Why climate change is a (cost-benefit) economic issue* above, there are two broad types of policy instrument: price-based systems, such as a levy on carbon emissions; and volume-based systems, such as issuing tradable permits to emit.

Both instruments increase the (relative) price of carbon: in a price-based system, the policy determines the price, and the market determines the volume; and in a volume-based system, the policy determines the volume, while the market determines the price. In a world of perfect information, the two instruments would be perfectly equivalent.

However, information is not perfect and, as a result, the two policies are not in practice equivalent. Many economists have tended to prefer a tax, largely on arguments about simplicity and certainty over price. Many scientists, however, prefer a volume limit, out of a preference for emissions volume certainty. The two views may come together if, for example, it is considered – as many scientists do – that, at some atmospheric carbon concentration, there is a risk of sudden or even irreversible damage to the ecosphere.

This therefore raises the question of which type of policy is preferable in the real world. Recent research suggests, tentatively, that in many cases a mixture, or ‘hybrid’, might produce the best overall results. Ultimately, perhaps, the choice should favour the instrument that, in the event of a mistake in the initial target, produces the lower, or less serious, cost.

In theory, a tax and an emissions trading scheme are equivalent

Are a tax and a trading scheme equivalent?

Both instruments increase the (relative) price of carbon: a price-based system, such as a tax-based policy, does so directly, leaving the market to determine the volume; whereas a volume-based system raises the price indirectly through market trading. Thus, policy can determine the price of carbon; or it can determine the volume of emissions: but it cannot simultaneously determine both.

In a world of perfect information, the two instruments would be equivalent. As shown in Figure 3 in the chapter *The measurement of the ‘social’ or ‘damage’ cost of carbon*, the ‘social’ cost of carbon determines the optimal abatement level and vice versa. Hence, when a policy determines the value for a tax that is, in theory, exactly equal to the ‘social’ cost of carbon, the market then determines the volume, which is equal to the optimal abatement level. Conversely, if a policy determines a volume of emissions that happens to be optimal, the resulting price equals the ‘social’ cost of carbon.

In practice, however, they are not, because of imperfect information

However, information is not perfect. The uncertainties are considerable; and so, in practice, the two instruments are not equivalent. A politician, seeking certainty over the price implications of policy, could well prefer a ‘tax’, even though the volume consequences would be *a priori* somewhat uncertain. Many economists, too, might prefer a tax, on considerations of simplicity and certainty as regards price. However, many scientists, seeking certainty over the volume of emissions, prefer a permit-based system, even though the price consequences would be *a priori* uncertain.

The natural question, therefore, is whether one policy instrument is superior to the other.

What type of instrument should be favoured?

An emerging body of literature²⁸ suggests, in essence, that the choice of instrument should depend on which of the two targets – price or volume – is the more important not to miss. What matters at root is the relative slope of two basic curves²⁹:

- 1) **If the curve of the marginal benefit from tightening the stabilisation target is steeper** than the curve of the marginal cost of abatement, i.e. if environmental

²⁸ For more details, see Philibert, C. (2006).

²⁹ Weitzman, M.L. (1974).

damage increases more than proportionately with the level of emissions than does the marginal cost of abatement, it may in general be preferable to achieve certainty about the level of emissions that will be achieved, and therefore **to implement a quantity instrument**;

- 2) Conversely, **if the curve of the marginal cost of abatement is steeper** than the curve of the marginal benefit, i.e. damages increase more slowly with the level of emissions than does the marginal cost of abatement, it may be preferable to achieve certainty on the marginal cost of abatement, and hence **to implement a tax**.

It is difficult to assess which of the two instruments should be favoured

In practice, it may often be difficult, or even impossible, to assess which of the two curves is the steeper. In that case, it may be that hybrid instruments, which combine a quantity target with a price aspect, will be the most efficient. An example is a trading system with a price cap and a price floor. If abatement costs reach the price cap, then governments sell additional permits and less abatement is thereby undertaken. Conversely, if abatement costs decrease below the price floor, then governments buy permits, thereby subsidising additional abatement. Experience with exchange rate bands suggests, however, that the problems of keeping the carbon price within a range could become quite demanding over the long term.

Even if there are uncertainties, however, it may be possible to draw some inferences about the two curves. Climate change is driven by the cumulative change in atmospheric greenhouse gas concentrations, i.e. the *stock* of greenhouse gases, rather than the *flows*. To that extent, marginal damage costs (i.e. the marginal benefits of the abatement policies) are likely to be broadly constant, at least over a relatively short period. On this argument, a tax instrument would be preferable.

Modelling exercises seem to prefer tax or hybrid instruments in the near term

Furthermore, modelling exercises seem to confirm the advantage of a tax over a quantity instrument with permits. For example, Pizer (2002)³⁰ suggests that the expected welfare gains with taxes would be five times higher than with permits. However, he considers a hybrid instrument with an emission cap and a price cap to be slightly more efficient than a tax policy. Other studies have found that the preference for taxes would be reversed only if key parameters were adjusted by a factor of more than 1,000³¹.

A longer-term analysis, however, may produce different results. The inherent volume uncertainty of a tax policy is inconsistent with the primary goal of the international community, i.e. the stabilisation of atmospheric greenhouse gas concentration. Furthermore, over the longer term, the marginal benefits of abatement policies may not be even approximately constant. It could be that, once greenhouse gas concentration has reached a particular level, marginal climate damages increase considerably, in which case a quantity target would be preferable.

But in the longer term, quantity concerns may demand quantity-based instruments

There is a further argument, however. Some economists maintain that while a tax may seem more appropriate today because of uncertainties about damage and the cost of abatement, the situation will change in the longer term. Progressively more information on abatement costs will become available, whereas it is unlikely that such will be the case for the damage cost given continuing scientific uncertainty on climate impacts. For this reason, they argue, a quantity mechanism would be preferable in the medium to longer term. Thus, it might be better to put the infrastructure in place for this quantity mechanism now rather than to switch later from a price-based to a quantity-based system.

Conclusion: pros and cons of taxing and trading

Three reasons are often advanced in favour of a tax-based policy over an emissions-trading scheme:

³⁰ Pizer, W.A. (2002).

³¹ Hoel, M. and Karp, L.S. (2002).

- 1) A tax is more efficient because an emissions-trading scheme implies price volatility, and volatility is in itself inefficient.
- 2) A tax provides a clear price floor, and the volume can be adjusted by changing the tax rate as experience accumulates about the volume-reduction consequences.
- 3) A tax raises revenue.

In our judgement, these reasons are not equally compelling, for the following reasons:

- 1) The volatility issue can be addressed in a number of ways, including the skilful issuing of permits, as with the issue of government bonds.
- 2) Adjusting emissions volume by varying the tax might not be easy, because of long lags in the reaction of volumes to prices.
- 3) Revenue can be raised under an emissions trading scheme, too, to the extent that permits are auctioned, rather than given for free.

Perhaps the main argument in favour of a permit-based system, however, is the desire or perceived need not to exceed a critical volume – the central argument of scientists.

Most recently, economists have been devising more complex, ‘hybrid’ systems, which combine volume limits with price ceilings and floors³². These have the potential to combine the best of both price-based and volume-based systems; but they have the disadvantage of being relatively complex.

In practice, the issue for the policymaker may well reduce to the basic question: in respect of which policy type – tax- or volume-based – might a policy mistake be the more serious?■

Ultimately, the choice should depend on which of the two targets – price or quantity – is more important not to miss

Figure 4. Summary: pros and cons of price-based and volume-based systems

Price-based system	Volume-based system
Price is certain	Price is uncertain
Volume is uncertain	Volume is certain
No price volatility	Price volatility
Revenue raised by the tax	Revenue raised only if auctioning

Source: Lehman Brothers.

³² Philibert, C. (2006).

CHAPTER 4: THE IMPLICIT PRICE OF CARBON IN REGULATION-BASED POLICIES

Summary

The chapter *Why climate change is a (cost-benefit) economic issue* argued that abatement policy, if it is to be optimal i.e. achieved at least cost, needs to place the price mechanism at its core – whether via a tax or the sale of permits.

Only price-based policies stand to direct resources efficiently to the reduction of greenhouse gases. While policies that do not make use of the price mechanism – regulation, for example – generally do succeed in restricting carbon emissions, there is no guarantee that the cost of so doing will be anywhere near the ‘social’ cost. Not infrequently, the cost is much higher – sometimes by an order of magnitude or more.

Regulation has its place. But calculation of the price of carbon implied by regulation-based policies should be made systematic to avoid imposing an unnecessarily high burden on society.

Even for non-price policies, it is possible to derive an (implicit) carbon price

Concept and measurement of the implicit price of carbon

Various policies, including technology ‘pushes’, standards policies and direct regulation, ignore the price mechanism. Nevertheless, just as each policy reduces carbon emissions, so too does each impose a cost on the emitter. Hence, every policy embodies a cost, albeit implicit, per tonne of carbon saved. Moreover, there is no *a priori* guarantee that, across a range of policies, these costs will be similar, whether to one another or to the ‘social’ cost of carbon.

In our experience, not everyone is exercised by this point, which is often regarded as merely an arcane preoccupation of economists. And so it might be, were the price of carbon implicit in non-price policies generally fairly close to the ‘social’ cost of carbon. In practice, however, the implicit price of carbon differs considerably from policy to policy, and in some instances may be very far removed from the ‘social’ cost of carbon.

To demonstrate the potential quantitative importance of this point, we have attempted to calculate illustrative figures for the cost of carbon implicit in a small selection of regulation-based policies. These calculations have been made essentially by taking: the (incremental) cost(s) incurred as a result of complying with the regulation; the resulting (incremental) reduction in carbon emissions; and then dividing the former by the latter.

Such calculations³³ require many assumptions and depend on uncertain data, so they are unavoidably subject to significant potential margins of error. Nevertheless, it is striking how much more it evidently costs to save a tonne of carbon emissions under some policies than under others:

- **Electricity produced by land-based wind turbines**, at least in regions where there is ample wind, costs much the same as electricity produced in conventional coal-fired plants. Yet such turbines save around 0.14kg of carbon per kWh. Strictly speaking, this implies a *negative* implicit price of carbon. Offshore turbines, however, are more expensive to construct and maintain: the implicit price of carbon saved by them may be of the order of \$150 per tonne;
- **Hydro electricity** too, where it is feasible, is broadly price competitive with conventional, carbon-based electricity generation, and hence reduces carbon emissions at little or no cost, again implying a *negative* implicit price of carbon;
- **Energy-efficient light bulbs**, at present prices, also save carbon extremely cheaply – at around \$10 per tonne on our estimates;
- **Draught-proofing** a house, we estimate, implicitly values the carbon saved at around \$130 per tonne. This is significantly higher than that for energy-efficient light bulbs, to be sure, but nevertheless is markedly less than some other alternatives;

³³ Details of the calculations are available upon request.

- **Reducing automobile emissions** will involve technologies that are still under development; whose costs are uncertain; and that will bring ancillary benefits, the value of which can so far only be guessed. However, as an example, our calculations suggest that recent European regulations requiring that emissions be reduced from the present 160g to 130g of CO₂ per 100 kilometres from technological improvements (and a further 10g of CO₂ per 100 kilometres from complementary measures), may prove implicitly to value carbon between \$700 and \$2,300 per tonne;
- **Solar thermal electricity**, too, is expensive in terms of the cost per tonne of carbon saved – perhaps around \$500 per tonne for up-to-date technologies in sunny locations; and
- **Solar photo-voltaic cells**, in cloudy Europe, at least, implicitly cost a staggering \$6,300 per tonne of carbon saved. Of course, this full cost may be disguised, to the extent that government pays a subsidy or grants a tax rebate: but that does not reduce the cost to society as a whole of saving carbon in this way.

It may be that many of these measures, as with the automobile example, could imply ancillary benefits, which would then reduce the calculated figure, perhaps markedly. But it seems unlikely, on the face of it, that such unquantified benefits would be sufficient to bring the implicit price into line with the optimal price.

Comparison with the ‘social’ cost of carbon

The implicit price should be calculated by policy makers, and compared with the ‘social’ cost of carbon

Such figures should be considered not only in relation to one another but also alongside estimates of the ‘social’ cost of carbon. As discussed in Chapter 2, *The measurement of the ‘social’ or ‘damage’ cost of carbon*, we take \$50 (€40) per tonne as a central working estimate of the ‘social’ cost of carbon today, rising to perhaps \$100 (€80) per tonne by 2050.

Use of the ‘social’ cost of carbon as the ‘benchmark’ against which to assess regulatory proposals is sometimes questioned on the basis that the ‘social’ cost of carbon is itself uncertain – as indeed it is. However, this argument is dubious, for three reasons. First, the range of estimates of the ‘social’ cost of carbon, as suggested above, is markedly narrower than the range of the (implicit) price of carbon under different regulatory proposals. Second, even if the estimates of the ‘social’ cost of carbon were particularly uncertain, that would not warrant the making of regulations without regard to cost. And third, even if the benchmark is uncertain, it is more efficient to ‘level the playing field’ by applying a single, reference, price to all emissions, regardless of source, than to introduce economic distortions by treating different polluters differently.

To take these points further, consider the situation of a typical inhabitant of the European Union. Through the European Union Emissions Trading Scheme, he or she is currently being ‘taxed’ about €20 for each tonne of CO₂, which is to say €70 per tonne of carbon, that he or she sends up the chimney in the generation of the energy used to light, heat or cool his or her home. But, under the European automobile regulations, it is proposed that he or she should be taxed at, perhaps, \$700-2,300 for each tonne that he or she sends down his or her car’s exhaust pipe. Both policies cannot be optimal. If the \$50-100 estimate of the optimal price of carbon is anything like correct, it is the automobile proposal, rather than the present EU ETS price, that is out of line.

The significance for policy

Such calculations strike some observers as essentially trivial. For example, some technologists with whom we have discussed the matter have said that it is only natural that some ways of reducing carbon emissions will cost more than others. And that is probably so – up to a point. Similarly, policy makers in some (non-finance) government departments exhibited little interest in the matter, adopting the view that what really matters is to reduce emissions, largely regardless of cost.

To some extent, all this is understandable. It probably does not matter greatly to many households, for example, whether an expenditure of, say \$40 on draught proofing their house implicitly values carbon at \$50 per tonne, \$100 per tonne, or even several times that, for the simple reason that spending \$40 is unlikely to break the household budget.

Similarly, perhaps, it may not matter particularly to some government departments if the price of carbon implicit in a policy is several times the 'social' cost, if the bill is to be paid by industry rather than out of taxation revenue.

However, once an emissions control policy starts to assume macro-economic dimensions – as it will have to if a meaningful reduction in global emissions is to be effected – the cost of policy, even if implicit, starts to matter considerably.

Consider the macro numbers. 'Business as usual' policies could imply a rising cost of damages from climate change, to reach a run rate of perhaps 3%-odd of global GDP annually by around 2050.

In turn, Stern estimates that this damage could be avoided by adopting policies that could cost around 1% of (global) GDP per year. Suppose, however, that carbon emissions were to be reduced not in the most efficient ways, but instead using less cost-effective, non-price-based, 'green plan' policies such as some auto emissions regulations, or the installation of solar panels, which cost 15-130 times as much. These would represent an enormous proportion of GDP, which finance ministers and ministries of finance could not even begin to countenance.

A few counter-arguments

It would be foolish to argue that only price-based policies should be promulgated: and few finance ministries – which stand to play a progressively greater role as climate change policy moves further to the centre of government – would suggest this. In some cases, for example, it can be both easier and more effective to regulate, in the first instance, and only thereafter, in the interest of minimising costs, to allow market mechanisms to work. This has often been the practice, for example, with financial regulations.

Furthermore, regulation can in some instances be not only effective, but also cost-efficient, in decreasing carbon emissions, for example in areas where large numbers of people individually produce very small emissions, but which in aggregate can be large, while demand is comparatively price-inelastic. Energy-efficient light bulbs are a case in point.

Conclusion

Regulations have their place. But it is important that policymakers calculate the price of carbon implicit in any regulations that they propose. This is already required, for example, under Australian law, and we suspect that pressure from treasuries and ministries of finance will progressively broaden the use of this practice. ■

In some cases, it can be easier and more effective to regulate in the first instance ...

... but never lose sight of the implicit price

CHAPTER 5: UNCERTAINTY AND RISK: THE CASE FOR PAYING A RISK PREMIUM

Summary

Earlier chapters treated the climate change issue as an economic issue, and invoked ‘cost-benefit analysis’ to determine the optimum degree of abatement and the (associated) ‘social’ cost of carbon.

However, as we observed in *The Business of Climate Change: Challenges and Opportunities*, society might rationally have reason to abate more than would be suggested by such a cost-benefit analysis, and hence to pay a price above the calculated ‘social’ cost of carbon. Specifically, we said, society might want to pay *an insurance premium*, to reduce the risk of an unforeseeable non-linearity, discontinuity, or catastrophe. Having thought and read about this matter further, we realise that, in the terminology of much – though not all – of the literature, we used the wrong word: what is at issue is a *risk premium*, rather than an *insurance premium*.

In addition to the risk of catastrophic events and irreversible climate change, there are also many uncertainties, at several levels: scientific, economic, and political. These complicate cost-benefit analysis. The consequence is that, while it may be *rational* to abate more than would be suggested by a basic economic cost-benefit, it is difficult, and perhaps impossible, to quantify the amount of additional abatement that it would be rational to undertake.

Uncertainty and risk are two distinct concepts

Uncertainty and risk: two distinct notions

There is an important distinction between the two concepts, introduced by Frank Knight in 1921³⁴.

- A decision is made under **risk** when the probabilities involved are objectively known, i.e. probabilities are agreed by rational economic agents; whereas
- A decision is made under **uncertainty** when the probabilities involved are subjective beliefs of the decision maker, i.e. rational agents can disagree about them.

Thus, under Knight’s schema, “risk” is “randomness with *knowable* probabilities”, whereas “uncertainty” is “randomness with *unknowable* probabilities”. In situations involving risk, decision-making rules, such as those resulting from maximisation of expected utility, apply; whereas in situations with uncertainty, such calculations are more complex³⁵.

Keynes (re)stated the matter in 1937³⁶:

“By ‘uncertain’ knowledge, let me explain, I do not mean merely to distinguish what is known for certain from what is merely probable. The game of roulette is not subject, in this sense, to uncertainty [...] the sense in which I am using the term is that in which the prospect of a European war is uncertain, or the price of copper and the rate of interest twenty years hence [...] about these matters there is no scientific basis on which to form any calculable probability whatever.”

Classic examples of choice under risk are lotteries, and the roulette wheel, where it is possible to establish objectively the probability of each number, type of number, or colour appearing. The probabilities being known, an agent can undertake an ‘expected utility’ analysis to enable him or her to take a rational decision.

Decision under uncertainty, however, is more complicated – just as it is also more common: many, perhaps most, real-life situations are unprecedented, and hence (history-informed) probabilities cannot be assigned.

Climate change features both uncertainty and risk

Climate change is characterised by the presence both of uncertainty *and* of risk. There is, as noted by Chichilnisky (1996), “uncertainty with catastrophic risks”. Examples include the risk of higher sea levels, the risk of more extreme weather events, and indeed the risk

³⁴ Knight, F. (1921).

³⁵ This distinction is not agreed by all economists: however, it is quite widely used, and we follow that terminology for convenience of exposition.

³⁶ Keynes, J.M. (1937).

of irreversible climate changes. But although scientists know what many of the risks are, they generally do not know the probabilities associated with them.

Several levels of uncertainty can be identified in climate change analysis:

- **Scientific uncertainties:** These attach to the response of the carbon cycle to different emission scenarios, which themselves are functions of economic assumptions (the sensitivity of the climate to changes in the carbon cycle, etc);
- **Socio-economic uncertainties:** These relate to the possible impacts on human societies; the economic costs of climate change and their regional distribution; the costs of emissions abatement; and the costs of adaptation;
- **Political uncertainties:** These include which policy instruments will be implemented and which countries will enact climate change policy.

Furthermore, a particular characteristic of climate change makes the issue even more complicated: climate change risk is endogenous. Climate change consequences depend on human behaviour; and in turn the reaction of the climate system following climate change action is uncertain.

It follows that any economic analysis of climate change should include both risk and uncertainty as central features; and both imply that society may wish to spend more than the cost-benefit-calculated ‘social’ cost of carbon.

Allowing for both risk and uncertainty

‘Risk aversion’

‘Aversion to catastrophic risk’ and ...

The oft-observed human reluctance to accept a bargain with an uncertain payoff instead of one with a more certain, but possibly lower, expected payoff, is included in most cost-benefit calculations. However, in the case of climate change there is another concern: the possibility of a gradual build-up in greenhouse gases reaching a trigger point and producing an abrupt change to a qualitatively different, and perhaps irreversible, condition. In the words of Alley et al. (2002)³⁷, abrupt climate change occurs “[...] when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause.”

Such *catastrophic* risks, and society’s wish to avoid them (‘aversion to catastrophic risk’), explains why society may prefer to pay a bit ‘over the odds’ to reduce further the risk of an irreversible climate-change-related event, i.e. people may be willing to pay more than the cost-benefit-calculated ‘social’ cost of carbon. The difference between this price that society wishes to pay and the cost-benefit-calculated ‘social’ cost of carbon is a *risk premium*.

‘Uncertainty aversion’ or ‘ambiguity aversion’

... ‘aversion to uncertainty’ may lead society to pay more than the ‘social’ cost of carbon

Although scientific knowledge has advanced considerably, it is difficult, even impossible, to quantify the probability of many climate-change-related events. Hence, a cost-benefit analysis becomes complicated because it is almost impossible to put accurate probabilities on all climate-change-related scenarios.

Furthermore, the cost-benefit method is applicable only if the variances of costs and benefits are finite. Tol (2003)³⁸ argues that finiteness of both variances is difficult, if not impossible, to demonstrate. Yet cost-benefit analysis can be applied only if the probabilities of catastrophic scenarios are so low that the variance of the expected outcome is finite. Hence, ‘aversion to uncertainty’ (also called ‘aversion to ambiguity’) also may lead society to spend more than would be implied by a simple cost-benefit estimate of the ‘social’ cost of carbon to abate greenhouse gases.

³⁷ Alley, R.B. et al. (2002).

³⁸ Tol, R.S.J. (2003).

The amount that should be spent on the risk premium is difficult to derive

How high a risk premium is appropriate?

How much should be spent on this risk premium? The answer is inherently difficult to derive: the uncertainties make an exact calculation impossible, yet it is because of these uncertainties that society is willing to spend a risk premium.

One way to derive this risk premium has however been suggested by Cline (1992)³⁹. Cline argues that, using the central values of key parameters (i.e. scientific, economic, and sociological parameters), the benefits of damage avoidance do not exactly cover the costs: Cline estimates the ratio of the discounted value of benefits to costs at approximately 3:4.

However, if agents (policymakers in this case) attach different weights to different outcomes – for example, a weight of ½ to the central outcome, but a weight three times as high to the high-damage outcome relative to the low-damage outcome – then the benefit-cost ratio becomes 1.3:1. By applying different weights to each scenario, it becomes possible to derive the amount that it would be rational to spend over and above that implied by a calculation of the ‘social’ cost of carbon. In the Cline example, paying 30% more than the ‘social’ cost of carbon would yield the (economically rational) 1:1 ratio.

Mathematically, the parameters on which the risk premium value depends are:

- The ‘catastrophic risk aversion’ factor: the higher this factor, the higher the risk premium;
- The probabilities to be applied to each climate-change-related event: the higher the probabilities of worst-case scenarios, the higher the risk premium;
- The weighting of each event, depending on aversion to risk and aversion to uncertainty: the higher the weights on worst-case scenarios, the higher the risk premium.

Conclusion

Risk and uncertainty lie at the heart of climate change analysis:

- Risk through events such as abrupt climate change, sea-level rise, irreversible consequences, etc; and
- Uncertainty because of issues in areas such as the science of climate change, the economic costs of climate change, and the costs of abatement, etc.

Given that economic agents are averse both to catastrophic risk and to uncertainty, they may rationally wish to spend more than the ‘usual’ cost-benefit-calculated ‘social’ cost of carbon. To that extent, therefore, a conventional cost-benefit calculation should be amended to allow for the payment of a *risk premium* over and above the ‘social’ cost of carbon.

However, no simple, clear, objective answer can be provided as to what risk premium it is rational to pay: the answer can be achieved only by specifying a subjective weight to the value of avoiding different outcomes. ■

³⁹ Cline, W. (1992).

Is climate change insurable?

An insurance premium and a risk premium differ fundamentally:

- An insurance premium is a payment for transferring risk from the insured party to one or more other parties;
- A risk premium, by contrast, represents expenditure that may reduce the likelihood of an event occurring, but does not transfer the risk to another party: hence a risk premium does not, and cannot, result in reimbursement.

Principles of insurance – “the institution that mitigates the influence of uncertainty”⁴⁰

Insurance is the equitable transfer of the risk of a potential loss, from one entity (the insured) to another (the insurer), in exchange for the *insurance premium*. This insurance premium is the difference between the expected damage (equal to $p \cdot D$, where D is the value of the damage, and p the probability of occurrence) and the amount paid to get insured, P .

A simple, basic insurance contract works to the advantage of both the insured and the insurer because the insured wishes to avoid the chance, even if small, of incurring substantial loss; while the insurer (for example, an insurance company or, yet more broadly, the capital market) benefits from pooling independent risks and, via the law of large numbers, converting risky individual contracts into almost ‘sure’ things. Two essential elements of an insurance contract are thus, *diversifiability* and *quantifiability* of risk:

1. **Diversifiability:** the risk should be spread among a large number of individuals so that the adverse consequences of an individual risk are transferred to a homogenous collective of individuals running the same risk.
2. **Quantifiability:** the risk should be quantifiable, so that an insurance premium can be determined. Indeed, no insurance company would agree to insure a risk that could not be quantified.

Two problems frequently complicate the simple insurance model. First, the transfer of risk from the insured to the insurer raises the risk of the insured party becoming careless. Such *moral hazard* can be reduced by making the insured party bear some of the costs of the contingency. Second, a problem of *adverse selection* may arise when the insurer lacks relevant information that is possessed by the insured. People who know that they face big risk are more likely to buy insurance than people who face small risks. Therefore, as a result of private information asymmetries, the insured are more likely to suffer a loss than are the uninsured; and the insurance companies have to adjust prices to internalize this issue.

Insurance in the case of climate change

Climate change implies a range of risks, against which economic agents may wish to insure. In the case of climate change, however, four problems arise:

Diversifiability: *A priori*, climate change risk falls on a collective rather than on an individual: in the limit, it could even fall on all individuals on earth. Large groups may not be able to take out insurance because it may be difficult, if not impossible, to find an outside body able or willing to assume the risk. *A fortiori*, the world as a whole cannot insure itself, because there is no outside body to assume the risk – unless insurers can be found on another planet.

Quantifiability: Climate change is a new subject: there is only a limited historical record; so probabilities and extents can only be guessed at. The industry is faced with the challenge of converting scientific predictions into practical guidance for the industry. As noted by Lloyd’s (2006)⁴¹, “... pricing and capital allocation models must be updated regularly to reflect the latest scientific evidence, and not just *in extremis*, as has tended to happen in the past, for example after Hurricane Katrina”.

Moral hazard: To the extent that insurance against climate change is possible, this could deter groups in society from taking actions against it, and in particular from abating greenhouse gas emissions, because even if climate-change-related events were to occur, people would get reimbursed.

Adverse selection: To the extent that losers and winners are readily identifiable *ex ante*, the winners will withdraw from the insurance. This issue could be prevented by binding contracts. But these would need to be enforced over a considerable period, which could be problematic⁴².

Whatever amount people may be prepared to spend on an insurance premium, however, this is not the same thing as the amount that people are willing to spend to avoid the risk of abrupt climate change: that amount is the risk premium (see chapter above).■

⁴⁰ McCall, J. J., “Insurance”, *The new Palgrave Dictionary of Economics*, ed. Eatwell, J., Milgate, M., and Newman, P. (The Macmillan Press Limited, 1991).

⁴¹ Lloyd’s (2006).

⁴² Tol, R.S.J. (2003).

CHAPTER 6: THE DISCOUNT RATE CONTROVERSY

Summary

Perhaps the question put to us more often than any other has been: “*The Stern Review*⁴³ showed particularly high costs resulting from climate change. But is this not because Stern assumed an unduly low – near zero – (real) rate of discount?”

That clients should have focussed on this issue is perhaps not surprising, given that practitioners in the financial services industry are well versed in reducing future financial flows to a present value by discounting by a (market) rate of interest. However, Stern’s so-called “discount rate” is in fact a rather more complex animal than that, not least because of the ethical ‘intergenerational’ issue – a normative issue that has no single ‘correct’ answer and that will doubtless continue to be much debated.

In *The Business of Climate Change*, we observed only that “... the choice of discount rate in multi-generational calculations is an ethical, as much as an economic, issue”. Our conclusion now, after reading further into the issue, and reporting on it below, is that while neither Stern, nor economists, nor philosophers more generally have had the last word on this issue, Stern’s cost estimates arguably were not biased upwards and hence warrant continued serious consideration.

A high discount rate would warrant almost no abatement expenditure

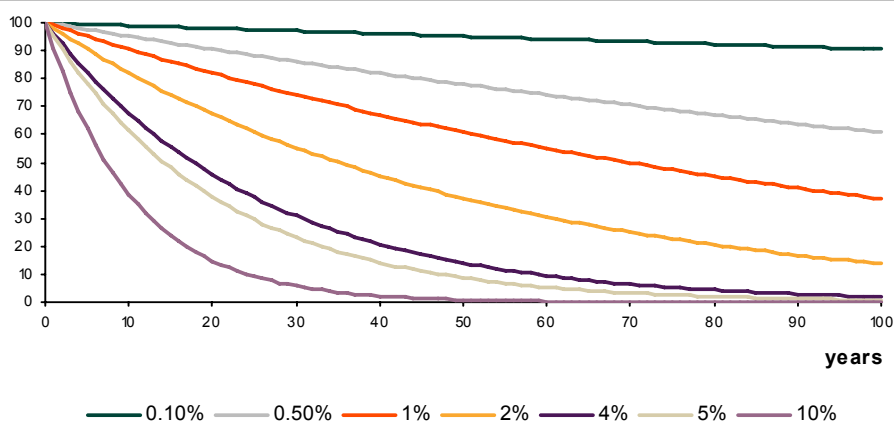
The discount rate issue in climate change analysis

The process whereby an agent discounts future incomes or expenditures to express them as a present value is conceptually straightforward, for a single generation. Were we to ask one of our (rational and economically literate) colleagues whether they would prefer to receive £100 today or £105.50 in a year’s time, they would reply that they were indifferent, the two sums being intrinsically the same, given today’s sterling rate of interest of 5.5%.

It is therefore intuitively appealing to apply the technique of discounting so as to obtain a present value of expected future damages caused by climate change. And, as a matter of arithmetic, the choice of discount rate is quantitatively important: different rates of discount yield markedly different results (Figure 5). To take an extreme case by way of illustration, a discount rate of 8% with a horizon of 200 years would imply that damages of \$1bn at the end of the period would be valued at only about \$200 today. On such a basis, even enormous losses in the distant future would warrant almost no abatement expenditure being undertaken by the present generation.

In thinking about this issue, economists, following the pioneering work of Ramsey (1928), decompose the social rate of discount (s) into two basic components, reflecting the two basic human considerations:

Figure 5. Value of £100 over time using various discount rates



Source: Lehman Brothers.

⁴³ Stern, N. et al. (2006).

- 1) Present generations might discount consumption of future generations simply because they care less about future generations than about themselves; and
- 2) To the extent that future generations will be wealthier than current generations, current generations will naturally attribute less marginal utility to future generations' consumption.

The discount rate breaks down into two components:

The equation of the social rate of discount given by Ramsey is therefore⁴⁴:

$$s = \delta + \eta g$$

where δ is the 'utility discount rate', also often referred as the 'pure rate of time preference', η is the 'elasticity of marginal utility', and g the expected future growth rate of consumption. Most debate focuses on the utility discount rate and the elasticity of marginal utility, and much less on the future growth rate of consumption.

The 'pure rate of time preference', i.e. the weight placed on future utility...

The 'utility discount rate' term (δ), or 'pure rate of time preference', represents the proportional rate of decline in the weight placed on a future unit of utility, or income, compared with an equal unit experienced today. At the level of the individual, the notion that it may be appropriate to discount the future derives from the fact that people apparently usually prefer good things to happen sooner, rather than later. At the level of society as a whole, it represents the weight that present generations attribute to the welfare of future generations. Thus a value of $\delta = 0$ means that future generations are treated equally with present generations; by contrast, $\delta > 0$ means that the welfare of future generations is discounted compared with present generations.

It is, however, debatable whether δ should have any value other than zero. Many economists consider that abatement and other long-lived public investments should be thought of as matters of moral obligation and altruism, rather than of self-interest. Some have even criticized the notion of *any* pure time preference: Pigou (1932) stated that pure time preference "... implies [that] our telescopic faculty is defective"⁴⁵, and Solow (1974) has said "[...] in solemn conclave assembled, so to speak, we ought to act as if the social rate of time preference were zero."⁴⁶ In the judgement of these economists, all generations should be treated equally, i.e. the rate of pure time preference should be zero.

Cline (1992)⁴⁷, too, proposes a zero pure time preference rate in evaluating climate change policies, on the argument that a positive rate would involve placing a lower weight on the welfare of future generations, and that this would be contrary to intergenerational equity.

Beckerman and Hepburn (2007)⁴⁸ argue that, in turn, the utility discount rate can be broken down into two components: the pure rate of time preference, and an allowance for the possibility of extinction of the human race. And indeed, Stern regarded the only justification for a positive rate of pure time preference as being the possibility that the human race might be extinguished. Accordingly, Stern used a value of zero for the former component, and a value of just 0.1% for the latter – reflecting an essentially-assumed 10% probability that humanity will not survive the coming 100-year period – giving a total value for the utility discount rate of just 0.1.

... and the 'elasticity of marginal utility', i.e. society's aversion to inequality of consumption

The 'elasticity of marginal utility' term (η) can, for present purposes, be taken to be a measure of society's aversion to inequality of consumption. A value $\eta = 1$ implies that a given proportionate increase in income generates the same utility, or satisfaction, for a rich person as for a poor person (the same as saying that £1 accruing to a poor person is valued ten times as highly than it would be were it to accrue to someone earning ten times as much).

⁴⁴ Ramsey, F.P. (1928).

⁴⁵ Pigou, A.C. (1932).

⁴⁶ Solow, R.M. (1974).

⁴⁷ Cline, W. (1992).

⁴⁸ Beckerman, W. and Hepburn, C. (2007).

Both components trigger unresolved debates about their appropriate values

However, η , the ‘elasticity of marginal utility’, is in practice a rather complicated concept, itself reflecting at least three different dimensions. First, as noted by Beckerman and Hepburn (2007)⁴⁹, individuals with higher η are more risk-averse than are individuals with lower η , because a consumption loss reduces utility more than an equivalent income gain increases utility; which in turn implies greater spending now to reduce the future risks of climate impacts. Second, at the level of society as a whole, a higher η places greater weight on the consumption of the poor, producing a higher social aversion to inequality of consumption. And third, a higher η implies that the current, relatively poor, generation should not spend much on preventing climate change impacts on future (richer) generations. Hence it is not obvious whether increasing η produces an increase, or a decrease, in the present value of future climate impacts.

Various attempts have been made to deduce what the appropriate value for η either might, or should, be. Stern opted for a value of 1, but others, e.g., Nordhaus (2006), have argued that that is too low, particularly when taken in conjunction with the near-zero pure time preference rate: Nordhaus argues that, in calibrating a growth model so that it fits historical data, the pure time preference and the elasticity of marginal utility cannot be chosen separately. He finds, in the context of his model that, to be consistent with a 0.1% rate of pure time preference, the elasticity of marginal utility should be a bit in excess of 2, instead of 1 as assumed by Stern.

There are other issues, too. As originally noted by Ramsey (1928)⁵⁰, a zero rate of time preference points to an excessively high warranted savings rate of all generations. The reason is intuitively obvious: the higher the rate of return, and the lower the rate of interest, the more it pays to save and invest today and consume tomorrow. Thus, Dasgupta (2006)⁵¹ calculates that, on the basis of a social rate of return on investment of 4% per year, the Stern assumptions would imply that the current generation ought to save as much as 97.5% of its aggregate output for future generations, which is self-evidently impossible. Dasgupta argues that a range of 2-4 for the elasticity parameter would lead to more satisfactory consequences, consistent with observations.

One possible compromise, as proposed by Nordhaus, would be, perhaps, to “choose global warming policies assuming the near-zero social discount rate, but leave the rest of the economy to operate with the present discount rate.”⁵²

Another possibility: a declining discount rate

An alternative solution could be to use a declining discount rate, a notion that is supported by both theoretical argument and empirical evidence⁵³. A survey of 1,700 economists by Weitzman (1998)⁵⁴ found that they believe that a lower discount rate should be applied to problems with a long horizon, and that the discount rate should decline over time. In that spirit, Nordhaus (2006) assumes a pure rate of social time preference that starts at 3% per year, and declines to 1% in 300 years.

A declining discount has also been used by United Kingdom HM Treasury in its Green Book (2003)⁵⁵, taking a discount rate equal to 3.5% for the first 30 years, decreasing to 1% in 300 years (Figure 6).

Given our druthers, we might, albeit with no great conviction, use a declining discount rate. This could start at 4% today, on the basis of an elasticity of marginal utility of consumption of 1.5, a consumption growth rate equal to 2%, and a pure time preference of 1%. It would then decline progressively, to a near-zero rate in, say, 300 years’ time.

Declining discount rates could provide a solution to the problem

We would use a discount rate starting at 4% today and declining to near zero in 300 years

⁴⁹ Beckerman, W. and Hepburn, C. (2007).

⁵⁰ Ramsey, F.P. (1928).

⁵¹ Dasgupta, P. (2006).

⁵² Nordhaus, W. (2006).

⁵³ Guo, J., Hepburn, C., Tol, R.S.J. and Anthoff, D. (2006).

⁵⁴ Weitzman, M.L. (1998).

⁵⁵ HM Treasury (2003).

Figure 6. Declining discount rate in the UK Green Book 2003

Period of years	Discount rate
0-30	3.5%
31-75	3.0%
76-125	2.5%
126-200	2.0%
201-300	1.5%
301+	1.0%

Source: HM Treasury (2003)

That proposal does not solve all difficulties, however. Declining discount rates imply problems of time inconsistency – a common problem in policymaking – which arise when a policymaker has an incentive to deviate from a plan made by someone else. With declining discount rates, today’s policymakers seek to commit future policymakers to what they consider to be an appropriate development path. But as the future arrives, the new generation of policymakers may be tempted to deviate from this path, reallocating resources on the basis of then-prevailing interest rates.

A further issue: uncertainty

As pointed out by Weitzman (2007)⁵⁶, one of the most troubling omissions from any analysis based on the Ramsey equation is uncertainty. An important feature of interest rates under uncertainty is that discount rates do not aggregate arithmetically into a simple certainty-equivalent interest rate. For example, discounting with an interest rate of 4% is not the same as having a discount rate of 2% with a 50% probability and a discount rate of 6% with a 50% probability.

Furthermore, in the certain world of Ramsey, no distinction is made between discount rates of different classes of assets. In reality, however, discount rates for different assets may differ considerably. Weitzman shows that it is appropriate to distinguish between at least two discount rates to account for different types of assets:

- A risky, economy-wide rate of return, applicable to investments that have pay-off characteristics *parallel* to the economy, i.e. *correlated* to economic conditions;
- A risk-free rate of return, applicable to investments whose pay-offs are *orthogonal* to the economy, i.e. *independent* of economic conditions.

Therefore, the issue is: are abatement costs and benefits parallel or orthogonal to the economy as a whole? If they are parallel, then a value for the discount rate close to the market interest rate should be used. Conversely, if they are orthogonal to the economy, then a discount rate close to the risk-free interest rate should be used.

When accounting for such uncertainties, Newell and Pizer (2001)⁵⁷ show that the valuation of future benefits of climate change abatement are much higher: for more on the issue of uncertainty in climate change analysis, see the chapter *Uncertainty and risk: the case for paying a risk premium*.

Why not use market interest rates?

It might seem curious that the discussion of discounting presented thus far (as in the *Stern Review*) has been undertaken without reference to market interest rates – rates that, arguably, reflect the market-determined discount rate. Such an observation would be understandable. Stern, and others before him⁵⁸, argues that various market distortions (such as taxation, short-termism, etc.) mean that the market rate of interest does not reflect the social rate of discount and hence cannot be used in this type of analysis.

Uncertainty makes the debate even more intricate

In climate change analysis, market rates are often said to be inappropriate

⁵⁶ Weitzman, M.L. (2007).
⁵⁷ Newell, R.G. and Pizer, W.A. (2001).
⁵⁸ Arrow, K.J. (1995).

*But they should not
be ignored*

While market interest rates should be used with caution, alternative measures have their own problems – as evinced, for example, by the controversy provoked by the methodology in the *Stern Review*.

Furthermore, using a discount rate very different from market rates can lead to practical problems, such as arise under the *Keeler Cretin* paradox. In this paradox, the policymaker must choose between implementing a socially valuable project today or in a year's time (its social value remains constant throughout). If the (risk and liquidity adjusted) market rate of interest is higher than the social discount rate, the rational policymaker will choose to postpone, because the interest earned over the year more than compensates for the loss of welfare. Indeed, in these circumstances, the policymaker will postpone the project indefinitely, because another year of interest is always more valuable! Overall, therefore, it can be argued that market rates, while not being the only guide to the social discount rate, should not be ignored, either.

Happily for Stern, market interest rates seem broadly to agree with his assessment. Long-term indexed government bonds from the major economies (the best available proxy for the risk-free long term real discount rate) are currently trading with yields of 2% or less. If anything, these yields suggest Stern has chosen too high a rate, given that these bonds should, in principle, attract small but significant credit and liquidity premia (that should presumably more than offset the convexity of these low volatility instruments), suggesting that they over-estimate the market's true long run real, risk-free, discount rate.

Conclusion: the effective rate of discount

The decision about what rate, if any, is appropriate to discount future costs is thus fraught with difficulty, and seems unlikely to be resolved in the near future. The choice of the rate of pure time preference is as much an ethical as an economic issue.

If this discussion has achieved nothing else, however, it has served to show that criticism of Stern's now-famous value of 0.1 relates not to the overall discount rate, but only to the 'pure rate of time preference' part of it. Indeed, Stern's implicit mean discount rate over the coming century is a non-negligible 2.1% per year, made up thus:

$$s = \delta + \eta g$$

$$2.1 = 0.1 + 1*2$$

It is possible to debate whether a higher or lower discount rate should be used. Interestingly, the market rate of interest on long term real bonds is in general a little *below* Stern's 2.1% figure, which is intriguing, given that such bonds could be expected to attract a (perhaps significant) liquidity premium.

All that said, whatever the pros and cons of Stern's case for climate change abatement, they do not rest fundamentally on his choice of discount rate.■

CHAPTER 7: ADAPTATION VS ABATEMENT: ARE THEY ALTERNATIVES?

Summary

In another – earlier – epoch, the principal protagonists in the climate change debate – mainly Non-Governmental Organisations (NGOs) – were reluctant to discuss adaptation, largely perhaps because to do so would have been to admit as inevitable the climate change that they wished to see avoided. However, time has moved on, and some climate change at least is recognised as being inevitable, if only because of lags: even were emissions to cease completely and immediately, earth’s mean temperature would nevertheless increase by an estimated 1°C⁵⁹.

This has led some clients to ask what we make of the argument that policy should not bother with abatement but instead simply concentrate on adapting to what is inevitable⁶⁰. Broadly, we see a two-part answer to that question. First, to the extent that there is already climate change ‘in the pipeline’, there must be at least some adaptation. Second, it is necessary to specify the principle whereby expenditure should be allocated between abatement on the one hand and adaptation on the other.

The rational economic approach would be to allocate resources between adaptation and abatement such that the last, or marginal, dollar or euro spent, whether on adaptation or abatement, would produce the same amount of benefit, i.e. reduction in damages. In a policy that was not only rational, but also optimal, that principle would be followed up to the point where the last dollar or euro spent would save exactly a dollar or a euro’s worth of damage. This is of course easier to say than to do, but the principle seems clear.

Adaptation is the adjustment to the consequences of climate change

... whether as an anticipation of, or a reaction to, climate change events

Definitions and general considerations

Consider first what lies behind the concepts of abatement and adaptation. Abatement encompasses actions that reduce emissions of greenhouse gases and hence climate change; whereas adaptation is the adjustment to the consequences of climate change. The Intergovernmental Panel on Climate Change (IPCC) adopts a broad definition of adaptation as:

“[any]... adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts...”

and refers to:

“... changes in processes, practices, and structures to moderate potential damage or to benefit from opportunities associated with climate change.”⁶¹

Natural and human systems have always adapted to variations in climate, by altering settlement and agricultural patterns, as well as other aspects of their lifestyles. And it seems that, over the long span of human history, adaptation to climate variations has been broadly successful⁶². Why, therefore, raise the issue of adaptation to climate change impacts at all, if mankind has always been able to adapt to climate variation?

First, because in a world subject to potentially rapid climate change, the historical climate records that have guided past adaptation may not be reliable. Second, to the extent that prospective climate change stands largely to result from human activity, and not just pure forces of nature, the question of who pays for adaptation becomes more complicated, particularly given that those who stand to be the (proportionately) hardest hit – in many cases the developing countries – are the least responsible for it.

Adaptation refers to two different levels of actions:

- 1) **Building adaptive capacity:** creating the information and conditions needed to support adaptation. This includes income and education levels, strength of government institutions, access to information and technology, etc.

⁵⁹ Wigley, T.M.L. (2005).

⁶⁰ In technical terms, what is being advocated is a “corner solution” which is optimal if every abatement plan fails in a cost-benefit analysis.

⁶¹ Intergovernmental Panel on Climate Change (2001), vol.III, ch.18.

⁶² However sometimes, it is believed, more extreme climate changes had dramatic effects, even leading to the demise of some civilizations.

- 2) **Implementing adaptation actions:** constructing sea walls to protect low-lying coastal zones from rising sea levels, establishing early warning systems for flooding and heat waves, introducing heat- or drought-resistant crop varieties, and so on (for a selection of specific examples, see box *Examples of adaptation policies*).

Historically, adaptation has been largely, if not entirely, reactive to climatic stimuli⁶³. Yet, adaptation in *anticipation* of climate change is likely to be less costly than adaptation that takes place in *response* to climate change events as they occur, as shown in the section below, *Adaptation and/or abatement?*.

Adaptation and/or abatement?

For many years, adaptation was scarcely studied, partly because most people concerned with drawing attention to climate change risk considered that merely to discuss adaptation would present governments with an excuse not to act to cut greenhouse gas emissions.

Protagonists at the other end of the spectrum, by contrast, have argued that mankind should not implement abatement policies at all, but should simply adapt to climate change and climate change impacts as and when they occur.

However, we judge that neither of these positions is correct: and that both adaptation *and* abatement will need to be implemented, together.

Why adaptation cannot be avoided. The first reason, of two, is that abatement policies cannot stop those climate changes that are already ‘in the pipeline’. Even if emissions were to cease today, the earth’s mean temperature would increase by an estimated 1°C, as a result of systemic inertia⁶⁴. Mankind will have no option but to adapt to this increase in the earth’s temperature, and the resulting climatic changes. It is widely agreed today that adaptation policies should be implemented, not least by Working Group II to the Intergovernmental Panel on Climate Change Fourth Assessment Report:

“...adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions.”⁶⁵

The second reason why adaptation cannot be avoided is that the damages caused by climate change are likely to be less, and possibly substantially so, if adaptation measures are taken before the event, rather than after. For example, a US property insurance company⁶⁶ has reported that the nearly 500 locations damaged by Hurricane Katrina that had implemented all of their recommended hurricane-loss-prevention methods experienced only one-eighth the losses of those that had not done so⁶⁷. And a paper prepared for the Federal Emergency Management Agency (FEMA)⁶⁸ demonstrates that money spent on reducing the risk of natural hazards is a sound investment, because “... on average, a dollar spent by FEMA on hazard mitigation⁶⁹ (actions to reduce disaster losses) saves the nation about \$4 ...” in reduced damages. Indeed, without adaptation, climate change costs would be much higher (Figure 7).

Nevertheless, just as adaptation cannot be avoided, neither can abatement be eschewed, also for two principal reasons.

Why abatement cannot be avoided. The first likely reason – although there is to date surprisingly little evidence one way or the other – is that abatement will often prove to be the cheaper option. The second reason, and here the evidence is clearer, is that costs of adaptation rise disproportionately with temperature⁷⁰. (And at worst there is a risk of ending up with irreversible change to the ecosphere, although in that case it might not be possible to adapt at all.)

Both adaptation and abatement are, and will be, needed

Adaptation is necessary to address unavoidable warming due to past emissions ...

... while abatement is necessary to avoid disproportionate adaptation costs

⁶³ Pew Center (2006).

⁶⁴ Wigley, T.M.L. (2005).

⁶⁵ Intergovernmental Panel on Climate Change (2007), vol.II.

⁶⁶ FM Global.

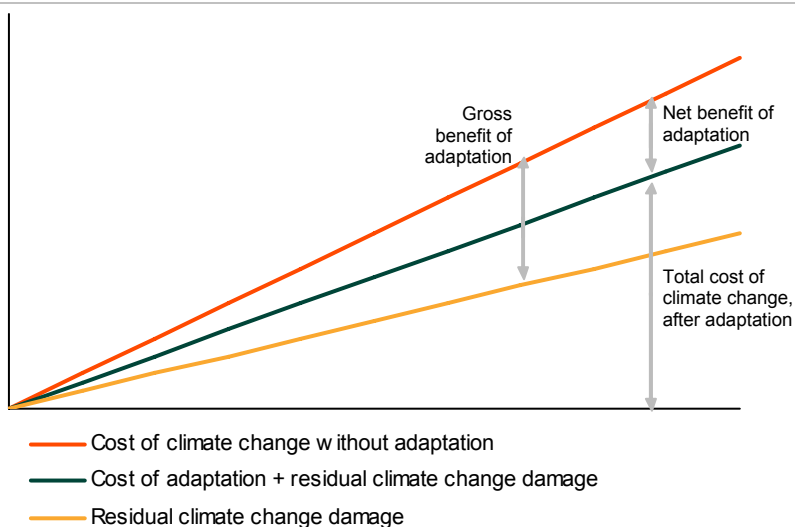
⁶⁷ Dankwa, D. (2006).

⁶⁸ Multihazard Mitigation Council (2006).

⁶⁹ “Mitigation” here means “adaptation”.

⁷⁰ Dietz, S. et al. (2007).

Figure 7. Climate change and adaptation costs⁷¹



Source: Stern, N. et al. (2006), ch.18 and Lehman Brothers.

Thus, to the question raised many times during our discussions with clients, about whether mankind should only *abate* greenhouse gases, or only *adapt* to climate change, the answer appears to be *both*, in principle. The natural follow-on question is how resources ought, rationally, to be allocated to the two aims. The answer is straightforward to establish in theoretical terms; but harder to implement in practice.

Trade-offs between adaptation and abatement

Abatement and adaptation can, as outlined above, be regarded as substitutes. For given expenditure, less effort on abatement will imply a greater effort at adaptation over the long-term horizon, and vice versa. Hence, a portfolio of both policies is appropriate – the question is: in what proportion? Cost-benefit analysis yields insights into the trade-offs between the two, as demonstrated by Tol (2005)⁷².

Total climate change costs can be broken down into two elements⁷³:

- **Adaptation costs:** depending on the study, adaptation represents 7-25% of total climate change costs for a doubling of atmospheric concentration of carbon dioxide.
- **Residual costs.**

Figure 8. Classification of climate change costs, with examples from sea level rise and agriculture

Adaptation costs	Residual costs
Costs of relocation from unprotected coastal areas	Flood damage during construction of protective structures
Cost of retraining farmers in new practices or for a non-farming job	Yield losses before the availability of more suitable crops
Maintenance and periodic replacement of coastal protection structures	Higher residual flooding risk of protected areas
Costs of additional irrigation, additional fertilizer or different crops	Change in food prices and crop yields that cannot be mitigated through adaptation

Source: Tol, R.S.J., Frankhauser, S. and Smith, J.B. (1998).

⁷¹ For expositional purposes, the chart depicts the functions as linear.

⁷² Tol, R.S.J. (2005).

⁷³ Tol, R.S.J., Frankhauser, S. and Smith, J.B. (1998)

In theory, the marginal cost of adaptation should equal the marginal cost of abatement

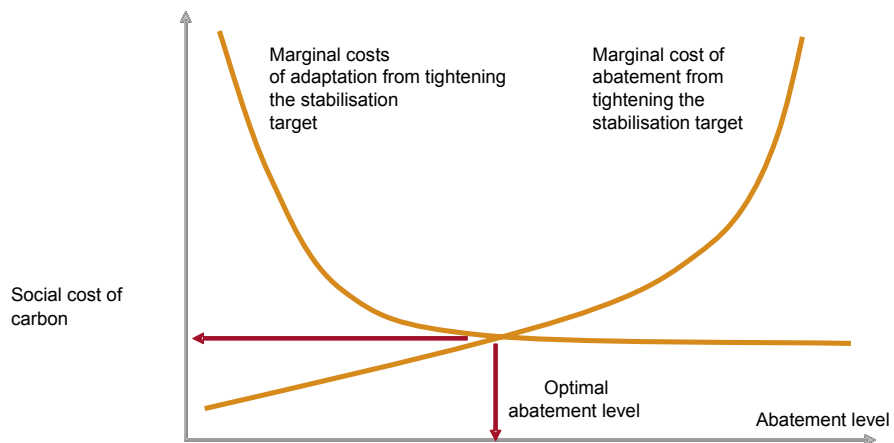
In principle, a basic cost-benefit analysis can be undertaken and from it can be derived the optimal levels of adaptation and of abatement that should be implemented. Hence, it is possible, in principle, to apply the method used to derive the optimal level of abatement and the ‘social’ cost of carbon. Given that adaptation costs are a component of the overall costs of climate change, it is possible to draw the same chart as before, which showed the balance between the marginal costs of abatement and the marginal benefits of it – i.e. the damages avoided, or in monetary terms, the climate change costs.

Thus, two curves are drawn:

- The **marginal cost of abatement**, which is an increasing function of the abatement level, as before; and
- The **marginal cost of adaptation**, which is a decreasing function of the abatement level⁷⁴.

The optimal abatement level and the derived optimal cost of adaptation are determined by the intersection of the two curves (Figure 9), i.e. where the marginal cost of abatement is exactly equal to the marginal cost of adaptation. Therefore, adaptation should be implemented up to the point where marginal cost of adaptation is just equal to the marginal cost of abatement.

Figure 9. Trade-off between adaptation and abatement



Source: Lehman Brothers.

In practice, trade-offs between adaptation and abatement are difficult to assess

However, while the basic theory is straightforward, the practice is likely to be more complicated.

First, it is difficult to assess adaptation costs, because adaptive capacity depends on a range of economic, sociological, technological, and development conditions.

Second, there is an inter-relationship between expenditure on adaptation and the appropriate amount to spend on abatement (Figure 7). The Stern Review, for example, assumes that, in industrialized countries, adaptation will reduce the impacts of climate change on market sectors of the economy by 90% and that, in lower-income regions, adaptation will reduce market impacts by 50%, irrespective of warming⁷⁵.

Third, additional difficulties arise from the three main differences between abatement and adaptation:

⁷⁴ Given that adaptation costs are a component of climate change costs, the marginal adaptation curve and the marginal abatement benefits (i.e. climate change costs) have the same slope and can be combined into a single curve.

⁷⁵ Dietz, S. et al. (2007).

1. **Difference in spatial scale:** Most abatement measures bring global ‘public goods’ benefits, whereas the benefits of adaptation are often private, or localised, ‘public goods’.
2. **Difference in time scale:** A cost-benefit analysis of abatement looks at short-term actions because of potentially detrimental long-term developments, whereas cost-benefit analysis of adaptation looks at short-term actions in the context of short- to medium-term developments.
3. **Difference in focus:** The sector that is the most concerned by the cost-benefit analysis of abatement is the energy sector, whereas adaptation will occur in a number of sectors (e.g. water, tourism, construction, etc.).

A further complication is that, on occasion, adaptation and abatement may work against one another. A simple example is air conditioning, which is an adaptation measure to heat waves, but which at the same time increases emissions of CO₂.

A yet further complication is that abatement may even hinder adaptation. Emission abatement implies important costs that could have negative effects on developing countries: the more a country spends on abatement policies, the less is available to spend on adaptation. This could be particularly serious in low per capita income countries.

It thus seems complicated, and probably verging on impossible, to compare abatement and adaptation and to estimate the trade-off between the two. However, another trade-off might be easier to make, at least in principle: that between abatement measures and facilitative adaptation measures – i.e. actions that allow households and companies to adapt better – because they would have, in particular, the same space and time scales.

Key challenges in implementing adaptation policy

Adaptation is difficult to implement efficiently, for several reasons:

- 1) **Uncertainties and imperfect information:** High-quality information on future climate change is important for a cost-effective, market-based mechanism necessary for the success of adaptation responses. But uncertainties abound concerning future global warming and climate change impacts. And other uncertainties, such as how the system will react to ongoing abatement policies, make it difficult to predict accurately how much adaptation will be warranted.
- 2) **Missing markets:** Effective adaptation could be challenging for private markets, given the inadequacy of information. Adaptation decisions are often private decisions, requiring agents to weigh uncertain future benefits of adaptation against considerably more certain costs. For example, developers may have little financial incentive to increase the resilience of new buildings unless buyers discriminate sufficiently between properties based on vulnerability to future climate change.
- 3) **Externality issues:** Adaptation can be viewed as a public good because it implies spill-over effects: certain benefits of private adaptation can be shared. The private sector, however, is unlikely to invest in adaptation up to the socially desirable level, because private agents are unable to capture the full benefits of their investments.

To overcome these issues, governments can play an important role in a variety of ways:

- Provide reliable information, capable of driving efficient markets;
- Set performance standards that encourage both private and public investments in building long-lived capital and infrastructure to take account of climate change; and
- Implement long-term policies for climate-sensitive public goods (natural resources protection, coastal protection, and emergency preparedness).

Conclusion

The argument about whether or not to bother with abatement, or simply to concentrate on adaptation, seems wrongly framed because, in reality, governments will have to do both:

Difficulties in implementing adaptation efficiently ...

... can be reduced by governments

1. Because governments have no option but to adapt to what is already ‘in the pipeline’, and because climate change damages stand to be more costly without adaptation before the events occur, it will not be possible to rely only on abatement.
2. Because scientists suggest that, above 550ppmv, there is a risk of irreversible climate change impacts; because it is difficult to estimate the future costs of adaptation; and because it seems that adaptation costs rise more rapidly than temperatures, it seems unwise to rely wholly upon adaptation.

In principle, adaptation and abatement policies should be implemented such that the last, or marginal, euro (or dollar) spent produces the same reduction in damages. The optimal policy would go further, to the point where the last euro or dollar spent, whether on abatement or on adaptation, would save a euro’s (or dollar’s) worth of damage.

In practice, however, it will be difficult to determine the optimal proportions of adaptation and abatement, because of fundamental analytical differences such as differences in spatial and time scales, and focus. What seems most likely is a mix of all sorts of different projects undertaken, quite likely with markedly different implicit prices of carbon. ■

Examples of adaptation policies

There is growing evidence of human activity adapting to observed or anticipated climate change⁷⁶. In particular, many public adaptation plans have already been implemented, both in developed countries and in some less developed regions, where actions to enhance adaptive capacity in particular have been undertaken.

The Netherlands. The Dutch have been coping with their low-lying location for nearly 800 years. Current Dutch law requires that river defences deliver so-called 1-in-1,250 protection, i.e. protection that limits the odds of catastrophic system failure and consequent flooding to once in every 1,250 years. The Netherlands parliament now wants to increase the level of protection around the North Sea to 1-in-100,000 years. Furthermore, instead of trying to contain floods, the government has launched the program “Living with Water”, whereby the Dutch will accommodate the extra water flow by allowing pre-designated areas to flood⁷⁷.

The United Kingdom. In response to a greater expected risk of flooding, the UK Environment Agency has initiated the Thames Estuary 2100 Project to develop a tidal flood risk management plan for London and the Thames Estuary. The Thames Barrier, which became operational in 1983, 30 years after the massive flood that motivated its building, is, on average, closed 10 times per year to keep ocean-storm surges from inundating London. In response to the risk of rising sea levels and storm surges, the government has stated that it is prepared to add 12 inches of protection to the height of the existing floodgates and to extend the Barrier. Although such defences will offer a high level of protection from today’s risks, they will provide protection of only 1-in-1,000 years until 2030. After that, the risk is expected to increase, potentially reaching 1-in-50 by the end of the century unless there is further upgrading of the capital’s sea defences⁷⁸.

The United States. In New Orleans, following Hurricane Katrina, protection improvements – in particular the increase in the height of the levees – have been designed to meet the requirements of the National Flood Insurance Program, which specifies a protection level of 1-in-100 years⁷⁹. This is a much lower protection level than in, for example, the Netherlands.

Japan. In Tokyo, the G-Cans project is a massive underground system that can pump 200 tons of water per second out of rivers and into the harbour before the city’s streets flood. Work on the project, which consists of five concrete containment silos with a height of 65 metres and a diameter of 32 metres, connected by 6.4km of tunnels 50 metres beneath the surface, began in 1992.

France. Following the 2003 summer heat wave, which caused 15,000 deaths in France, the French government prepared a national heatwave plan, a series of actions that focus on particular vulnerabilities. The government has spent €300-400m on this plan, which has three levels: further vigilance during the summer; alerts and action in the case of heat wave risk; and requisition, i.e. the application of exceptional measures in case of sanitary, environmental, or economic consequences.

Bangladesh. The economy’s sensitivity to monsoon flooding has been significantly reduced as a result of structural change in agriculture including: a rapid expansion of much lower-risk dry-season-irrigated rice; better internal market integration; and increased private food imports.

Nepal. Pursuant to an OECD project on Development and Climate Change, Nepal has carried out many actions to adapt its hydropower sector. Recent climatic trends analysis has revealed a significant warming trend in past decades, with many significant impacts in the Himalayas, including glacier retreat and increases in the size and volume of glacial lakes. This is increasing the variability of water resources and hydropower: one example was the 1985 flood that destroyed the almost-complete Namche Small Hydro Project. Attention is therefore increasingly being paid to the risk of “glacial lake outburst floods” and some adaptation options are considered, such as: building hydropower facilities at low-risk locations; implementing early warning systems; and reducing the potential impact of floods⁸⁰.

Elsewhere. The United Nations Framework Convention for Climate Change (UNFCCC) has implemented National Adaptation Programmes of Action (NAPAs). These “... focus on urgent and immediate needs – those for which further delay could increase vulnerability or lead to increased costs at a later stage” and “... provide a process for Least Developed Countries (LDC) to identify priority activities that respond to their urgent and immediate needs with regard to adaptation to climate change”. Countries involved in these NAPAs include Bangladesh, Cambodia, Madagascar, Niger, and Senegal. ■

⁷⁶ Intergovernmental Panel on Climate Change (2007), vol.II.

⁷⁷ On the front line of climate change, *Time* (9 April 2007).

⁷⁸ *Stern*, N. (2006), ch.19.

⁷⁹ US Army Corps of Engineers (2007).

⁸⁰ Agrawala, S. et al. (2003).

CHAPTER 8: THE EQUITY DIMENSION

Summary

Many clients have dwelled on the thought that one of the biggest obstacles to securing a global agreement to limit greenhouse gas emissions may well prove to be the unwillingness of countries such as China and India to forswear the right to pursue the sort of fossil-fuel-burning development path followed by the developed countries as they became rich.

This argument is already being heard in the early skirmishing over the successor to Kyoto: limiting greenhouse gas emissions is going to come at a price, and negotiations are bound to be protracted over who should pay the ‘climate change bill’. Indeed, distributional implications could even be the ‘make or break’ in international negotiations to limit greenhouse gas emissions.

At the level of economic theory, two propositions are clear. First, in the interest of economic efficiency, all economic agents – regardless of country – should pay the same ‘social’ cost of carbon. Second, to the extent that equity considerations are important – as they are – these should be met through (lump-sum) transfer payments, not through policy-induced distortion to the ‘social’ cost of carbon.

In practice, however, the situation is likely to be more complicated. Our reading of the economic literature to date is that there are many, quite different, ways of formulating the equity issue; that they do not all yield anything like the same answer; and that none is demonstrably superior.

While the international negotiations will likely be long and difficult, we believe that it will ultimately be possible to reach an international agreement to limit greenhouse gas emissions. That said, the agreement will likely be far from ideal, and be characterised by considerable *ad hoc-ery*.

The case for an equity criterion in climate change policy

The issue of international equity arises because of differences between countries in at least four key respects:

1. The extent to which they stand to be affected by climate change (see box: *Regional impacts of climate change*);
2. The extent to which they have contributed to past greenhouse gas emissions;
3. The extent to which they will contribute to greenhouse gas emissions in future; and
4. Their ability to pay for adapting to climate change and abating future emissions.

Hence, in addition to the various criteria for policy design considered in other chapters, including:

- environmental effectiveness;
- institutional feasibility; and particularly
- cost effectiveness (considered in Part I – *The fundamental role of the price mechanism*),

international policies to limit greenhouse gas emissions are also going to have to take account, to some degree at least, of equity considerations across countries.

The equity issue has already been raised in international negotiations

Indeed, the equity issue is already being raised, both in public debate and in initial policy skirmishing over the potential shape of any post-Kyoto agreement. Developing countries argue that they are not only poorer and more vulnerable to various of the likely impacts of climate change, but also that they have not contributed to greenhouse gas emissions to anything like the same extent as the developed countries have. Even if emissions were to cease today, they argue, the earth’s temperature would still rise by around another 1°C. A simple rule of thumb is that the developed countries, with per capita incomes in excess of \$20,000, emit, on average, between 5 and 10 tons of CO₂ annually per capita while, at the other end of the spectrum, the bulk of the world’s poor countries, with annual incomes of below \$5,000 per capita, emit less than ½ a tonne of CO₂ per capita. And indeed, there is a high correlation between income and CO₂ emissions right along the income spectrum (Figure 10).

Equity arguments have already been recognised formally. For example, Article 3 of the 1992 UN Framework Convention on Climate Change (UNFCCC) stipulates that:

“The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capacities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effect thereof.”

That said, turning broad principle into operational proposal is complicated.

Recognising responsibilities for the past and the future

There are many elements to the argument about how the ‘climate change bill’ should be allocated between countries.

The ‘climate change bill’ should take into account both past and future emissions

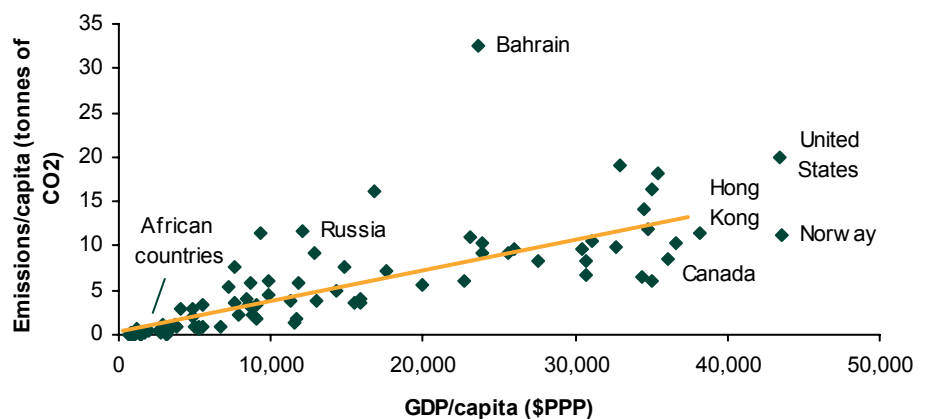
One element derives from the fact that *future* abatement costs are in part a function of *past* emissions. Many scientists judge it important – and some would say ‘vital’ – to prevent atmospheric *greenhouse gas* concentration from exceeding 550 ppmv in *CO₂ equivalent* (equivalent to limiting atmospheric *carbon* concentration to around 500 ppmv). Past evidence suggests that, above that figure, there would be a high chance of catastrophic and possibly irreversible changes to the ecosphere. Atmospheric greenhouse gas concentration has already reached around 380 ppmv as a result of the past emissions of the now-developed countries, which leads to the argument that the cost of preventing the critical 550 figure from being exceeded should be borne in substantial part by those countries.

A second element of the argument is that, not surprisingly, China, India and other developing countries argue that developed countries grew rich through a fossil-fuel-burning economic model of growth, and that it would be inequitable to seek to prevent them from following a similar path.

A third element is that a significant part of the industrial production of China and India is destined not for consumption at home, but for consumers in developed countries. We estimate that, in 2005, around 12.5% of China’s total industrial production was exported to the United States, the European Union and Japan. We also estimate that multinational companies accounted for more than 30% of total Chinese industrial production that year.

However, many developed countries (and particularly the United States) are unlikely to agree to be the only ones to pay for future abatement. They argue that future emissions, and thereby the future stock of atmospheric greenhouse gases, stand increasingly to be the result of today’s developing countries, especially China and India, and that these countries’ industrial production is growing fast not only for export but also to serve their domestic demand – see for example the box below on the projected growth of automobiles in China.

Figure 10. Per capita GDP and emissions in 2004



Source: Lehman Brothers.

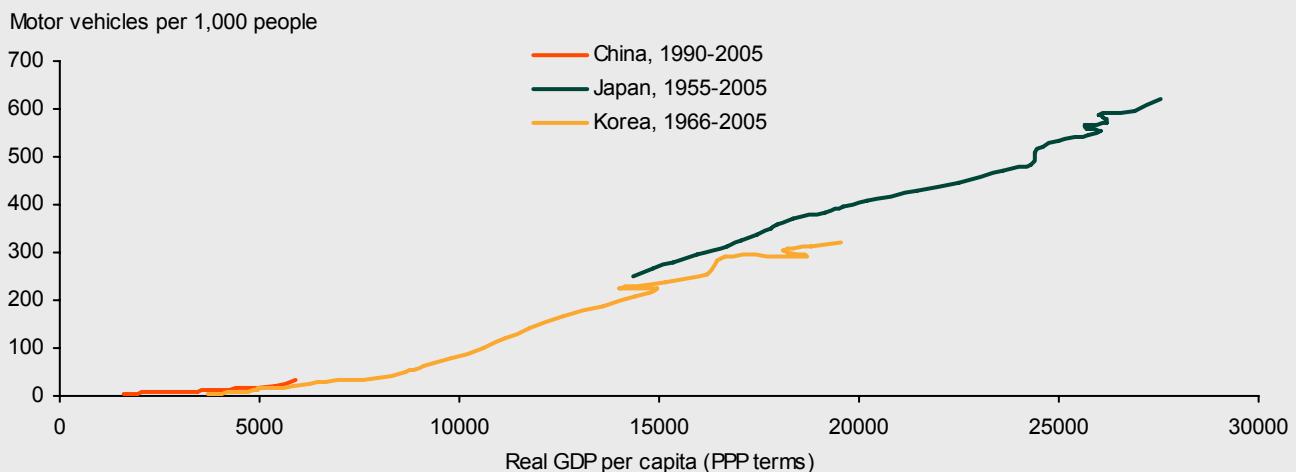
China's demand for motor vehicles

Mingchun Sun (minsun@lehman.com)

With per capita incomes rising rapidly, China's domestic demand is growing strongly. Demand looks set continue on its steep upward trajectory, thereby exerting significant upward pressure on global resources and the environment. In 2006, China's GDP per capita was only \$2000, leaving significant scope for development 'catch-up'. Indeed, China's demand for durable consumer goods is starting to take off. Certainly, plotting motor vehicles owned per 1,000 people against real GDP per capita, and comparing China's economic development with that of Japan and South Korea, suggests that China is near the point at which motor vehicle demand could surge (Figure 11). If China broadly follows the path of South Korea and Japan, its motor vehicle ownership could reach around 600 per 1,000 people by 2025, compared with only 42 in 2006. Given China's population of 1.3bn, this implies that it could have 780m motor vehicles in 2025 – almost equal to the total number of motor vehicles in the entire world today (about 900m).

To meet this growing demand, China's automobile production is already accelerating rapidly. For example, production of the Cherry motorcar has just passed the 1m mark. This figure was reached in just seven years. And while production of the first 500,000 cars took five and a half years, it took only one and a half years to produce the second 500,000⁸¹. ■

Figure 11. Vehicle ownership and real income per capita



Source: CEIC, World Bank and Lehman Brothers.

The International Energy Agency (IEA) now estimates that China may overtake the United States as the world's biggest emitter of greenhouse gases before the end of 2007; and the Netherlands Environmental Assessment Agency recently assessed China's emissions as already having done so⁸². Figures 12 and 13 show regional contributions to global emissions in 2004, and IEA projections for 2030⁸³.

Thus, there are two distinct but complementary aspects to sharing the 'climate change bill' equitably:

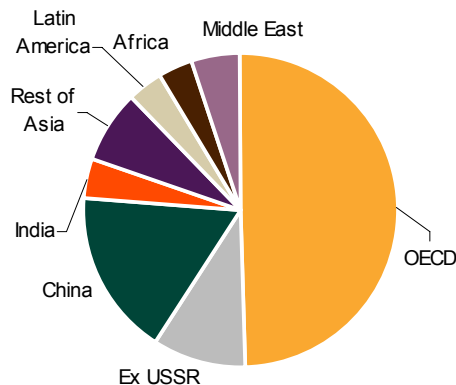
1. **Equitable allocation of the overall abatement cost between countries** – i.e. the equitable allocation of the cost of reducing carbon emissions from today's level to some future target level. This is considered in the section *The first element of the 'climate change bill': the abatement cost*; and
2. **Responsibilities for past emissions** – i.e. the portion of the 'climate change bill' that developed countries should pay for the damages they have caused – and will cause – through the build-up of the stock of atmospheric carbon thus far. This is considered in the section *The second element of the 'climate change bill': responsibility for the past*.

⁸¹ China Radio International, 22 August 2007.

⁸² See the Netherlands Environmental Assessment Agency Website, www.mnp.nl.

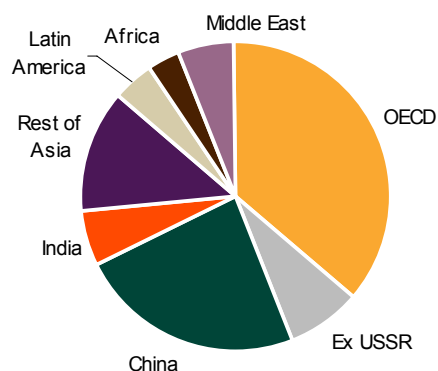
⁸³ See International Energy Agency (2006), pp. 189.

Figure 12. Global emissions by region, 2004



Source: Energy Information Administration (2006).

Figure 13. Global emissions by region, 2030 in the IEA Reference Scenario



Source: International Energy Agency (2006).

The first element of the ‘climate change bill’: the abatement cost

The concept of sharing the ‘climate change bill’ equitably usually refers to the allocation of abatement costs among countries. The natural calculation to undertake first, therefore, is of the overall annual abatement cost. The analytic tool generally used for this method is a general equilibrium model⁸⁴, which calculates the parameter values of policies that maximise the flow of consumption by balancing the marginal cost of policies and the marginal damage of emissions of CO₂ over a long time horizon. Such models are complex. However, by making a number of simple assumptions, it is possible to reproduce the broad results: an illustrative order of magnitude of the overall annual abatement cost can be established as follows.

Evaluation of annual abatement cost

To assess the annual abatement cost, assumptions must be made: emissions in the ‘business-as-usual scenario’, i.e. emissions if no policy is implemented; emissions in the ‘abatement scenario’, i.e. emissions if abatement policies are implemented; and the ‘social’ cost of carbon in the ‘abatement scenario’, i.e. the cost per tonne of carbon that prevails in the ‘abatement scenario’.

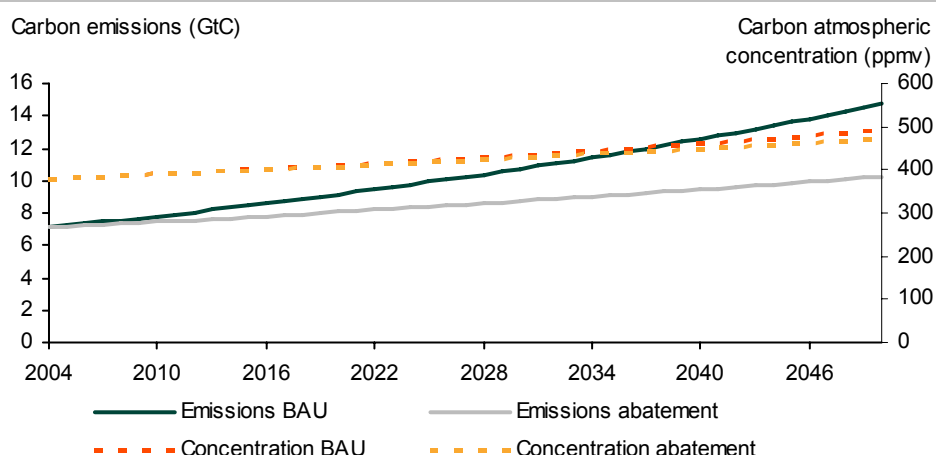
1. **Emissions in the ‘business-as-usual scenario’.** The world currently emits around 7 giga tonnes of carbon annually. On the basis of the IEA reference scenario growth of 1.6%⁸⁵ per year, emissions will reach 10.5 giga tonnes of carbon by 2030, and around 15 giga tonnes of carbon by 2050.
2. **Emissions in the ‘abatement scenario’.** Now assume that abatement results in a halving of the rate of emissions growth relative to the ‘business-as-usual’ scenario, i.e. to an annual growth rate of 0.8%. On this basis, carbon emissions would reach around 8.5 giga tonnes of carbon by 2030 (a reduction of 20% compared with ‘business-as-usual’ emissions) and 10 giga tonnes of carbon by 2050 (a reduction of 30%); and the atmospheric carbon concentration would rise to 470ppmv in 2050, compared with around 500 ppmv in the business-as-usual scenario (Figure 14).

Annual abatement cost can be estimated ...

⁸⁴ See for example Nordhaus, W. (2007).

⁸⁵ This is the projection made by the International Energy Agency in its Reference Scenario of its World Energy Outlook 2006 for the period 2004-2030, which we have extrapolated to 2050.

Figure 14. Business-as-usual scenario vs abatement scenario



Source: Lehman Brothers.

3. **‘Social’ cost of carbon in the ‘abatement scenario’.** General equilibrium models, by balancing the marginal cost and the marginal benefit of abatement policies, solve for the optimal price of carbon. As seen in the chapter *The measurement of the ‘social’ or ‘damage’ cost of carbon*, different models produce different values. However, the basic point can be illustrated as follows.

At the end of the Pre-Industrial Era, it can be assumed that the ‘social’ cost of carbon was approximately zero, i.e. the first tonne of industrial carbon emitted into the atmosphere did little damage, if any. However, successive tonnes of carbon progressively started to cause harm, so that the ‘social’ cost of carbon has risen over time, perhaps – studies suggest – to reach around \$100 per tonne by 2050⁸⁶. Intermediate values could be, say, around \$50 today, around \$65 in 2020 and around \$80 in 2030.

On the basis of these assumptions and the further assumption that⁸⁷:

$$\text{Abatement cost} \approx \text{social cost of carbon}_{\text{abat}} * (\text{emissions}_{\text{BAU}} - \text{emissions}_{\text{abat}})^{88}$$

total future abatement costs reach around \$75bn annually by 2020, \$150bn in 2030 and \$450bn in 2050, equivalent throughout to around 1% of global GDP – much the same value given by Stern for the total cost of abatement. The annual abatement costs for 2020, 2030 and 2050 are summarized in Figure 15.

Figure 15. Annual abatement cost

	2020	2030	2050
Emissions business as usual in GtC (1)	9.2	10.7	14.7
Emissions abatement scenario in GtC (2)	8.1	8.7	10.2
Total abated emissions in GtC (3=1-2)	1.1	2	4.5
Social cost of carbon in \$/tC (4)	66.5	77	100
Total abatement cost in \$bn (5=3*4)	75	150	450

Source: Lehman Brothers.

Allocating the bill equitably across countries

Having estimated an illustrative order of magnitude for this first – i.e. future – component of the ‘climate change bill’, the next issue is how to share the bill equitably among countries.

⁸⁶ See the chapter *The measurement of the ‘social’ or ‘damage’ cost of carbon*.

⁸⁷ In the equation, BAU stands for “business as usual scenario”, and abat for “abatement scenario”.

⁸⁸ This is equivalent to assuming that the marginal abatement cost equals the average abatement cost.

... and shared between countries

One simple way to allocate the abatement cost between countries would be to invoke the ‘polluter-pays’ principle, i.e. to allocate the cost in proportion to each country’s contribution to total emissions. On the basis of the emission projections of the International Energy Agency (IEA) in its Reference Scenario, the derived allocations between countries for 2030 on this basis would be as summarized in Figure 16.

In 2030 the OECD countries, together with Russia, would spend around \$70bn on abatement. China’s contribution to the ‘climate change bill’ would be the largest – around \$35bn – in line with rapidly-growing China’s correspondingly growing proportion of global emissions.

Figure 16. Allocation of abatement cost in 2030

Country or region	Contribution to global emissions in 2030	Abatement allocations in 2030 (\$bn)
United States	16.6%	25
European Union	10.1%	16
Japan	2.6%	4
Rest OECD	7.2%	11
Ex USSR	7.4%	11
China	23.7%	36
India	5.7%	9
Rest of Asia	13.1%	20
Latin America	4.0%	6
Africa	3.8%	6
Middle East	5.8%	9
Total	100%	\$150bn

Source: Lehman Brothers.

However, the ‘polluter-pays’ principle is only one of a range of equity principles that could be used to apportion the ‘climate change bill’.

Various other principles of apportioning the ‘climate change bill’

An equitable sharing can be achieved through various equity criteria ...

Many ways have been suggested for determining equitable burden sharing. Cazorla and Toman (2000)⁸⁹ suggest, on the basis of a literature review, no fewer than 12 notions of equity (Figure 17). These can, however, be classified into four main approaches:

1. **Emissions-based approach:** the ‘climate change bill’ is allocated according to criteria related to countries’ emission levels, either past or future. Examples include:
 - the *egalitarian* principle (in proportion to per capita emissions), which has recently found favour with German Chancellor Merkel; and
 - the *polluter-pays* principle (in proportion to past emissions).
2. **Income-based approach:** the ‘climate change bill’ is allocated according to criteria related to countries’ income or wealth characteristics – the richer the country, the greater its share⁹⁰. Examples include:
 - the *ability to pay* principle, which allocates costs across nations in proportion to per capita GDP; and
 - the *maxi-min* rule, which allocates a disproportionate amount of the total cost to the wealthier nations.

⁸⁹ Cazorla, M. and Toman, M. (2000).

⁹⁰ See for example the Oxfam study (2007), which suggests what developed countries should spend on adaptation in poor countries. Oxfam estimates that adaptation in developing countries will cost at least \$50bn per year. Based on countries’ ability to pay – as well as on past emissions – Oxfam suggests that the United States, the European Union, Japan, Canada, and Australia should contribute over 95% of this amount.

3. **Net-cost approach:** the ‘climate change bill’ is allocated according to criteria that meet some abatement net cost constraints. The *compensation* principle, for example, shares costs such that ‘winners’ contribute to compensating ‘losers’.
4. **International-policy approach:** the ‘climate change bill’ is shared among countries so as to satisfy political criteria. One example is the *consensus* principle, which distributes costs so as to satisfy the greatest number of countries. This could entail payments via income transfers or investment to avoid losses by any nation.

Figure 17. Equity criteria for sharing the burden

Equity principle	Interpretation	Implied burden-sharing rule
Emission-based approach		
<i>Egalitarian</i>	People have equal rights to use atmospheric resources	Share costs in proportion to population, or equal per capita emission
<i>Sovereignty</i>	Current rate of emissions constitutes a status quo right now	Share costs proportionally across all countries to maintain relative emission levels between them
<i>Polluter pays</i>	Allocate abatement burden corresponding to emissions (may include historical emissions)	Share costs across countries in proportion to emission levels
Income-based approach		
<i>Ability to pay</i>	Equalize abatement costs across nations relative to economic circumstances	Net cost allocations are inversely correlated with per capita GDP
<i>Maxi-min</i>	Maximize the net benefit to the poorest nations	Distribute the majority of costs to wealthier nations
<i>Horizontal</i>	Similar economic circumstances have similar emission rights and burden-sharing responsibilities	Equalize net welfare change across countries so that net allocated cost as a proportion of GDP is the same for each country
<i>Vertical</i>	The greater the ability to pay, the greater the economic burden	Net cost allocated grows relative to GDP
Net-cost approach		
<i>Compensation (Pareto-rule)</i>	“Winners” should compensate “losers” so that both are better off	Share costs so that no nation suffers a net loss of welfare
<i>Market justice</i>	Make greater use of markets	Share costs so as to achieve lowest net world cost for emissions abatement
International-policy approach		
<i>Consensus</i>	Seek a political solution that promotes stability	Distribute costs so the majority of nations (power weighted) are satisfied
<i>Sovereign bargaining</i>	Principles of fairness emerge endogenously as a result of multistage negotiations	Distribute costs according to equity principles that result from international bargaining and negotiation over time
<i>Kantian allocation rule</i>	Each country chooses an abatement level at least as large as the uniform abatement level it would like all countries to undertake	Differentiate by country’s preferred world abatement, possibly in tiers or groups

Source: Cazorla, M. and Toman, M. (2000), Lehman Brothers.

Estimates of distribution consequences of various principles

... that produce various distributional consequences

An equivalent way of thinking about sharing the abatement cost between countries is in terms of a carbon market, and the allocation of permits to emit. Assuming a regime whereby permits are given free – i.e. *gratis* – the larger the proportion of abatement cost that a country had to bear, the smaller would be the number of emission permits that it would receive; and *vice versa*.

In this context, Rose et al. (1998)⁹¹ have attempted to assess the potential cost implications of a number of these equity principles. Using a non-linear programming model, and given assumptions about individual country emission projections, global abatement requirements and equilibrium permit prices (\$50 in 2020), they simulate different burden-sharing criteria that extend to all nations, grouped into nine major regions. Their results are presented in Figure 18. Rose et al. consider five burden-sharing criteria, thus:

⁹¹ For more details on the method and results, see Rose, A. and al. (1998).

1. **Sovereignty criterion:** permits distributed in proportion to emissions.
2. **Egalitarian criterion:** permits distributed in proportion to population.
3. **Horizontal criterion:** permits distributed to equalize the change in net welfare.
4. **Vertical criterion:** permits distributed inversely with respect to per capita GDP.
5. **Consensus criterion:** permits distributed to satisfy the (power-weighted) majority of nations.

Assuming a global market for permits, the cost of which is borne by the purchaser, and the revenues of which are received by the seller, the total value of this global market is then shared among the nine regions (Figure 18).

Figure 18. Implied annual cost^(a) of different allocation rules in 2020 (present value, US \$bn, 2007^(b))

Country or area	Sovereignty	Egalitarian	Horizontal	Vertical	Consensus
United States	70.3	565.3	83.2	152.6	193.1
Canada and Western Europe	47.7	249.1	60.8	30.6	28.4
Other OECD countries	12.8	104.1	34.4	81.2	-41.0
Eastern Europe and former Soviet Union	59.3	538.3	38.6	12.0	433.7
China	37.1	-174.0	13.2	0.2	68.9
Middle East	10.0	1.8	13.4	5.1	-17.5
Africa	12.9	-360.8.3	8.3	0.2	-158.8
Latin America	11.8	-90.2	12.9	0.8	-34.1
South East Asia	20.7	-550.9	17.4	0.2	-190.2
Total^(c)	282.7	282.7	282.7	282.7	282.7
Total OECD countries^(c)	130.8	918.4	178.4	264.4	180.5

Source: Rose, A. et al. (1998).

(a) i.e. value of permits issued.

(b) The values given in Rose et al. are in billions of 1990 US dollars. We have converted them into billions of 2007 dollars by multiplying their values by the ratio of OECD GDP deflators for 1990 and an estimated value for 2007.

(c) Column entries may not match exactly because of rounding.

Under the egalitarian principle, for example, considerable transfers would take place from the United States and the former Soviet Union to China, Africa, and South East Asia. The vertical principle, by contrast, implies large burdens for OECD countries and small burdens for developing ones, with insignificant wealth transfers between regions. The sovereignty and horizontal equity principles suggest broadly similar outcomes.

However, the story does not stop here: if developing countries are to agree to shoulder part of the financial responsibility for their future emissions, they will almost certainly demand that developed countries pay compensation for past emissions, for which they were largely responsible.

The second element of the 'climate change bill': responsibility for the past

The United States, the European Union, Japan, and Russia are estimated to have accounted jointly for nearly 70% of the build-up of fossil-fuel CO₂ between 1850 and 2004. Developed countries are also, directly or indirectly, responsible for much of the destruction of the world's carbon sinks, most notably its forests. By contrast, India and China are estimated as having contributed less than 10% of the total⁹².

Developing countries are already making the point that the 'social' cost of carbon – and therefore the total abatement cost – is as high as it is because of past emissions. Hence, they argue, the developed countries should be paying for the amount by which the 'social' cost of carbon is higher than it would have been but for their actions.

The issue of the damage arising from this historical, *stock* problem can, in principle, be thought of in a framework analogous to that which the US has used domestically to deal with past damage from other forms of pollution. In 1980, the United States enacted the

⁹² *Financial Times*, 16 August 2006.

Developing countries argue that developed countries should also pay for past emissions ...

Comprehensive Environmental Response, Compensation and Liability Act, commonly known as the ‘Superfund’. The Act provides for the levying of a tax on the chemical and petroleum industries, and the establishment of liability for people responsible for the release of hazardous waste at closed and abandoned hazardous waste sites. It also provides for the establishment of a trust fund to pay for ‘clean-up’ when no responsible party can be identified.

In the case of climate change, those nations responsible for the bulk of the release of CO₂ into the atmosphere in the past could agree to pay for these responsibilities by paying into a global warming ‘superfund’. That fund could in turn be used to reduce the amount that would otherwise be paid by the emerging countries in respect of their future emissions – or, of course, to pay for example for research and development, or adaptation.

Reaching an equitable international agreement

... while the developed countries argue that de facto they already are

The calculations above illustrate conceivable orders of magnitude of the payments that could rationally be required of greenhouse-gas-emitting countries. However, the uncertainties inherent in measuring climate change impacts and their economic and social implications are considerable, and it will be difficult for policymakers to construct the comprehensive and reliable estimates needed for a truly and demonstrably rational schema for allocating costs. This will complicate the already difficult – and politically charged – task of developing a set of rational equity principles, both as regards the past and the future, acceptable to all the major players.

Ultimately, political agreement will have to be reached on the basis of a balance of competing arguments. Most recently, the developed countries have started to put some arguments that relate to responsibility for the stock of atmospheric greenhouse gases. For example, the United States in particular argues, with some justification, that it is the developed countries that are bearing most of the burden of developing new, carbon-reducing, technologies. Moreover, the OECD has already shown that countries’ abatement commitments under Kyoto correlate positively, and quite closely, with GDP per capita⁹³.

The developed countries also argue that, under the Clean Development Mechanism (CDM) of the Kyoto Protocol, they are transferring considerable resources to developing countries (see box *The clean development mechanism*).

A limitation of the CDM, however, particularly in respect of Africa, is that this region does not have a power generation infrastructure to replace with more efficient production capabilities, and hence it is difficult to generate CDM credits there.

Conclusion

In all probability, distributional considerations will remain intrinsically subjective; and the outcome will be the result of a protracted and difficult bargaining process.

The issue was recently summarised neatly by Jose Miguez, Climate Change Coordinator for Brazil’s Ministry of Science and Technology:

“Future emissions will require more responsibility from developing world countries, but the developed world’s demands on countries such as ours is like when someone turns up for a coffee at the end of the meal, and then is expected to share the whole bill.”⁹⁴ ■

⁹³ OECD (1999).

⁹⁴ Interview with Jose Miguez by Point Carbon, Brazil Steadfast in Opposition to Avoided Deforestation in CDM, 27 June 2007, www.pointcarbon.com/article.php?articleID=23173.

The clean development mechanism

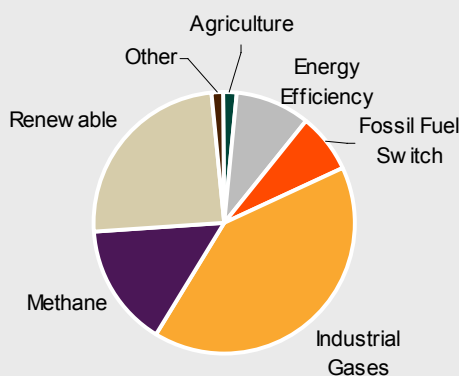
The Clean Development Mechanism (CDM) is an arrangement under the Kyoto Protocol whereby Annex 1 countries may invest in emission reductions in developing countries and use these to meet their own emissions reduction commitments. CDM projects thereby help these countries to meet their targets more cheaply, while incorporating developing countries into the Kyoto process without the need for binding emissions reduction targets. Furthermore, the CDM transfers technology to developing nations and supports sustainable development goals. In this way, it represents the main response so far to the issue of equity in climate change policy-making. CDM projects come in a variety of forms, including: replacing fossil fuels with renewable energy sources; increasing energy efficiency; reducing industrial gas emissions; and encouraging forestation and reforestation. Each project is issued with credits (Certified Emission Reductions, CERs) by the United Nations, according to the reductions generated. There are currently 763 registered CDM projects, with 2,200m credits expected from current projects to 2012⁹⁵.

The largest buyers of these credits are members of the European Union Emission Trading Scheme, which are able to use CERs to meet up to 50% of their targets. Other Annex I countries participate in the CDM, most notably Japan, which has a budget for 100m credits so far⁹⁶. Buyers of CERs can either invest directly in CDM projects, or buy credits once they have been issued. There is also increasing interest in the CDM from the voluntary offset market. The regulatory process around the CDM ensures that CERs are permanent and ‘additional’, i.e. credits are not given to projects that would have been undertaken anyway. Hence, the CDM has more credibility than many projects in the voluntary market. Nevertheless, there is concern that a large proportion of projects so far have involved industrial gas reduction. These projects generate low sustainable development benefits for local communities. This has led to a premium on non-industrial gas CERs. The ‘quality’ of CERs is therefore a continuing concern for some buyers. More stringent requirements have been developed, such as the CDM Gold Standard, created by 44 non governmental organisations in response to this problem.

The largest developers of CDM projects are China, which hosts the greatest volume of projects, and India, which hosts the largest number. A large potential for emissions abatement, a quickness to see the potential in the CDM, and a supportive policy environment have combined to make them such popular project locations. Although the CDM has enjoyed considerable success in China, India and Latin America, its progress in Africa has been minimal. If the CDM is to become a vehicle for improving the equity of climate change policy, this limitation will need to be addressed.

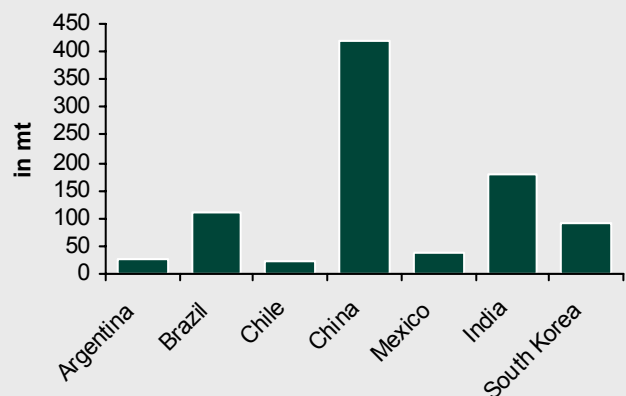
Although a Kyoto-style framework post-2012 has not been established, the market is confident that the CDM will continue, albeit with some reform: inclusion of avoided deforestation as a valid project type, and restrictions on gas-fired plant projects, are both likely. A major uncertainty facing the CDM is the potential for countries such as China and South Korea to take on binding emissions targets post-2012. Notwithstanding these issues, however, the market for CERs has grown consistently, with buyers becoming more confident and prices increasing. CERs will be a major tool of compliance for EU companies in Phase II, and several utilities are already major buyers in the CDM market. ■

Figure 19. CERs from pipeline projects by project type



Source: www.cdmpipeline.org.

Figure 20. CERs from registered projects by country



Source: www.cdmpipeline.org.

⁹⁵ See the CDM page on the UNFCCC website, www.unfccc.int.

⁹⁶ See Point Carbon website, www.pointcarbon.com.

Regional impacts of climate change

It is widely agreed that climate change impacts will vary among regions, particularly between higher and lower latitudes. Developing countries are likely to suffer more from climate-change-related impacts than are developed and industrialised regions; and will be the least able to adapt to new climatic conditions. Some impacts by region are listed below⁹⁷.

Africa. New studies confirm that Africa is one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptability. Between 75m and 250m people are expected to be exposed to an increase of water stress as a result of climate change. Agricultural production stands to be severely compromised by climate variability and change because yield potential, especially along the margins of semi-arid and arid areas, is expected to decrease. This would worsen food security and exacerbate malnutrition on the continent. Furthermore, by the end of the 21st century, projected sea-level rise may affect low-lying coastal areas with large populations.

Asia. Climate change is projected to hinder sustainable development of most countries in Asia because it compounds the pressures on natural resources and the environment that are associated with industrialisation, rapid urbanisation and economic development. In particular, glacier melt in the Himalayas is projected to increase flooding, potentially displacing millions of people, especially in the heavily populated mega-delta region. Mountain snow levels may be reduced, thereby cutting river flows and threatening water resources: it is estimated that the Himalayas provide more than half the drinking water for 40% of the world's population⁹⁸. Finally, mortality as a result of diarrhoeal disease associated with floods and droughts is expected to rise in East, South and Southeast Asia. Increases in coastal water temperature may exacerbate the abundance and/or toxicity of cholera in South Asia.

Australia and New Zealand. Water security problems are projected to intensify by 2030, and a drier climate may also endanger ecosystems in some ecologically-rich sites, including the Great Barrier Reef and Queensland Wet Tropics. Furthermore, ongoing population growth in low coastal zones is projected to exacerbate risks from sea-level rise and coastal flooding. Agriculture production is projected to decline in southern and eastern Australia because of increased drier conditions. However, some parts of New Zealand are expected to benefit.

Europe. Retreating glaciers, longer growing seasons, shift of species ranges and the health impacts of unprecedented heat waves have already been observed. Future potential impacts include: increased risk of floods; more frequent coastal flooding and increased erosion; reduced snow and winter tourism; and extensive species loss. Climate change is also expected to widen regional differences. Southern Europe, for example, stands to be increasingly vulnerable to climate change because of reduced water availability, reduced hydropower potential, and reduced crop productivity. In Northern Europe, climate change is expected to bring some benefits, at least initially, such as reduced demand for heating, increased crop yields and increased forest growth.

Latin America. By 2050, increases in temperature and associated decreases in soil water may lead to gradual replacement of tropical forest by savannah in eastern Amazonia; and there is a risk of significant species extinction in tropical Latin America. Because of drier conditions, productivity of some important crops is projected to fall, with adverse consequences for food security. Furthermore, sea-level rise is projected to cause increased risk of flooding in low-lying areas.

North America. In western mountains, warming is projected to cause decreased snow pack (particularly in Oregon), more winter flooding, and reduced summer flows. However, moderate climate change in the next decades is projected to increase aggregate yields of rain-fed agriculture by 5-20%, but with important variability among regions. Furthermore, cities that currently experience heat waves are expected to be further challenged by an increasing number, intensity, and duration of them, with potential adverse impacts on health.

Polar regions. In the Arctic, climate change impacts may include: higher temperatures; reductions in the extent of sea ice; increased coastal erosion; and an increase in the depth of permafrost seasonal thawing. These changes will likely have further negative impacts (on infrastructures), but also positive impacts (such as reduced heating costs and more navigable northern sea routes). It is also likely that the Antarctic will be warmer and, as in the Arctic, that precipitation will increase.

Small islands. They are especially vulnerable to the effects of climate change, sea level rise, and extreme events. Sea-level rise, in particular, is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thereby threatening infrastructure, settlements, and facilities. ■

⁹⁷ Intergovernmental Panel on Climate Change (2007), vol.II, Summary for Policymakers.
⁹⁸ Gore, A. (2006).

CHAPTER 9: EMISSIONS TRADING: GRANDFATHERING VS AUCTIONING

Summary

One of the main debates concerns how emissions permits should be allocated. There are two principal methods: *gratis* – i.e. allocation of emission permits without charge, often on the basis of historical emissions (*grandfathering*); and *auctioning* – i.e. sale of emission permits.

Much of the experience to date derives from the European Union Emissions Trading Scheme (EU ETS), where, so far, almost all allowances have been grandfathered. Under phase I of the EU ETS (2005-2008), only 5% of the initial allowance was auctionable. Moreover, in phase I, only four of 25 member countries have auctioned any permits at all, and only in Denmark has auctioning been used up to the 5% limit. For phase II of the EU ETS (2008-2012), this figure has been increased, but only to 10%. This low degree of auctioning contrasts with other cap-and-trade systems, such as the Regional Greenhouse Gas Initiative (RGGI) between North Eastern states in the US, where a minimum of 25% of emission permits have to be auctioned. Moreover, many states are contemplating full, 100%, auctioning.

Many, perhaps most, economists favour a full-auctioned scheme, as it has many advantages over the grandfathering approach, both in terms of transfer of wealth effects within the economy and in terms of the dynamic efficiency of the trading scheme. Not surprisingly, however, many businesses prefer permits to be allocated *gratis*.

As a matter of practical policy-making, the most efficacious way to proceed is first to agree on what an ideal policy would look like; and then to implement such a policy only fairly loosely in the first instance, before finally proceeding to make the policy really ‘bite’.

Auctioning and grandfathering both raise the price of carbon

A common misunderstanding

It is commonly thought that only auctioning raises the price of carbon, and that therefore only auctioning results in higher prices to downstream companies and consumers. However, that is in general not so: the way in which allowances are allocated is not the principal reason why consumer prices increase after the implementation of a trading scheme to limit carbon emissions.

As shown in the chapter *Why climate change is a (cost-benefit) economic issue*, any regime that restricts carbon emissions raises the price of carbon and thereby increases firms’ *marginal* cost of production – i.e. the change in total cost that arises when the output produced changes by one unit. This is the case regardless of whether the government auctions the permits, or hands them out free. Either way, *marginal* costs rise by the amount of the increase in the price of carbon.

To the extent that firms practice marginal cost pricing, their output prices rise whenever the price of an input – in this case carbon – rises; and this happens regardless of the allocation method.

What *does* differ according to the allocation method is who gets the revenue from this price rise. Basically, when permits are given away free, for example under the grandfathering method, the additional revenue goes to the firm; by contrast, when permits are auctioned, the revenue goes to the government – and is thereby potentially available to be redistributed to, say, consumers or to investors in new technologies. This is why the choice between auctioning and grandfathering raises questions of revenue distribution, as discussed in more detail below.

Rationales for auctioning allowances

Equity and distributional impacts

Auctioning brings several advantages over grandfathering, such as ...

When allowances are freely allocated, some participating sectors enjoy an increase in profit. Fundamentally, this comes from the difference between the *marginal cost* and the *average cost* of production. The marginal cost of production is the cost of one extra unit of product; whereas the average cost of production is the sum of average variable costs plus average fixed costs, divided by the number of units of output produced. When

permits are auctioned, the average cost of production increases, because firms have to pay to purchase each and every permit. However, when permits are grandfathered, the firms' average costs remain largely unchanged; yet they may pass the marginal cost increase through to the prices paid by downstream companies and consumers. Thus, they benefit from the price increase without necessarily suffering any significant increase in their (average) cost base⁹⁹.

Thus it has been that the electricity generation sector in Europe, for example, has benefited from free allowances¹⁰⁰. The companies have raised their prices by (approximately) sufficient to match the now-higher marginal cost of producing electricity, without having had to pay for any emissions permits. There has therefore been a transfer of income from consumers (downstream companies and individuals) to the electricity generators. Not all firms are in this situation, however.

In the case of downstream industries, however, such as aluminium smelting, cement, and some chemicals, which did not receive any allocation of free allowances yet are big users of electricity, this has raised their operating costs considerably. This is obliging them either to raise their prices markedly or to move their operations to regions where electricity is cheaper.

*... avoiding distortive
distributional impacts, ...*

Auctioning has the potential to avoid such distributional impacts. Under a grandfathering system, the scarcity 'rents' created by the regulation of carbon go to those who receive the permits: by contrast, under an auctioning system the 'rents' are collected as revenue by governments. Auctioning thus suppresses the advantage that participating sectors gain vis-à-vis non-participating sectors with grandfathering, and therefore offers an equity advantage vis-à-vis grandfathering.

Distributional impacts of carbon trading schemes are also felt at the consumer level. The carbon price may interact with other taxes: for example, imposing a carbon price via a trading scheme raises the price of energy, and thereby reduces the real wage. Therefore, any policy that raises the carbon price without raising revenue suffers these tax interactions without the benefit of raising revenue. Auctioning in such a circumstance would thus be favoured because the revenue raised by governments could be used to compensate these distortive tax interactions, and would have potential for a 'revenue-recycling' effect. For example, the government could use the proceeds of permit auctions to cut labour, payroll, capital, or consumption taxes¹⁰¹.

Dynamic and cost efficiency

*... fostering dynamic and
cost efficiency ...*

Another reason why economists favour auctioning is its superiority over grandfathering in terms of dynamic efficiency. Grandfathering can lead to perverse dynamic incentives. If future allowances are allocated as a function of present emission levels, firms have an incentive to emit more now so as to gain more allowances in the future. A further perverse dynamic incentive arises if free allocations to existing installations are generous, while allocations to new installations are more restrictive. In that case, there is a disincentive to undertake innovation, because incentives are created for long-lasting plants but not for the building of modern plants.

Auctioning is also likely to bring cost-effectiveness advantages. A research paper by the Resources for the Future (RFF)¹⁰² compares the cost-effectiveness and distributional effects under an emission-trading program in the electricity sector under three approaches: auctioning; grandfathering; and a third approach called "generation performance standard" (GPS), whereby allowances are allocated on the basis of shares of current electricity generation. The main finding of the paper is that an auction is far more cost-effective than the other approaches – around 50% cheaper than grandfathering or the generation performance standard approach.

⁹⁹ For more on price and competitiveness effects, see the chapter on Carbon trading and competitiveness.

¹⁰⁰ Hepburn, C. et al. (2006a).

¹⁰¹ For an elaboration of this argument, see for example Cramton, P. and Kerr, S. (1998).

¹⁰² Burtraw, D. (2001).

... facilitating price stability
...

Price stability

Auctioning could play an important role in facilitating price stability because it offers a basis for a clear and long-term carbon-price signal. In particular, it could help to create a long-term price floor by, for example, setting a reserve price, with a government commitment to repurchase allowances at the price floor.

Another way to achieve price stability has been proposed by Helm and Hepburn (2005)¹⁰³: the revenue from auctions could be recycled to industry in a technologically neutral way that provides long-term carbon price certainty. To achieve this, national governments would sign “carbon contracts” whereby government would pay the private sector a fixed price (to be determined by another auction) for the supply of emission reductions over a long time horizon.

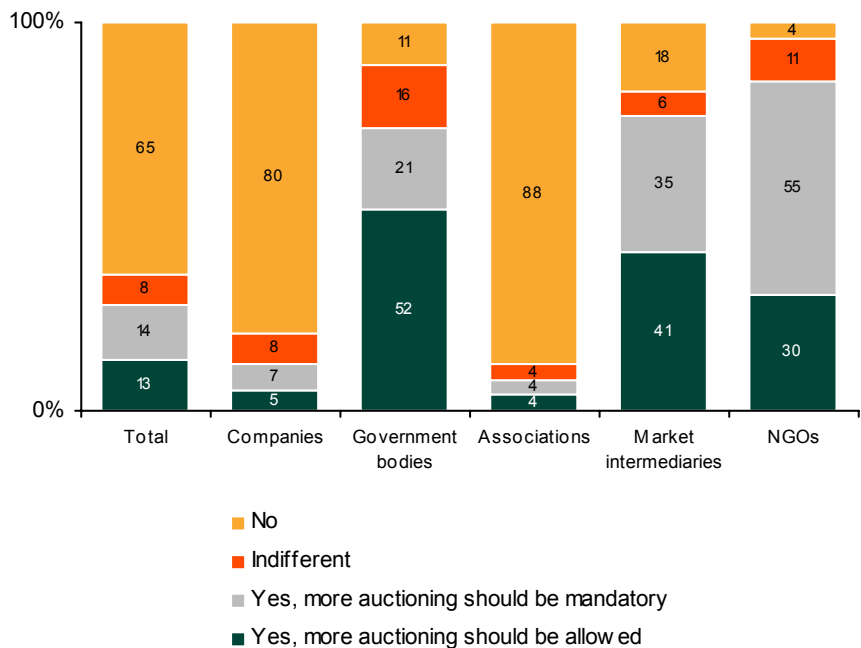
... and enhancing
management attention

Management attention

Apart from the fact that auctioning favours efficient revenue-raising, dynamic efficiency, and equitable distributional effects, other practical arguments in favour of auctioning permits are given by Hepburn et al. (2006)¹⁰⁴. In principle, as discussed above, the pass-through of cost increases to consumers does not depend on the method of allocating allowances. However, in practice, management attention may shift to include allowance costs when optimizing production decisions. This could help enhance responsiveness to price signals and thereby increase market efficiency.

Notwithstanding the many arguments in favour of auctioning, however, arguments against it are still prominent, particularly in the business world. Perhaps the main argument is that auctioning puts sectors participating in the emissions trading scheme at a competitive disadvantage compared with non-participating sectors and, in the absence of a global agreement, with those abroad. This is presumably why, when companies were asked if the EU Directive should allow for more auctioning beyond 2012, 80% answered “No” (Figure 21). These issues are reviewed in more detail in the chapter *Carbon trading and competitiveness*.

Figure 21. More auctioning beyond 2012?



Source: McKinsey & Company (2005).

¹⁰³ Helm, D. and Hepburn, C. (2005).

¹⁰⁴ Hepburn, C. et al. (2006a).

But the revenue raised by auctioning needs to be well-managed

Managing the rents from auctions

As shown above, auctioning has a number of theoretical advantages over grandfathering, including the capacity to raise revenue. These revenues could be spent in various ways by the governments that receive them:

1. Redistribute the revenues to disadvantaged sectors (e.g. energy-intensive sectors).
2. Redistribute the revenues to the consumers, for example, via cuts in taxes.
3. Invest in low-carbon technologies.

Such redistribution could increase consumer welfare, and the welfare of the society as a whole. However, achieving this would depend on the good management of the rents by governments. For example, if government did not redistribute the revenues of the rents to consumers, then auctioning would be as inequitable as grandfathering for the consumer, who would suffer higher electricity and energy prices in both cases.

It is thus important to ensure that the destination of revenues from the auctions is well specified, so that the desired equity and distributional results are achieved. The role of a carbon policy is to raise the (relative) price of carbon – whether through a tax or a carbon trading scheme – not to raise more revenues for the government.

A further risk with auctions is that, if badly managed, there can be problems of collusion, to the extent that they are not regulated by the competition authorities in the way that other firm interactions currently are.

How much auctioning should be implemented?

Given that auctioning has many theoretical benefits, but meets business opposition in practice, the natural follow-on question is: how much grandfathering might be needed to make a firm indifferent to the introduction of a permit scheme?

Hepburn et al. (2006)¹⁰⁵ have addressed this question. Taking the specific cases of four industries (electricity generation, cement, printing, and steel), Hepburn et al. show that, to be profit-neutral, the electricity sector might require zero or even negative grandfathering; the cement industry might need between 30 and 65% grandfathering; and newsprint and steel might require around 15-35%.

However, the principal story might well not be at the sector level, but at the firm level. Given that firms differ by size, their demand function, and other characteristics, the impact of the emission trading scheme is not necessarily the same on every firm in a given sector. In particular, larger firms may need more grandfathering. Sometimes, in some circumstances, full grandfathering might not be sufficient to protect the profit of an industry as a whole. And, under other circumstances, auctioning might be necessary for profit-neutrality.

This has many practical implications for present and future policy. Preliminary indications suggest that, in future (particularly after 2012) a slightly greater proportion of European emissions allowances stand to be auctioned, “in most cases probably more than 50%”¹⁰⁶. More generally, however, the inclusion of new sectors into the EU ETS seems certain to be preceded by intense lobbying by potentially affected industries; hence, the process will likely need to be accompanied by thorough economic analysis to determine the profit-neutral level of the mix of grandfathered vs auctioned allowances.

Arguably a greater proportion of European emission allowances should be auctioned

¹⁰⁵ Hepburn, C. et al. (2006b).

¹⁰⁶ Hepburn, C. et al. (2006b).

Conclusion

Although auctioning presents clear and demonstrable economic advantages over grandfathering – in terms of equity, distribution, dynamic efficiency, and price stability, among others – businesses usually argue that, in the particular case of the EU ETS, no more auctioning than already agreed should be implemented, mainly on the argument that auctioning permits would damage firms' price competitiveness, at least in the absence of a global agreement.

While it is a mistake to think that only auctioning increases the marginal cost of production – marginal cost rises regardless of the means whereby carbon emissions are limited – it is true that the way that allowances are allocated has an impact on who gets the revenue resulting from the price increase. The revenue is absorbed by firms when permits are grandfathered, whereas it is received by governments, and hence is available for redistribution, when permits are auctioned.

The example of the European Union Emissions Trading Scheme shows that economic principles are not always a good guide to which policy will be adopted. However, this may change and, in negotiations for the regime post-2012, full auctioning could be agreed, at least for sectors facing little or no international competition. It could be even more the case if, as we think likely, a federal and EU-ETS-compatible cap-and-trade scheme is implemented in the United States (and possibly in Canada), which could well auction a greater proportion of permits than the 10% prevailing under phase II of the EU ETS. ■

CHAPTER 10: CARBON TRADING AND COMPETITIVENESS

Summary

The introduction of the European Union Emissions Trading Scheme (EU ETS), which covers a little under half of the industrial carbon emissions in Europe, has triggered discussion and concern about the impact of such a carbon trading scheme on (European) industrial competitiveness. The concern is that, by acting unilaterally, European firms may be disadvantaged, and the economy thereby damaged relative to non-EU firms and economies.

As considered in the chapter *Emissions trading: grandfathering vs auctioning*, any scheme – be it cap and trade, a carbon tax, or whatever – that limits emissions thereby raises the (relative) price of carbon, a proportion of which is in turn passed on to intermediate and final prices. Depending upon whether the emissions permits are issued free or auctioned, firms may or may not experience a decrease in profit. Either way, however, firms stand to be disadvantaged relative to competitors abroad which do not face the increased marginal cost of carbon.

This loss of international competitiveness could be resolved by the region (Europe in this case) imposing a border tax on imported goods according to their carbon content; or by other economies raising the relative price of carbon, whether by joining the carbon trading scheme or otherwise. The risk with a border tax is of retaliation, and the potential for a trade war. More likely, we judge, is that some sort of global scheme to limit carbon emissions, and quite possibly a global cap-and-trade scheme, will be in place within the next five years.

A semantic issue

The word “competitiveness” is used differently in different quarters. At the global level, macroeconomists usually refer to relative export prices, or relative labour costs, or, indeed, to relative input costs of any sort. Others, however, particularly in a single-economy context, may use the term to mean the rate of profit, the level of profit, or even other phenomena, such as the industrial structure.

In what follows, we consider how an increase in the price of carbon stands to affect a firm’s selling prices, its profits, or both.

The price competitiveness impact

Any regime that restricts carbon emissions raises the (relative) price of carbon. A cap-and-trade scheme in particular implies an increase in the relative price of carbon, and thereby a rise in the marginal cost of production. To the extent that firms practice marginal cost pricing, prices to the consumer will rise by some proportion of this carbon-price-induced increase in marginal cost.

In practice, firms can usually pass on only a proportion of the increase in their marginal costs of production to their customers, this proportion being a function of three main factors:

- **The price elasticity of demand:** Sectors in which demand is not very sensitive to price will not suffer a significant loss in market share when prices are increased, and vice versa.
- **The nature of competition:** Market structure influences pricing dynamics. Furthermore, in some markets, regulation does not allow firms to pass through the entire marginal cost increase.
- **The geography of the sector market:** Firms facing competition from other firms outside the emissions trading scheme are hesitant to pass costs through to the consumers, lest they lose market share.

There are two principal ways in which firms may see an increase in their marginal cost:

- 1) Through a *direct* effect, flowing from the carbon limitation, and the consequential need to buy permits or invest in emission-reduction technologies.

Any regime that limits carbon emissions raises firms’ marginal costs

This increase in marginal cost is passed on, in some proportion, to prices

- 2) Through an *indirect* effect, flowing from a rise in the price of inputs that contain carbon.

In turn, the size of the increase in marginal cost depends on two main characteristics:

- 1) **The firm’s energy intensity:** The greater the proportion of energy in a firm’s costs, the more, proportionately, its marginal cost increases; and
- 2) **The firm’s ability to abate carbon:** Investments in low-carbon technologies enable companies to limit exposure to adverse competitiveness effects resulting from the emissions trading scheme. The greater the investment in low-carbon technologies that a firm is able to undertake, the less it will be exposed to carbon emissions limits.

Figure 22 classifies various sectors according to the two principle dimensions of competitive exposure in the European Union Emissions Trading Scheme: the “potential value at stake”, defined as the energy intensity, and the competitiveness exposure.

Figure 22. Classification of industrial sectors

Competitiveness exposure Energy intensity	LOW	MEDIUM	HIGH
HIGH	Electricity	Chemicals Cement Oil refining	Glass Aluminium
LOW		Pharmaceuticals Retail Transport	Paper Food and drink

Source: Carbon Trust (2004) and Lehman Brothers.

The electricity sector has a high ability to pass cost increases through to prices, because it faces little, if any, competition from outside the European Union. At the time the scheme was introduced, this pass-through was masked to some extent by the prevailing volatility of fossil fuel prices. At the other end of the spectrum, the aluminium sector consumes energy heavily, and faces global competition.

The role of emissions allocation in firms’ profitability

Now consider the effects of the allocation method on firms’ profits. Even if it appears surprising to say that some sectors will *profit* from the implementation of a carbon trading scheme, this can happen, when permits are given for free.

Although companies will face an added cost of carbon at the margin of their operations, this will not apply to the main part of their cost base because free allocation of emission permits is equivalent to a lump-sum revenue transfer from governments. Therefore, even if firms cannot raise their prices because of sharp international competition, this revenue transfer boosts their profits and helps them maintain market share.

Competitiveness impacts of the EU ETS on industrial sectors

A convenient way of summarizing the various competitiveness effects – cost exposure, international competition, and allocation method – is shown for the United Kingdom in Figure 23¹⁰⁷. The vertical axis shows the “potential value at stake” for major industrial sectors, defined as the potential impact of the EU ETS on **input costs** relative to sector value-added, before any abatement measures, or pass-through of costs to product prices. The horizontal axis shows **exposure to international competition**.

The lower end of the vertical bars shows the “net value at stake”, which is the impact when all allowances are given free. This gives an indication only of how marginal cost increases, following the increase in energy prices. The upper end of the vertical bars shows the “maximum value at stake”, which is the impact when all allowances are sold

The permit allocation method impacts on firms’ profits

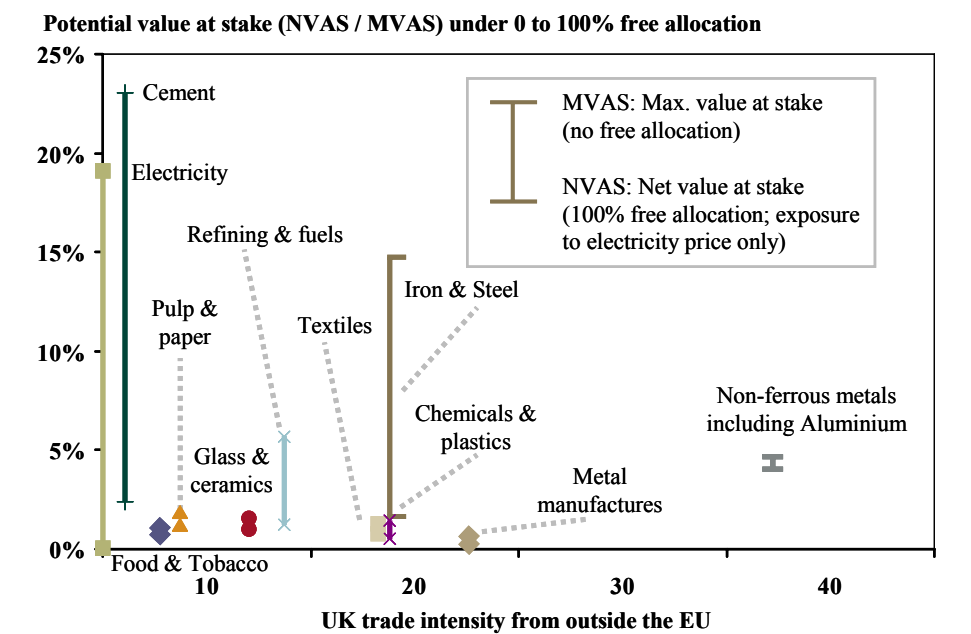
¹⁰⁷ Demailly, D. et al. (2007).

The ability to pass costs through to prices depends on the exposure to international competition

to companies (100% auctioning). This gives an indication of the impact of the EU ETS on the marginal cost increase resulting from the limitation of carbon emissions.

The height of bars shows the potential for the sector to profit from the difference between the *average* cost impact after allocation and the *marginal* cost impact. If all allowances are given free, then the *average* cost is equal to the lower end of the bar, and the marginal cost is equal to the upper end of the bar. To the extent that a sector – such as the energy sector – is able to pass through all of this marginal cost, it will tend to profit from the difference. This ability to pass marginal costs on to consumers in the form of price increase is constrained by the exposure to international competition.

Figure 23. EU ETS impacts on industrial sectors in the United Kingdom



Source: Demailly, D. et al. (2007).

This ability, in combination with free allocation of permits, boosts firms' profits

The chart underlines the unique position of the aluminium sector. Assuming that it buys electricity in Europe, its net value at stake is twice that of any other sector, and it faces sharp international competition. The case of the cement sector is also interesting: it faces almost no competition from outside the European Union. However, its maximum value at stake is very high. Therefore, if it passes all this additional marginal cost through to customers, the price differential could become so large that it could overcome the barriers – including importantly transport costs – that have traditionally kept foreign imports out.

Some competitiveness effects of the EU ETS have also been illustrated in a report by McKinsey for the European Commission¹⁰⁸. The method used to analyse the impact of the emission trading scheme on competitiveness is, basically, to add all the cost increases for input factors (electricity) to the cost of direct emissions (allowances); then to estimate the potential to pass through the cost increase onto consumers; and finally to calculate the value of free allowances, so as to obtain a net impact on profits.

Several sectors in Europe have benefited from large free allocations of permits

The McKinsey conclusions are similar to those found elsewhere: the power sector is likely to benefit in the short and medium term; the cement industry on average across Europe might come out neutral, or experience a net benefit; but the aluminium industry, by contrast, is under heavy pressure because, while it faces an increase in energy prices, it does not receive any free allowances to compensate.

¹⁰⁸ Mc Kinsey and Company (2006).

Conclusion

The disastrous impacts of a carbon trading scheme on firms' competitiveness, as they are often described, are likely to be more fairy tale than reality. While the impacts of cap-and-trade scheme might seem likely to be the most significant for energy-intensive sectors and for those facing international competition, as far as the EU ETS is concerned, several of these sectors have been able to profit from the trading scheme through their large free allocation of permits.

The sectors most severely hit are actually those outside the EU ETS, such as the aluminium sector, which face the increase in energy prices without benefiting from the revenue transfer resulting from free allocation of permits. Other sectors, such as cement, may face an erosion of their market share, even though they have not known significant international competition so far.

While these studies are instructive, and point to potentially large effects for some of the industries surveyed, they should not lead to a broader conclusion being overlooked. Any scheme that limits the level of carbon emissions raises the relative price of carbon. As this feeds through into prices it changes the relative prices of virtually *all* goods and services in the economy. So while the main effects on some of the industries most affected can be broadly estimated along the lines outlined in this chapter, there will also be effects on the prices of millions of other products produced in the modern economy, and these are too numerous to be modelled fully.

This is likely to have a number of market implications. As discussed in the chapter *Motivation: Why climate change matters to business*, the adjustment to a higher (relative) price of carbon is a process which, in our judgement, will take many years to work through, and hence take many years to reflect fully in firms' cash flows, profitability, and stock market valuations.

Amongst the many implications that this may have, one is that, to the extent that it proves possible to anticipate this effect in portfolio allocations, it stands potentially to offer a modest, but quite possibly comparatively steady, addition ("alpha") to fund returns. ■

CHAPTER 11: INDUSTRY IMPLICATIONS OF CLIMATE CHANGE POLICIES

Introduction

The aim of this chapter is to review impacts of climate change policies on various sectors. Neither the range of impacts nor the list of sectors is exhaustive, as some sectors are comparatively little affected by climate change policies.

The chapter is based on conversations with, and subsequent comments from, the following Lehman Brothers equity analysts: Chris Will, Daniel Billinton and Manas Satpathy (Autos), David Fintzen (Aviation), Ankur Agarwal (Building Materials), Lisa Randall (Capital Goods) and Andrew Kaplowitz (Engineering and Construction), Jenny Barker and Mikiya Yamada (Chemicals), Ian Shackleton (Consumer), Allegra Perry (Luxury), Fraser Ramzan, Matthew Truman and Meredith Adler (Retail), Lucy Haskins, Paul Cheng and Mansi Singhal (Integrated Oil), Christopher LaFemina (Mining and Metals), Chet Riley (Real Estate), Rupesh Madlani (Renewables), Stuart Jeffrey (Technology), Graeme Pearson (Telecoms), and Martin Young, Daniel Ford, Evan Li, and Ivan Lee (Utilities). However, the views expressed below are only ours.

AUTOS

Climate change policy exposure

The auto sector is particularly affected by climate change policy, especially – so far – in Europe, where the European Commission plans to introduce legislation to reduce the CO₂ emissions of new cars. Automobiles in Europe account for only 1.5% of global emissions – whereas US automobile emissions account for around 4.5% – and are the lowest-emitting in the world. Indeed, the industry has reduced European fleet average emissions from 186g CO₂/km in 1995 to 160g CO₂/km in 2006 (Figure 24). The sector must also comply with Euro 4 and 5 regulations with respect to toxic CO₂, NO_x and HC emissions (which increase CO₂ emissions) and meet EuroNCAP safety standards, which include an increase in cars' weight and, therefore, in their CO₂ emissions.

Figure 24. Manufacturer fleets – average CO₂ emissions

Manufacturer	1997	2005	2006	Improvement 1997-2006
BMW	216	192	185	14%
Citroen	172	144	147	14%
Mercedes	223	185	191	14%
Fiat	169	139	141	17%
Peugeot	177	151	147	17%
Porsche	310	280	276	11%
Renault	173	149	147	15%
Volkswagen	170	159	163	4%
European fleet average	182	164	160	11%

Source: R.L. Polk Marketing Systems GmbH, ICCT.

The European Commission claims that despite a 5% cut in overall European carbon emissions from 1990 to 2005, transport emissions (including trucks) rose by 32%, thereby undermining a 9.5% reduction in other sectors and hindering Europe's commitments under Kyoto. This increase in transport emissions is primarily the result of: a 2% per year growth in the number of automobiles in Europe; a 2% per year increase in miles travelled per car; and lower average driving speeds as a result of congestion, which exacerbates CO₂ emissions.

At the same time, the auto sector is important in the European economy, with the jobs of an estimated 12m employees depending on auto manufacture. The auto sector is also the largest investor in R&D in the European Union, spending €20bn per year. Manufacturers

have raised the spectre of a decimated auto industry should the legislation not be formulated carefully.

The auto industry, for its part, faces a dilemma. Legislation may require a shift to low emission, *lighter* vehicles. Yet at the same time, consumer demand is increasingly moving towards larger, safer, *heavier* vehicles with more optional extras – all of which add weight and increase CO₂ emissions. Moreover, such cars are considerably more profitable: for example, it is estimated that BMW generates around €3,500 profit per unit, versus €350 for Peugeot.

Legislation milestones

- In 1998, the Association des Constructeurs Européens d'Automobiles (ACEA) signed a *voluntary* agreement to reduce average emissions to 140g CO₂/km by 2008.
- In November 2006, the European fleet average was 160g CO₂/km. Extrapolating to 2008, this suggested that the voluntary target was unlikely ever to be met. This led the Environment Commissioner Stavros Dimas to declare that he had “lost faith” in the voluntary approach.
- In February 2007, the political landscape shifted abruptly when the Commission published draft legislation for a mandatory 120g CO₂/km target by 2012.
- Also in February 2007, EU Industry Commissioner Guenter Verheugen negotiated an easier target of 130g CO₂/km from technical measures, with the remaining 10g CO₂/km to be achieved through complementary measures.
- In July 2007, ACEA proposed that, to preserve the diversity of the European fleet – there is a fundamental split between French and Italian small cars on the one hand, and German larger cars on the other – there should be a sliding scale, with each car having a CO₂ target determined by weight. However, the European Federation for Transport and Environment argued that weight was the wrong determinant as it could allow manufacturers to make heavier vehicles. Instead it urged categories based on footprint, determined as a function of track (width of a car measured from the centre line of the wheels) multiplied by wheelbase (distance between front and rear wheels).
- It seems the ACEA view may prevail. In August 2007, Malcolm Harbour, a member of the European Parliament, observed: “... there is some consensus that a weight-based target system looks to be sensible.”
- In September 2007, the EU Environment Committee will prepare legislation, which will be voted by the European Parliament in November 2007, and possibly be in place by mid 2008.

What seems most likely, although it is too soon to be certain, is the implementation of categories of emissions targets that differentiate according to vehicle weight, and targets that would be applied at the group level, rather than at the individual manufacturer level. Furthermore, there could be fines of around €150 per gram of CO₂/km, for each vehicle that exceeds the target.

In the United States, the Corporate Average Fuel Economy (CAFE) standard sets a target of 27.5 miles per gallon (mpg) – equivalent to UK 33mpg which is 210g CO₂/km – for cars, and 20.7mpg for light trucks. The fine per 0.1mpg under the standard has recently been raised from \$5 to \$5.5, and the system will move to a ‘footprint’ system in 2011, i.e. a function of track multiplied by wheelbase. Regulation is stricter for NO_x and particulates, which has led Mercedes, for example, to develop special “Bluetec” diesel engines to meet the requirements. Furthermore, the Renewable Fuels Standard (RFS) mandates a minimum consumption of biofuels. The current standard is at 7.5bn gallons by 2012, and current review by the Congress could raise this further, to 13bn by 2012.

Regulation has also been implemented in Japan, with a 138g CO₂/km weight-based target to be met by 2008, and 125g CO₂/km by 2012.

Actions taken by auto manufacturers

To mitigate the exposure to strict regulation, manufacturers are taking a range of actions. Examples include:

- BMW, in a joint venture with Peugeot, has developed direct-injection petrol engines that are being launched across the range (MINI in 2006, 1 Series and 5 Series in H1 2007, 3 series in H2 2007). It has also invested strongly in R&D: its “EfficientDynamics” programme has reduced emissions by 19% across the range of cars. Furthermore, BMW has a hybrid joint venture with Daimler Chrysler.
- Daimler Chrysler has developed a Bluetec range of low-emission diesel engines.
- Fiat Group is the pioneer of common rail injection, and aims to produce the lowest emitting cars in Europe by 2012.
- In 2006, PSA Peugeot-Citroen sold 1m vehicles below 140g CO₂/km. Of these, more than 450,000 were below 120g CO₂/km. As stated above, it has also developed direct-injection engines via a JV with BMW.
- Porsche has introduced direct injection to its Cayenne model and will do the same to its sport cars. Porsche is also due to launch a hybrid model in 2009.
- Renault has launched a range of “eco2” vehicles that emit less than 140g CO₂/km. It aims to sell 1m such vehicles in 2008, of which a third will emit less than 120g CO₂/km.
- Volkswagen’s Bluemotions initiative – low-emission versions of their vehicles – has already been applied to the Polo and the Passat models and is to be extended to the entire range.

Car manufacturers are exposed to climate change policy not only at the regional level, but also at the national and local levels. For example, band G vehicles, which emit more than 226g CO₂/km, could, under the congestion charge scheme, be charged £25 per day to enter London starting in October 2008. By contrast, models that emit 120g CO₂/km or less will be exempt from the £8 daily charge. This has led BMW, in particular, to launch a revised X5 3.0d with CO₂ emissions cut to 214g CO₂/km (instead of 231g CO₂/km) by using regenerative braking, intelligent alternator control and intelligent aerodynamic airflaps. Similarly, BMW aims to reduce the emissions of its 318d model from 122g CO₂/km to below the crucial 120g CO₂/km threshold for congestion charge exemption. These improvements will apply to all BMW’s products, wherever sold.

Technological solutions

Ultimately, the European Commission seeks escalating targets to reach 95g CO₂/km by 2020 and 80g CO₂/km by 2025. Manufacturers will therefore have to shift to ultra-low emission vehicles (ULEV) or even to zero-emission vehicles (ZEV). With current technologies, there are only three basic ways to achieve this, and all have inherent issues that seem unlikely to be resolved in the near future:

- **Biofuels:** It looks unlikely that biofuels will account for more than 10% of global vehicle fuels, giving the amount of land required to produce them;
- **Battery electric vehicles:** The performance is limited, recharge is slow, and it only shifts the problem: most power generation emits CO₂;
- **Hydrogen and fuel cells:** Costs are high, refuelling infrastructures are still missing and there are particular safety implications. Hydrogen is likely to be a solution, but only over a 20-year horizon.

Until these issues are resolved, it seems likely that manufacturers will increasingly resort to ‘transition’ technologies, such as hybrid electric vehicles (HEV); mild hybrid electric vehicles (MHEV); downsized, highly tuned turbo diesels; gasoline direct injection (GDI); homogenous charge combustion (HCC); variable valve timing (VVT); low viscosity lubricants (LVL); auto “stop-start”; regenerative braking; lighter vehicles; active aerodynamics; intelligent alternator control (IAC); electronic ancillaries; efficient transmissions such as twin clutch gearboxes (DSG), etc.

Other complementary measures are being developed to help achieve the additional 10g CO₂/km reduction in emissions, including: low rolling resistance tyres (LRRT); gear shift indicators (GSI); tyre pressure monitoring system (TPMS); improved mobile air conditioning (MAC); and fuel consumption indicators.

In the medium term, we believe the United States might focus on diesel technology – as has been the case in Europe in the past decade – given that diesel engines emit about 20% less CO₂ than gasoline engines. However, diesels emit greater quantities of particulates and NO_x, creating the need to develop advanced emissions-control equipment (diesel particulate filters, de-NO_x catalyst, diesel oxidation catalyst, etc.).

AVIATION

Climate change policy exposure

Although aviation currently accounts for just 1.6% of global greenhouse gas emissions, and on present projections will account for 2.5% of global greenhouse gas emissions by 2050¹⁰⁹, the sector is attracting disproportionate attention in the climate change debate.

The sector is affected by climate change policy on two main fronts:

- 1) **Carbon trading:** In December 2006, the European Commission proposed legislation to bring airlines within the European Union Emissions Trading Scheme (EU ETS). The proposal covers emissions from flights within the EU from 2011, and all flights from and to EU airports from 2012, regardless of the nationality of the carrier. Allowances will be capped at their average 2004-06 level.

The European Commission estimates that, once airlines are included in the EU ETS, and assuming that they fully pass on any extra cost to passengers, the price of a typical return flight within the EU could rise by between €1.8 and €9 by 2020.

- 2) **Carbon taxes:** Such taxes are usually implemented on passenger tickets (e.g., the UK’s Air Passenger Duty). Recently, new proposals have been made to raise the tax on plane tickets by around £27 for every return flight. This follows UK Prime Minister Gordon Brown’s doubling of Air Passenger Duty in his final budget as Chancellor of the Exchequer¹¹⁰.

However, the scope for limiting travel by a carbon tax is limited at present by a longstanding agreement with the International Civil Aviation Organisation (ICAO) forbidding the levying of tax on international flights.

Impacts of climate change policies

A carbon-trading scheme implies direct and indirect impacts on the aviation sector:

- **Direct impacts:** If the sector is included in a carbon-trading scheme, all carbon emissions represent a cost, obliging airlines either to invest in low-carbon-emitting technologies or to buy emission rights;

¹⁰⁹ Stern, N. et al. (2006).

¹¹⁰ See the Telegraph website, 20 August 2007.

- **Indirect impacts:** The emission trading scheme implies an increase in the price of carbon and thereby an increase in the price of fuel. In the aviation sector, fuel costs represent a large part of the total cost structure.

The impact of a carbon trading scheme is likely to be characteristic of industries with limited ability to pass on additional costs. Hence, the net increase in airlines' costs will likely necessitate capacity reductions relative to what would have been obtained otherwise. For established full-service airlines, this could mean lower utilization of the existing fleet in the near term, and slower capacity growth over the long-term. For the low-cost segment, a segment of the industry that prices aggressively to drive volume, higher costs will likely lead to reductions in growth.

Higher energy-related costs will also likely drive continued interest in fuel-saving technologies, such as winglets, and in more fuel-efficient operating procedures, such as single-engine taxiing.

Companies' reactions

The potential impact of climate change policies on aviation companies is gaining progressively more attention in the sector.

Technologies to improve fuel efficiency are being developed, and airlines are looking for design innovations – such as the A380, the 787 Dreamliner, and the A350XWB – that will lower the weight and fuel consumption of new jet engines. Indeed, British Airways CEO Willie Walsh has stated that "... environmental performance will be one of the key criteria in [British Airways'] choice [of aircraft] ensuring greater fuel efficiency, reduced noise and emissions."¹¹¹

More generally, the Advisory Council for Aeronautics Research in Europe (ACARE) has committed the industry to developing technology that would cut carbon dioxide emissions by 50% per passenger kilometre.

How quickly new engine improvements will actually show up in airline fleets also depends on the rate of new orders. US airlines such as American and Delta will be making some technological upgrades fairly quickly; but the full aircraft replacement cycle takes 10-15 years.

BUILDING MATERIALS

Climate change policy exposure

As significant contributors of carbon emissions, building materials are particularly exposed to climate change policy. Indeed, the cement sector alone accounts for 5% of global man-made emissions. The sector is affected on two main fronts:

- 1) **Carbon trading:** A carbon trading scheme, such as the European Union Emissions Trading Scheme, implies both direct and indirect impacts:

First, **direct impacts.** Any carbon trading scheme limits the right to emit. The EU ETS, in particular, includes emissions from the minerals industry, i.e. cement, glass and ceramic bricks. The resulting rise in the price of carbon implies an increase in marginal cost, which, as noted in chapters above, can to some extent be passed through to customers. The cement sector, for example, faces almost no competition from outside the European Union. However, if it were to pass all of the increase in its marginal cost on to consumers, the sector could start to face international competition and adverse competitiveness effects. Therefore, carbon trading obliges companies either to invest in low-carbon-emitting technologies and in new, efficient plants to limit emissions, or to purchase carbon emissions permits.

¹¹¹ See British Airways' website, www.britishairways.com/travel/bapress/public/en_gb.

Second, **indirect impacts**. Any carbon trading scheme implies an increase in the price of all carbon-intensive products and, thereby, an increase in energy prices. This could affect operating margins, particularly in the cement sector, which consumes much energy – around 110-120kWh per tonne of cement produced. Furthermore, transport costs will increase as a result of the increase in (carbon intensive) fuel prices. This will also likely affect firms’ margins.

As a result of these impacts, building materials manufacturing is likely to shift – unless or until emissions limitation schemes become global – to locations where the cost of emissions, when taken together with other costs of manufacturing and the cost of freight, is lower.

- 2) **Regulation on buildings**: The myriad new and tighter building regulations that require reduced carbon emissions will also affect – and are already affecting – building materials companies, which will have to develop – and they already are – improved insulation standards.

Actions taken by building materials companies

To mitigate climate change policy exposure, companies are already doing various things:

- 1) Carbon emissions can be decreased by **lowering clinker content** in cement manufacturing. Given that 50% of CO₂ emissions occur during the process of producing clinker (an intermediate product), reducing clinker content can have significant effects. To achieve this, companies are increasingly shifting to blended cement, which involves using fly ash, or slag, instead of clinker. In India, for example, 56% of the cement consumed/produced is blended cement.
- 2) **New products** that imply lower CO₂ emissions are being developed. Lafarge has developed Ductal, a concrete that uses about 35% less natural resources and the production of which produces 50% less CO₂. Cemex produces concrete that utilizes waste materials with greenhouse gas potential that would otherwise be discarded¹¹².
- 3) Carbon emissions can also be decreased by **improving energy efficiency in industrial processes**, particularly in kilns: companies are shifting to improved manufacturing processes, such as dry process, instead of wet process, which could save 40% of energy. Furthermore, companies, such as Cemex, are developing new processes to produce clinker at lower temperature. Several companies are also starting to use alternative fuels, such as pet-coke and lignite; and bio-waste, such as husks of rice, millet, sawdust, etc.

Climate change policies also offer commercial opportunities, particularly for new materials that contribute to energy savings in buildings. Saint Gobain notes that “low-emission” double glazing offers three times the thermal insulation of standard double glazing.

CAPITAL GOODS AND ENGINEERING & CONSTRUCTION

Climate change policy exposure

Climate change policies have few direct effects on capital goods and engineering & construction (E&C) companies because the sector is not a big carbon dioxide emitter.

However, climate change policy could have indirect impacts on such companies as a result of customer demand shifts towards cleaner solutions. For example, E&C companies, which have historically focused on ‘generic’ new coal-fired generation, may have slightly more muted growth, at least in the near term, whereas companies that have specialized in nuclear, gas generation and carbon retrofitting technology could benefit over time, especially as the United States is starting to focus more on green power generation. Furthermore, regulations and standards to promote sustainable buildings could affect E&C companies by obliging them to invest in new products and technologies.

¹¹² See the Carbon Disclosure Project website: www.cdproject.net.

Electrical companies, as suppliers of electricity generators to industrial facilities, and E&C companies, as suppliers of the infrastructure, can provide solutions.

Capital goods and E&C companies represent part of the solution

Electrical companies can deliver solutions in various ways:

- 1) **Energy efficiency:** One solution for power plants is to use more efficient turbines, resulting in fuel savings and lower emissions. Such turbines can be provided by electrical equipment companies. Furthermore, in factories, the use of variable speed motors, instead of traditional stop/start motors, can potentially save up to 40% of total electricity usage. In Europe, for example, the EU Motor Challenge Program is a voluntary program to encourage the use of these variable speed motors. As electrical motor use accounts for 40% of total energy in many facilities, any project that decreases this use will produce major cost savings.

Residential and commercial buildings account for 40% of total energy consumption in the United States¹¹³ and Europe¹¹⁴. Thus, solutions such as building management, control, and lighting, can potentially have an important aggregate effect.

Furthermore, to provide energy efficiency solutions to power plants and factories, electrical companies have also moved to new business areas, such as energy management services.

- 2) **Emission reductions:** Large expenditures have already been made in pursuit of clean coal technologies, such as Integrated Gasification Combined Cycle (IGCC). However, this solution is not yet commercially viable, at least on a large scale. Companies have also moved to renewables. For example, General Electric entered the market in 2004, Siemens in 2006, and Alstom acquired a Spanish wind turbine in July 2007. ABB offers induction and synchronous generators for wind turbines.
- 3) **Energy savings in transmission and distribution:** Considerable energy can be saved by reducing the transmission losses between the generator and the end-user: in particular, systems using HVDC (High Voltage Direct Current) result in substantial savings. China plans to use HVDC in the building of what will be the world's most efficient 'supergrid'.

Thus, there are clear commercial opportunities for electricals. However, although there has been a shift to the products mentioned above on the large-scale generation side, this has generally not yet percolated down to the factory level.

E&C companies can also offer solutions to power plants by focusing on clean coal technologies, such as Integrated Gasification Combined Cycle (IGCC), carbon sequestration, and oxycombustion. KBR, Foster Wheeler Ltd, Fluor Corporation, and McDermott International are all currently working on commercially viable clean technology solutions. Notable projects include KBR's partnership with Southern Company on building an IGCC plant in Florida, and McDermott's partnership with American Electric Power to study the application of oxy-coal combustion as a retrofit to an existing plant.

However, these technologies are still expensive – it costs perhaps twice as much to build a nuclear power plant or an IGCC than a 'generic' coal plant. Developing a cost-effective method for generating clean coal may take several years.

¹¹³ See Energy Information Administration website, www.eia.doe.gov.

¹¹⁴ See DEFRA website, www.defra.gov.uk/environment/energy/internet/ecbuildings.htm.

CHEMICALS

Climate change policy exposure

Chemical manufacturing processes release a wide range of greenhouse gases. Accordingly, the industry is subject to a range of emissions controls and, in Europe, to carbon quotas also. This is already starting to increase the costs of many chemicals, in addition to the direct effect of higher energy prices which, BASF has stated, can represent up to 60% of product manufacturing costs¹¹⁵.

The commercial risk of tighter future restrictions largely depends on whether abatement measures are imposed globally or regionally. In general, demand for chemicals is price inelastic – there are few cost-competitive substitutes – so the industry stands to be able to pass higher regulatory costs on to its customers, *if those costs are imposed globally*. However, if costs are imposed in some countries but not in others, companies in regulated regimes will be at a competitive disadvantage to those elsewhere.

Chemical companies will likely continue to invest in reducing both their carbon emissions and their energy use, through, for example, combined heat and power. DuPont estimates that the cost of achieving its energy and greenhouse gases emission reduction has exceeded \$50m, but that this expenditure produced \$3bn in total energy savings between 1990 and 2005.

Chemicals represent part of the solution

Technological change will present several opportunities for the chemical industry. Examples of where chemicals can provide a solution to help reduce carbon emissions include:

- Plastics replacing metal and glass in autos and aircraft: for example, DuPont is producing light weight thermoplastic parts, and Mitsubishi Chemical Holdings has developed engineering plastics and carbon composites to replace metals, including metal parts in autos.
- New materials for building insulation, solar cells and wind turbines: for example, Fujikura and Tokyo Ink are developing DSSC (Die Sensitised Solar Cell) materials.
- Industrial gases technology for carbon capture: for example, Praxair is working with the US Department of Energy and other companies to develop high efficiency oxygen supply systems for next generation IGCC power plants.
- Industrial gases technology for low emission manufacturing processes.
- Biotechnology (e.g. lignocellulosic) for biofuels.

CONSUMER AND RETAIL (FOOD AND GENERAL)

Climate change policy exposure

Consumer staples and retail companies are not big emitters of carbon dioxide. They are therefore not directly impacted strongly by climate change policy, such as a carbon tax or a carbon trading scheme. However, at each step of the consumer-retail chain – i.e. supplier ==> store ==> consumer – other impacts of climate change policy are already being felt:

- 1) **Increase in food/commodity prices:** Food prices have increased recently because of the push for greater ethanol production, which has produced a surge in agricultural prices (see box *Food prices and the 'ethanol push'*).
- 2) **Increase in transport costs:** The increase in the carbon price, resulting from climate change policies (whether from a carbon tax or a carbon trading scheme),

¹¹⁵ See Carbon Disclosure Project website, www.cdproject.net.

implies also an increase in energy prices, and thereby in transport prices. Even if transport cost is not the most material element in the overall cost structure, given that margins are tight, any small cost increase could have a significant repercussion.

- 3) **Increase in production costs:** Rises in energy prices and tighter building regulations push up production and selling costs.

Furthermore, **‘food miles’ regulation** could oblige retailers to shift to more local sourcing. Global sourcing has enabled prices to decrease by 35% over the past 10 years and enabled a doubling of clothing volumes sold. ‘Food miles’ regulation, coupled with an increase in transport costs, could offset such gains made from global sourcing. At present, China is the ‘hub’ for exports, especially for clothing and textiles. However, a rapid increase in freight costs has already been seen (30% y-o-y).

There is also a **consumer exposure**. Climate change policies have become increasingly important to consumers. While it may be premature to call the end of the ‘throw-away society’, it is certainly changing the products retailers offer to a small, but growing, environmentally-aware niche. Furthermore, rising transport costs could have an impact on consumers’ behaviour, diminishing their willingness to drive to out-of-town shopping centres. Indeed, recent exceptional growth in out-of-town shopping may well slow over the medium term. Such dynamic and fast changes by food retailers in particular may well be to the advantage of local producers, but may come at a higher price to consumers.

Meanwhile, consumers’ tastes and behaviour may also change as a result of regulation to encourage CO₂-compliant food consumption, for example through labels indicating the level of CO₂ emissions associated with some products. Some staple manufacturers have already started to introduce products with a lower carbon footprint.

Actions taken by retailers

To mitigate their exposure to climate change policies, retailers are already undertaking various actions:

- 1) **Increase in food/commodity prices:** A significant proportion of this cost increase has been passed through to consumers recently. This is mainly due to the price inelasticity of demand. In more cyclical sectors, however, there appears to be more price resistance, although US retailers suggest food cost increases experienced in the first half of 2007 have now been incorporated into retail prices for all categories.
- 2) **Increase in transport costs and ‘food mile’ regulations:** To reduce transport costs, retailers are starting to work on transport efficiency improvements. In the UK, for example, Tesco is working with suppliers to ensure that their vehicles do not travel empty after making a delivery. Suppliers’ vehicles are used to make deliveries to stores on the return trip, thereby reducing the number of vehicles making unnecessary journeys. This has resulted in more than 8m fewer miles travelled¹¹⁶. In the United States, Kroger, the country’s largest supermarket chain, is making significant effort to improve the efficiency of the engines of its trucks; reduce the weight of 1,350 trucks and 7,100 trailers; and limit the number of miles driven, by using more multi-temperature vehicles and increasing backhaul.

In response to the ‘food mile’ issue, some retailers are taking actions to source their products more locally. For example, Marks and Spencer aim to source as much food from Britain and Ireland as it can to double regional food sourcing within 12 months; and, within six months, to label all air-freighted foods as “flown”.

European clothing retailers have shifted some production back to the near East (Turkey) – although this is also a function of the rise of “fast fashion” and the need for shorter lead times. US clothing retailers continue to be highly dependent on Asian

¹¹⁶ See the Carbon Disclosure Project website, www.cdproject.net.

sourcing, although some production is starting to be undertaken in Latin America and the Caribbean as a result of a desire to reduce the length of the product cycle.

- 3) **Increase in energy prices:** To decrease spending on energy, retailers – particularly food retailers – have started investing in energy-saving projects and in green-oriented technologies. Tesco has established a £100m fund for investment in sustainable environmental technology, which aims to reduce its energy use per square foot by 50% by 2100, relative to a baseline in 2000. Green supermarkets in Diss (Norfolk) and Wick (Scotland) have been opened in the past 12 months and more are likely to follow. Tesco is to open its first environmentally friendly store in Korea following successful experiments there, while Carrefour is testing solar panels at six hypermarkets in Spain. M&S intends to invest £200m in “Plan A”, a five-year plan that focuses on five commitments, one of which is to address climate change. The main objectives are to reduce energy use and to use more green energy.

Kroger was able to reduce energy consumption by 20% from 2000 levels via changes in lighting and refrigeration technologies at its stores and distribution centres.

Food prices and the 'ethanol push'

A push for ethanol production

Ethanol production is the beneficiary of a range of incentives from the US government. In 2006, the United States consumed 350,000 barrels per day (b/d) of ethanol, which accounted for 3.8% of total gasoline consumption. With support of the nascent biofuels industry having become a priority for the Bush administration and many members of Congress, this share stands to rise over the next five years: the current Renewable Fuels Standards (RFS) requires 7.5bn gallons by 2012. And proposals currently before Congress may raise this to 8.5bn in 2008, 10.5bn in 2009, and 36bn by 2022. Even faster progress was urged by President Bush in his latest State of the Union address, when he called for production of 35bn gallons of renewable fuel per year by 2017.

In March 2007, President Bush and Brazil's President Lula da Silva launched a new partnership to promote biofuels from sugar cane, Brazil still being the world's biggest ethanol producer (45.2% of global production), although tariffs on imported ethanol remain in place. The European Commission too is encouraging the production of biofuels, using legislative measures to promote biodiesel made from rapeseed and sunflower seeds.

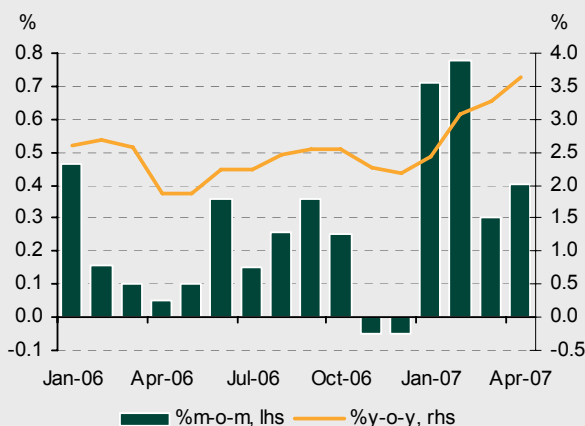
Impacts of the push for ethanol

Corn prices (Figure 26) increased by 50% between August 2006 and August 2007, and this increase is directly linked to the increased demand for ethanol¹¹⁷. Moreover, this seems set to continue. The International Food Policy Research Institute (IFPRI) projects that the increase in global biofuel production will push global corn prices up by 20% by 2010, and by 41% by 2020. The prices of oilseeds, including soy, rape, and sunflower, are projected to rise by 26% by 2010, and 76% by 2020; and wheat prices by 11% by 2010 and 30% by 2020.

A related effect of the increase in corn prices has been a doubling of corn tortilla prices in Mexico, in part because of a rise in US corn prices from \$2.80 to \$3.90 a bushel from October 2006 to February 2007, triggering protest marches in Mexico City¹¹⁸. However, a strong corn harvest has recently brought corn prices down to \$3.25. Prices of related products have also increased. Livestock prices, for example, particularly poultry and pork, which are fed mainly on corn, have accelerated. More generally, all products using corn face higher production costs, which are likely to be passed on to consumers.

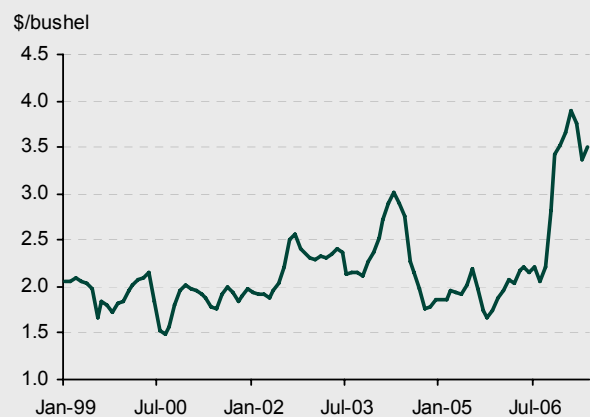
Ethanol incentives have also diverted corn from the food market. According to the United States Department of Agriculture, 14% of the 2005/06 corn harvest was used for ethanol production. With government backing for biofuels continuing, the share of the annual corn crop devoted to ethanol production is likely to increase to over 30% by 2010¹¹⁹. ■

Figure 25. Food price changes



Source: Bureau of Labor Statistics.

Figure 26. Corn spot price



Source: Bloomberg.

¹¹⁷ MIT Technology Review, 13 February 2007.

¹¹⁸ Foreign Affairs (2007).

¹¹⁹ See US Focus Piece, Lehman Brothers Global Weekly Economic Monitor, 18 May 2007.

INTEGRATED OIL

Climate change policy exposure

Oil is responsible for around 40% of total world emissions¹²⁰ and gas for around 20%. The principal characteristic of the sector is that, while it is responsible for the supply of the hydrocarbons oil and gas, it is not responsible for the burning of them. This is done by downstream sectors – the electricity sector, mainly, and transport. Hence, climate change policies and regulations that have an impact on downstream sectors may also affect the oil and gas sector.

A carbon tax or a carbon trading scheme has the immediate effect of increasing the price of all carbon-intensive products, such as gasoline, and thereby has at least some impact on consumers' willingness to purchase oil. The extent of this impact depends importantly on uses – power generation, transport or heating:

1) **Power generation.** The increase in fuel prices could lead to some fuel switching, from coal to gas, for example, which could be an opportunity for oil and gas companies. Furthermore, there will be continued governmental support for renewable energy sources, such as wind, solar, etc., which will affect the demand for oil.

2) **Transport sector.** The market in which an increase in carbon-intensive products could have the biggest impact is the United States, where per capita consumption is high and gasoline taxes are low. However, notwithstanding the 148% rise in US pump prices over the past five years, there has been little evidence of any significant effect on demand, perhaps because consumers do not see gasoline as a discretionary spend. Moreover, as there are currently no real commercially available alternative products, any changes in the consumption pattern will likely be gradual.

The transport sector could also be hit by climate change regulations that oblige automobile manufacturers to produce more fuel-efficient cars. In Europe, the European Commission has made proposals to decrease cars' CO₂ emissions to 120g CO₂/km (see *Autos* section, above). In the United States, the Renewable Fuel Standard (RFS) mandates a minimum consumption of biofuels. The current standard is at 7.5bn gallons by 2012. Furthermore, a proposal that has already been passed by the Senate, and that is currently under review by Congress, would raise the standard further, to 13bn gallons by 2012. If the Senate version of the new RFS is passed into law by the end of this year, it could displace approximately 300,000b/d of gasoline demand over the next five years, i.e. 40-65% of the expected demand increase.

3) **Heating sector.** The increase in the price of carbon could also lead to fuel switching from heating oil to gas. The seasonality of demand has been changing in recent years, with a less marked difference between Q1 and Q2 as Northern hemisphere winter demand seems to be growing at a less pronounced rate relative to rising non-OECD summer air-conditioning demand. This has had an impact on US and UK spot gas prices, with a disconnect now opening up. UK and US spot prices now trade at a marked discount to equivalent oil prices (Figure 27).

Apart from these impacts on downstream sectors, oil and gas companies are also directly affected by climate change policies because they are already included in some carbon markets, particularly the European Union Emissions Trading Scheme, which obliges companies to reduce their emissions. The financial consequences of such schemes seem, however, likely to be fairly limited.

Actions taken by integrated oil companies

To mitigate the exposure to climate change policies in the transport sector, companies have tried to develop new products. However, it is hard to find a low-cost alternative to gasoline; and biofuels do not seem to be the simplest solution. The UN Food and

¹²⁰ Energy Information Administration (2006).

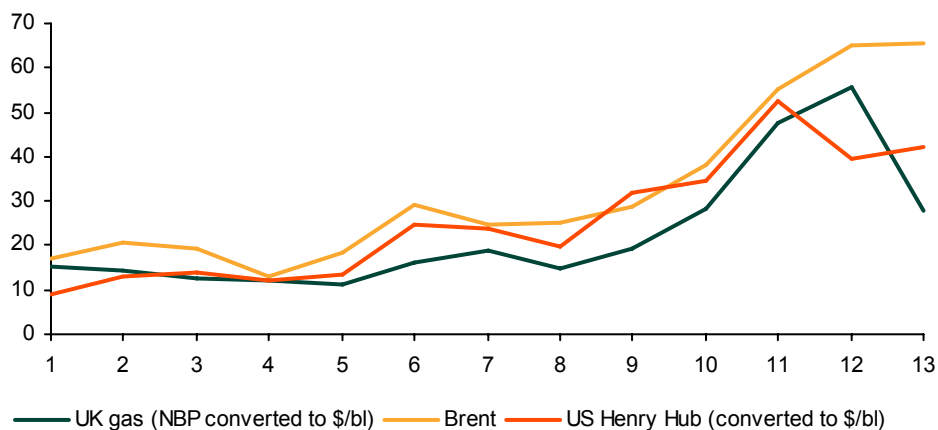
Agriculture Organisation is now pushing for a high level meeting in June 2008 to explore the implications of bioenergy initiatives and resulting pressures on food prices. In 2006, the United States biofuel industry consumed about 20% of the country’s corn crop, and in 2007, corn prices have reached an 11-year high at \$4.30/bushel as a consequence of this increased demand. More companies are now looking at sustainable biofuels initiatives that do not distort the food chain. Conoco Phillips, for example, is in a joint venture with Tyson to process animal waste, while Chevron is investing in cellulosic ethanol research. That said, major integrated oil companies are a comparatively minor force in this area, and may remain so for some time.

Integrated oil companies are also investing in projects that directly reduce carbon emissions, such as carbon capture and storage. In February, Total announced the launch of the first integrated carbon capture and geological sequestration project in France. Shell also is involved in large-scale demonstration projects in this area. In Norway, Shell has invested in the largest offshore project to date to store CO₂ and use it to enhance oil recovery. This project is at the feasibility stage. However, Shell’s sustainability report states that “... government policy will play a decisive role in determining the future of CO₂ capture and storage.”

Government policy, particularly subsidy policy, can be key: many of the alternative strategies are dependent on government subsidies to generate an economic rate of return. Indeed, since February some initiatives have been abandoned. For example, Total and Neste have announced they will not pursue their proposed joint-venture for a biofuel plant at a refinery in France. And BP and Scottish & Southern are no longer pressing ahead with the clean coal and capture power station at Peterhead, apparently because government subsidy was not forthcoming on the time horizon that the companies required.

However, major integrated oil companies are increasingly playing a role in debates: BP, Shell and Total are major players on the European carbon trading market and BP and Shell were signatories of the United Kingdom Manifesto for the European Union Emissions Trading Scheme in April 2007, which calls for “... the development of emissions trading as the key part of the EU’s strategy for reducing emissions from industry.” US oil majors, too, have been participating more actively in policy debate: for example, ExxonMobil’s CEO and Chairman, Rex Tillerson, has made several trips to Capitol Hill to discuss the subject with members of Congress (see Box *Awareness is increasing among businesses*).

Figure 27. UK natural gas prices converted to \$/bl relative to Brent



Source: Reuters, Lehman Brothers.

MINING AND METALS

Climate change policy exposure

Potential climate change policies will lead to energy efficiency requirement and reduction in carbon emissions.

Mining companies can be part of the problem, as they release emissions from smelters and mining machines, and extract resources, such as coal, which ultimately generate carbon emissions. Nevertheless, mining companies can also be part of the solution. For example, companies that produce copper are part of the process of increasing energy efficiency in power cables, just as companies that produce aluminium can improve fuel efficiency in motor vehicles, and companies that produce uranium contribute to the generation of 'clean' electricity.

Mining and metals form part of the solution

Mining and metals companies can deliver solutions in various areas:

- 1) **Energy efficiency:** Copper is an excellent energy conductor. Using copper (rather than aluminium, for example) in power transmission, especially over long distances, can reduce power loss, and thereby fossil fuel requirements at power plants.
- 2) **Emission reduction:** Using more aluminium and less steel in motor vehicles results in lighter-weight, and thereby more fuel-efficient, vehicles. The reduction in emissions is even greater if scrap aluminium, rather than primary aluminium, is used: recycling aluminium from scrap requires less than 5% as much energy, and produces much lower greenhouse gas emissions.

Furthermore, using more nuclear power and less fossil-fuel-fired power would reduce carbon emissions. However, public opposition to new nuclear plants, permits, and other regulatory hurdles, constrain nuclear power capacity growth in many countries.

Thus, a carbon-constrained world provides a range of commercial opportunities for mining companies. Diversified miners such as Rio Tinto and BHP Billiton, which produce copper, aluminium, and uranium, can be part of the solution to the carbon emissions problem. However, these companies also generate emissions from their mining activities and produce commodities, such as coal, the demand for which may be negatively affected in the very long-run. But, at present, expectations of declining coal demand look premature.

REAL ESTATE

Climate change policy exposure

Residential and commercial buildings account for around 40% of total emissions in the European Union. Real estate companies are therefore directly exposed to local, national, and international climate change policy, particularly to regulation and standards obligations. Authorities are implementing more stringent energy efficiency and sustainability regimes, with ever-increasing costs of compliance.

In Europe, the European Union Energy Performance of Buildings Directive was published in the EU Official Journal in January 2003, and became European law the day after publication. The Directive indicates that by improving energy efficiency, carbon emissions from building could be reduced by 22%, which would help the EU meet its climate change objectives under the Kyoto Protocol. The principal objectives of the Directive are to promote:

- improvement of the energy performance of buildings within the EU through cost-effective measures; and

- convergence of building standards towards those of Member States which already have ambitious levels¹²¹.

Buildings regulations operate at various levels:

- 1) **Emission reductions:** in the United Kingdom, new and refurbished buildings must meet new standards aimed at reducing carbon emissions by 27% from current levels.
- 2) **Energy sourcing:** in many European countries, regulation has been enacted to source energy consumed by buildings from renewable sources. For example, in the United Kingdom, 10% of energy must come from on-site renewable sources. A plan to drive this towards 20%, which may be difficult to achieve technically, is under review.
- 3) **Labelling:** buildings may be awarded energy ratings in the future. In the UK, BREEAM (Building Research Establishment Environmental Assessment Methodology) ratings are given to buildings that meet certain environmental performance requirements¹²².

Impacts on real estate companies

The myriad climate change regulations constitute a key challenge for real estate companies. On the one hand, new buildings have to meet sustainable energy requirements. On the other, the treatment of the existing stock of buildings poses a major difficulty for real estate companies because of the risk of obsolescence from regulation. Indeed some projects currently under way are already, given the long lead times in the construction industry, obsolete in terms of the most efficient sustainable energy technology.

In the future, buildings' value may well be affected substantially by environmental labels. This could be a significant issue for smaller companies, for whom compliance costs could represent a considerable burden. The most notable green building in London (30 St Mary Axe, the "Gherkin") offers a potential pointer to the future. It is now letting well, after a slow start – commanding around £65 per square foot, a very high value for the City. Part of the high letting costs stands to be offset by lower overall energy costs. Increasingly, this is likely to be the trade-off in the sector – higher rents for greener buildings that enable energy savings and thereby cost savings.

RENEWABLES

Climate change policy exposure

Climate change policies are a powerful driver in the development of renewable power generation. Many aspects of climate change policies drive this appeal to renewables:

- 1) **Mandatory reductions in greenhouse gas emissions:** In the European Union, reduction in greenhouse gas emissions has been fixed at 20% by 2020, as an addition to the Kyoto Protocol's target of 5.2% by 2012. If there is international support, the EU may increase this target to 30% and even to 60-80%. Such mandatory reductions help to impel the switch to the low-carbon power generation, and even to zero-carbon power generation, that is achieved by renewables.
- 2) **More stringent regulation:** In several countries, mandatory proportions of energy are sourced from renewables. This is the case particularly in Europe (France: 10% by 2010, Germany: 20% by 2020, UK: 10% by 2010). In Asia, too, wind power companies have been able to grow their production on the back of favourable government policies. Such is the case of Suzlon in India, which has developed and implemented several large-scale wind farms throughout the country.

¹²¹ See Defra website, www.defra.gov.uk/environment/energy/international/ecbuildings.htm.

¹²² See BREEAM website, www.breeam.org.

- 3) **Carbon trading schemes:** These have the direct consequence of increasing the prices of carbon-intensive products. There is therefore a positive substitution effect towards renewables, which are carbon-free.

Renewables represent part of the solution

These various climate change policies imply major commercial opportunities for the renewables sector. Contracts have already been signed with utilities and other sectors. For example, BP has a \$4.2bn turbine supply agreement with Clipper Windpower and Iberdrola a \$4bn deal with Gamesa.

However, not all renewable energy sources are economically efficient. Wind seems to be the main beneficiary of climate change policies: at present, onshore wind is, along with hydropower, the only renewables technology that does not require subsidy to be cost effective (Figure 28).

The offshore wind market is still small but future cost reductions linked to market maturity and technology improvements will likely make this a new growth area, particularly as climate change policies strengthen. Other options are still too expensive to be commercially viable: solar in particular is still uneconomic, except in extremely sunny parts of the world: even if the cost of solar energy were halved, it would still, in many of the largest economies, be twice as expensive as traditional sources of energy.

Nuclear, being carbon neutral, also stands to be a beneficiary of climate change policies. But public sentiment and long lead times in building new plants are major hurdles to general adoption.

In the future, it seems more likely that there will be a combination of wind, solar and nuclear, rather than a competition between these different sources.

Figure 28. Renewable energy costs

Renewable	Current energy cost (2001 US\$ cents/kWh)	Potential future energy cost (2001 US\$ cents/kWh)
Biomass energy	1-12	1-10
Wind energy	4-8	3-10
Solar photovoltaic electricity	25-160	6-25
Solar thermal electricity	12-34	4-20
Hydro energy – large	2-10	2-10
Hydro energy – small	2-12	2-10
Geothermal energy (electricity)	2-10	2-8
Wave energy	10-30	5-10

Source: United Nations Development Programme (2004).

TECHNOLOGY

Climate change policy exposure

Technology companies, being generally small greenhouse gas emitters, are directly affected only a little by climate change policies. However, the more stringent that climate change policies become, the more energy-efficient solutions customers will require. To that extent, technology companies can provide solutions.

Technology companies represent part of the solution

Climate change policies imply an increase in the price of energy, which leads to a need for energy-efficient products. Energy efficiency is the focus of an increasing number of technology companies:

- **Semi-conductor** companies are increasingly focusing on reducing power consumption. Intel provides Instantly Available PC (IAPC), which, according to the

US Environmental Protection Agency (US EPA), enables PCs to consume 71% less energy;

- **Telecommunication equipment** companies are increasingly focusing on reducing the power consumption of network elements; and
- **Consumer electronics** are seeking to respond to a shift in consumer demand towards more energy-efficient products. Product labelling seems likely to be progressively more widely employed. In response to these factors, Philips, for example, has moved to more efficient lighting products.

Climate change policies also imply less need for some types of travel. One particularly important example is the increased use of video conferences, and other telecommunication means, resulting in a demand boost for network capacity and specialist applications.

TELECOMS

Climate change policy exposure

The telecom sector is not significantly directly affected by climate change policies because it does not contribute much to carbon emissions. However, as one of the larger energy consumers – BT estimates that it alone accounts for 2% of the total electricity consumed by UK businesses, and for 0.7% of total electricity consumed in the entire country – the telecom sector will be importantly affected by the energy cost increases that flow from climate change policies. However, this cost increase can, in general, be passed through to the customers.

To mitigate this exposure, companies are investing in projects to decrease their carbon-intensive energy consumption. For example, the recent renewal of BT's green energy contract until 2100 means that approximately 50% of its electricity needs in the United Kingdom will be met by renewable sources and 50% from combined heat and power.

Telecoms represent part of the solution

Climate change policies imply higher energy prices, and therefore more expensive travel. Internet-based solutions may be part of the response. And at least as far as business travel is involved, telecom operators could be part of the solution.

Telecoms have an important role to play in dematerialization and transport substitution. For example, they enable:

- flexible working solutions, such as work from home;
- audio and video conferences to avoid travel: BT estimates that every conference call saves a minimum of 32kg of travel-related CO₂ emissions.

As people and businesses still take advantage of only a tiny fraction of the services available via the internet, we see a significant opportunity for telecom companies in the development and marketing of innovative products and services that reduce reliance on carbon-intensive journeys.

UTILITIES

Climate change – and climate change policy – is of considerable importance for the utility companies: they have been facing up to the issue for some time, particularly in Europe, although movement towards some form of legislation is now gathering pace in the United States.

Climate change policy exposure – Europe

In Europe, the EU ETS will enter its second phase next year. Further to proposals made in the January 2007 *Energy Sector Report*, the European Council of Ministers committed in March to reduce greenhouse gas emissions by 20% vis-à-vis 1990 levels. The Council also indicated a willingness to sign up to a 30% reduction, with an extension to 60-80% by 2050, if developed countries also commit to emission reductions.

The European Commission has also taken a firm line in setting NAPs for phase II (2008-12) of the EU ETS, requesting an average reduction of 10.7% against the requests submitted – this after surpluses of allowances of 3.2% in 2005 and 7.5% in 2006 were confirmed. The required reductions were particularly demanding in respect of a number of countries (Figure 29), some of which have indicated that they will seek to sue the Commission. Although allocations at an industry/installation level have not yet been made in many member states, it may well be that the power industry will bear the bulk of the squeeze in phase II allocations:

- The power industry emits about half of the emissions covered by the scheme;
- CO₂ prices have generally been incorporated in power prices which, coupled with the level of free allocations in phase I, has boosted profitability, to the consternation of some policy setters;
- Some technical solutions to abate CO₂ such as switching from coal to gas and renewables, already exist.

Utility companies' reactions

Emission Reduction Units (ERUs) and Certified Emission Reductions (CERs). These relate to JI and CDM projects respectively, and are an alternative form of abatement. Typically, a country is allowed to meet a minimum of 10% – and a maximum of 50% – of its phase II allocations through JIs/CDMs, although some have elected to include less. In total, approximately 300m tonnes per annum of these credits could be utilised in the EU ETS in 2008-12. The attraction of such mechanisms is that they may be cheaper than traded European Union Allowances (EUAs), and therefore a way of reducing the carbon emissions cost. The price of CDMs/JIs is not particularly transparent in the primary market, but it appears that there is an upward trend to a range of €9-13/t against a phase II EUA price of €19-22/t. A number of utility companies are increasingly involved in this market, notably EDF, Endesa, Enel and RWE.

Clean coal technology. This received EU backing in January 2007. Clean coal technology in its simplest form involves reducing carbon intensity, but projects under development by E.ON and RWE seek to develop CO₂-free coal generation. However, the construction cost per MW of such technology is estimated to be twice that of conventional coal technology, although there are many uncertainties and a number of pilot projects have been cancelled. Carbon capture and storage is also on the agenda, but again there are many issues: finding suitable storage sites, a way to transport the CO₂ and the legality of doing so. Accordingly, there stands to be upward pressure on capex budgets, but the timing of the impact is open to question. This may well jeopardise the EU's target of having all new coal plants fitted with CO₂ capture-and-store technology by 2020.

Figure 29. EU ETS – Phase I NAPs, phase II draft NAPs and 2005 out-turn

Member states	Ph 1 (2005-07) ETS Allocation	Average annual ETS allowance (mt)	Implied % CO ₂ within ETS	2005 ETS Allocation	2005 Reported	Surplus/ (shortfall)	2006 reported	Surplus/ (shortfall) vs average allocation	Mvt vs 2005	Draft phase II (mt)	% increase/ reduction from 2006A	% increase/ reduction from phase I	EC decision (mt)	% Cut
Austria	99	33	36%	32	33.4	-3%	32	2%	-3%	32.8	1.3%	-0.6%	30.7	-6.4
Belgium	189	63	43%	58	55.4	5%	55	13%	-1%	63.3	15.6%	0.6%	58.7	-7.6%
Cyprus	17	6	62%	6	5.1	8%	5	7%	4%	7.1	35.4%	25.6%	5.5	-23%
Czech Republic	293	98	67%	97	82.5	15%	84	14%	1%	101.9	21.9%	4.4%	86.8	-14.8%
Denmark	101	34	45%	37	26.5	29%	34	-2%	29%	24.5	-28.4%	-26.9%	24.5	0.0%
Estonia	57	19	89%	17	12.6	25%	12	36%	-4%	24.4	101.3%	28.5%	12.7	-47.8%
Finland	137	46	53%	45	33.1	26%	45	2%	35%	39.6	-11.3%	-13%	37.6	-5.1%
France	470	157	28%	150	131.3	13%	123	21%	-6%	132.8	7.7%	-15.1%	132.8	0.0%
Germany	1,497	499	49%	495	474.6	4%	478	4%	1%	482	0.9%	-3.4%	453.1	-6.0%
Greece	223	74	54%	71	71.3	0%	70	6%	-2%	75.5	7.9%	1.5%	69.1	-8.5%
Hungary	94	31	38%	30	26	14%	26	17%	-1%	30.7	18.8%	-1.8%	26.9	-12.4%
Ireland	67	22	33%	19	22.4	-17%	22	3%	-3%	22.6	4.1%	1.2%	22.3	-1.3%
Italy	698	233	41%	216	225.9	-5%	227	2%	1%	209	-8%	-10.1%	195.8	-6.3%
Latvia	14	5	43%	4	2.9	30%	3	36%	3%	7.7	161.8%	68.6%	3.4	-55.5%
Lithuania	37	12	71%	14	6.6	51%	7	47%	-1%	16.6	154.7%	35.3%	8.8	-47%
Luxembourg	10	3	30%	3	2.6	23%	3	19%	4%	4.0	45.6%	17.3%	2.5	-36.7%
Malta	9	3	101%	3	2	30%	nk	na	na	3.0	na	0.9%	2.1	-29.1%
Netherlands	286	95	44%	86	80.4	7%	77	20%	-5%	90.4	17.9%	-5.1%	85.8	-5.1%
Poland	717	239	62%	214	202.3	5%	209	13%	3%	284.6	36.4%	19%	208.5	-26.7%
Portugal	115	38	47%	37	36.4	1%	33	13%	-9%	33.9	2.6%	-11.1%	nk	na
Slovakia	92	31	59%	35	25.2	29%	26	16%	1%	41.3	61.7%	35.4%	30.9	-25.2%
Slovenia	26	9	44%	9	8.7	5%	9	-1%	1%	8.3	-6.1%	-5.3%	8.3	0.0%
Spain	523	174	43%	172	183.6	-7%	179	-2%	-3%	152.7	-14.5%	-12.5%	152.3	-0.2%
Sweden	69	23	33%	22	19.4	13%	20	13%	3%	25.2	26.8%	10.0%	22.8	-9.5%
UK	736	245	38%	206	242	-18%	251	-2%	4%	246.2	-2.0%	0.4%	246.2	0.0%
Total	6,572	2,191	44%	2,079	2,013	3.2%	2,027	7.5%	0.7%	2,160	6.6%	-1.4%	1,927.9	-10.7%

Sources: European Environment Agency, Point Carbon, European Commission, and Lehman Brothers estimates.

Nuclear. This technology is undergoing a ‘renaissance’ and is on the agenda of many countries: indeed, in Finland and France, plants are already under construction. The cost (upwards of €2m/MW) will put upward pressure on utility budgets. Among European countries, the United Kingdom is arguably the most advanced. The government is already in favour and the results of a consultation are to be published on 10 October 2007. This is likely to trigger strong interest in nuclear in the UK, with the incumbents (British Energy, EDF, E.ON, Iberdrola, RWE, Scottish & Southern) being joined by Suez in the process of applying for technology approval. Furthermore, EDF, the world’s leader, has publicly stated that it intends to maintain this position, with four countries, China, South Africa, the UK and the US, being at the top of its priority list. Indeed, it has already signed a joint-venture cooperation agreement in the US with Constellation Energy to build four new nuclear stations.

Renewables. Many utility companies have already invested significantly in renewable capacity (mostly wind), and countries such as Germany and Spain are already well penetrated. In our previous study, *The Business of Climate Change: Challenges and Opportunities*, we highlighted that we expected renewables to become an increasingly important part of utility company budgets. This is already turning out to be so, most notably via a spate of acquisitions – some still to reach completion – by utility companies largely driven by the renewables portfolios of the target (e.g. Iberdrola/Scottish Power, EDP/Horizon, Acciona/Endesa Renewables, International Power/Trinergy, E.ON/Energi E2). Figure 30 shows wind farm operators and their capacity:

Figure 30. Wind farm operators (global, 2006A, MW)

Company	Country	Capacity (MW)
Iberdrola (acquired Scottish Power)	Spain	4,434
FPL	US	4,300
Acciona (pending offer for Endesa with Enel)	Spain	3,133
Babcok Brown Windpartner	Australia	1,631
Scottish Power (acquired by Iberdrola)	UK	1,593
Endesa (under offer from Enel/Acciona)	Spain	1,500
Eurus Energy Holding	Japan	1,324
EDP (acquired Horizon)	Portugal	1,010
Shell	Netherlands	849
Essent/Nuon	Netherlands	840
Horizon (acquired by EDP)	US	824
EDF Energies Nouvelles	France	790
Dong (Iberian assets sold to E.ON)	Denmark	724
Enel (pending offer for Endesa with Acciona)	Italy	600
Vattenfall	Sweden	534

Source: Lehman Brothers.

Climate change policy exposure – US

A growing consensus among voters, politicians, and businesses on the importance of addressing the climate change issue, leads us to conclude that some sort of climate change policy is almost inevitable (see the conclusion chapter *What next?*). Although discussion on a federal level has recently taken on a new level of intensity, our base case continues to be that, early in the next presidential term (2009), a national carbon policy will be adopted. In the meantime, states will continue to move forward independently.

Given President Bush's continued opposition to mandatory limits, the apparent desire of Congress to defer meaningful legislation to withhold credit from the current administration and the general distraction of the coming election cycle, we judge that the most likely time for passage is early 2009. We would then expect 3-4 years of legal discussion and negotiation, with implementation coming around 2012. The political affiliation of the new president may not be a deciding matter, given that leading candidates on both sides of the aisle have endorsed, to varying degrees, the idea of curbing CO₂ emissions.

With the ushering-in of the Democratic majority this year, congressional attention to this issue has increased substantially. Along with hearings and many rounds of testimony, seven comprehensive climate change bills have been introduced. Although the bills vary greatly in the aggressiveness of their targeted emissions levels, most propose to utilise a cap-and-trade system to regulate the utility sector or the market as a whole. The three bills that appear to have the broadest initial support are those introduced by Senator Carper (D-DE), Senator Feinstein (D-CA), and Senator Alexander (R-TN), which aim to reduce 2020 emissions by 10%, 15% and 30%, respectively¹²³. ■

¹²³ For further discussion of these and other proposed bills, please refer to Lehman Washington Analyst Kim Wallace's work: "Dictating Climate Change Legislation Options" published March 26th, 2007, and "Climate Change Call" published on May 15th, 2007.

Awareness is increasing among businesses

Over the past year, awareness of, and interest in, climate change has been growing in many businesses. The quotes below illustrate the range of sectors and countries in which the issue has been spoken about by senior business people.

“Without question, evidence shows that the earth’s average temperature has warmed by approximately 0.7°C in the last century. Without question, many global ecosystems, especially polar ones, are showing signs of warming. Without question, emissions and concentrations of carbon dioxide – one of several greenhouse gases – have increased during this same time period. The burning of fossil fuels and changes in land use are significant sources of CO₂ emissions (...) But it has become increasingly clear that climate change poses risks to society and ecosystems that are serious enough to warrant action – by individuals, by businesses, and by governments (...) And we believe achieving a uniform and predictable cost for carbon across the economy will enable market mechanisms to work effectively to this end.” **Rex W. Tillerson**, Chairman and Chief Executive Officer, Exxon Mobil Corporation, *at the Royal Institute for International Affairs (21 June 2007)*.

“Assuming that the science is correct, public opinion will move much faster than policy. Consumers are going to get more and more environmentally aware. Firms that don’t get that will simply go to the wall.” **Kit Braden**, Managing Director, L’Occitane en Provence, from one conversation with one of the authors.

“For us, as a company, the debate about whether man-made climate change is happening is over. The debate now is about what we can do about it. Businesses, like ours, need to turn to CO₂ management into a business opportunity by leading the search for responsible ways to manage CO₂, and use energy more efficiently. But that also requires concerted action by governments to create the long-term, market-based policies needed to make it worthwhile for companies to invest. With fossil fuel use and CO₂ levels continuing to grow fast, there is no time to lose.” **Jeroen van der Veer**, Chief Executive Officer, Shell, *Sustainability Report (2006)*.

“Environmental sustainability continues to be a key focus of our activities. As a global energy player, we have to work to the best of our ability to deliver a better world to future generations and disseminate environmental awareness, so as to respond to the challenge of not changing the world: that’s the real revolution.” **Fulvio Conti**, Chief Executive Officer, Enel, *Sustainability Report (2006)*.

“Scientists say with ever-increasing clarity that, if we fail to secure radical cuts in greenhouse gas emissions, the consequences for all of us could be severe. For each one of us this poses a challenge. I am determined that Tesco should meet this challenge by being a leader in helping to create a low-carbon economy.” **Sir Terry Leahy**, Chief Executive, Tesco, *Corporate Responsibility Review (2007)*.

“... we as a company, have to rise to the huge challenges we all face and make our contribution – first and foremost the reduction of CO₂ emissions and their consequences for climate change. Here all members of society are called upon to contribute whatever they can. (...) We have to meet our customers’ wishes for efficient and dynamic vehicles and, at the same time, continue to keep environmental protection in mind. And we must push ahead with innovations and develop drive concepts that guarantee individual mobility even in an age without fossil fuels.” **Norbert Reithofer**, Chairman of the Board of Management, BMW, *Annual Report (2006)*.

“To achieve sustainable mobility in the twenty-first century, Toyota is taking on the challenge to develop various technologies and incorporate them in products, including improved fuel efficiency to reduce carbon dioxide emissions, diversification of energy sources with an eye towards restricted petroleum consumption, and clean emissions and safety technologies.” **Katsuaki Watanabe**, President, Toyota Motor Corporation, *Sustainability Report (2006)*.

“Climate change and its potential impact on key sectors of the economy, such as agriculture, tourism, energy, transport and insurance, are dangers of the same order as the currency or interest rate risk. (...) As debate continues on the relationship between global warming and the rising frequency of high-impact weather related natural disasters, it is clear that the clustering of people and infrastructures in high risk areas multiplies the intensity of the potential adverse impacts of such events.” **Henri de Castries**, Chief Executive Summary, AXA, *at the Colloquium on Climate Change: What Risks for Business? (28 October 2005)*. ■

CONCLUSION: WHAT NEXT?

Summary

The question that we have been asked more often than any other – indeed, it has been put to us at the end of almost every client meeting – is: “What do you expect to happen next?”

Clearly, any response can only be highly speculative. Hence, the suggestions below are offered not in the belief that it is possible to predict with any certainty what will happen, but rather to serve as a yardstick against which to assess policy and other events as they unfold.

Suggestions are offered first on what may conceivably be seen in the field of the science, for that is the root of the climate change issue. Then come some suggestions about what may occur in the areas of climatology, and assessments of the resulting economic costs. There then follows what can only be called, at best, an educated guess about what may emerge in the all-important area of climate change policy, both internationally and nationally. The chapter concludes with a few potential implications for companies and investors.

We expect, over the coming several years:

Science

More evidence on feedbacks will become available

While the great majority of scientists now judge that earth’s recent warming is largely a result of man’s activities, and is capable of producing serious consequences, there is considerable uncertainty about how fast that warming will occur. Based on our discussions with scientists in the field, we suspect that:

- recent evidence suggesting that positive feedbacks are stronger than previously thought will strengthen; and
- projections of likely sea level rises may increase above the IPCC’s current estimate of 18-59 centimetres by the end of the 21st century¹²⁴.

Climatology

Climatic models will be refined

While climate change models are regarded by their constructors as affording a reasonable indication of the likely basic climatic consequences of warming, they are still in the course of development, and are being tested against the evolving data. We expect that, as the models are progressively refined:

- regional differentiation of projected climatic changes will continue to improve;
- the refinements will suggest stronger climate events in some areas, as for example has recently been suggested regarding the increasing destructive potential of tropical cyclones¹²⁵; and
- more reliable estimates will be produced of when these developments might be expected to occur.

Economic costs

Central estimates of economic damage could rise

The estimates that we have quoted in this report have, deliberately, been chosen from the conservative end of the spectrum. As further research is undertaken and integrated more completely with the evolving output of climate change models, we would expect the central estimates of economic damage to rise, because:

- as suggested above, the climatic simulations on which the economic cost estimates are based will themselves be somewhat greater; and

¹²⁴ Intergovernmental Panel on Climate Change (2007), vol.1, Summary for Policy Makers.

¹²⁵ Emanuel, K. (2005).

- the present generation of economic cost estimates do not fully include some potentially important consequences of climate change, such as effects on health, life expectancy, and population migrations.

We see a 75% probability that some sort of international agreement will be implemented ...

International policy

On the basis of our judgement and expectations concerning the likely evolution of scientific findings, the simulated climatic consequences and estimates of the economic consequences, we judge that present social and political preoccupations with climate change will intensify. Hence, we consider that:

... with carbon trading likely to be a significant component

- Political pressure for internationally-agreed policy action to limit emissions of greenhouse gases will continue to strengthen;
- The probability of some sort of international greenhouse-gas-limiting agreement in the next three to five years involving the US, China, and perhaps India, which earlier this year we put at 50%, will continue to rise. We now put the probability at around 75%;
- Equity considerations will figure importantly, in both national and international agreements. Negotiations will be both protracted and difficult, with agreements being reached more by political negotiation, than by objective criteria;
- Carbon trading is likely to be a significant component of most national policies;
- National carbon markets will in turn increasingly be linked with one another, probably with the EU ETS at the core, at least in the first instance; and
- The size of the carbon market globally, as measured by the value of permits issued, could, on a conservative estimate, be over \$100bn by 2020 or thereabouts. This assumes that the United States, Japan, and China join the EU in moving to an emissions trading scheme covering around 50% of their total emissions. Annual turnover would be a multiple of that figure. This compares with the US Treasury market which currently stands around \$2 trillion.

National policies

A number of features are likely to be common to many national policies:

National policy-making will move into treasuries and ministries of finance

- National policy-making responsibility will tend to move from ministries of environment, technology, and/or industry, into treasuries and ministries of finance;
- Treasuries and finance ministries will tend to favour policies that produce economically efficient, i.e. least-cost, solutions, and hence will place a greater emphasis on the price mechanism than has been the case so far;
- The proportion of country permits that are auctioned may well be higher than at present under the EU ETS. Permits are particularly likely to be fully auctioned in sectors, such as electricity generation, that do not face international competition;
- Policies will address *both* abatement *and* adaptation. Although the guiding principle that they will seek to apply will be that the last (marginal) dollar spent on each will save a dollar's worth of damage, in practice all sorts of abatement and adaptation projects will be undertaken, each with different implicit prices for carbon;
- Policymakers, particularly in finance ministries and treasuries, will be increasingly keen to refine a working value for the 'social' or 'damage' cost of carbon, and will increasingly require of non-price measures that they imply an implicit price of carbon that is reasonably close to that cost;
- Increasingly, it will be required of all regulatory proposals that they be costed (as is already the case in Australia); and
- Standards, particularly for buildings, will likely tighten considerably.

There are, however, likely to be a number of important differences between countries in the policies adopted:

In Europe:

In Europe, the EU ETS will be extended ...

- There will be an extension of the cap-and-trade system to other sectors, and aviation in particular;
- The proportion of permits that is auctioned will be higher than at present (5% in the first phase 2005-07, and 10% in the second phase 2008-12);
- The allocation processes across Member States will be harmonised, to avoid distorting competition across Europe;

... and regulations tightened

- The tightening of regulations, and standards, especially for buildings, will continue;
- The mandated share of renewable energy in total energy production will be raised, to 20% by 2020;
- The European Union will commit to achieving at least a 20% reduction of greenhouse gas emissions by 2020; and
- Legislation will be enacted in some countries to define emissions reduction targets beyond any international agreement, such as in the United Kingdom, where the Climate Change Bill, which could become law by mid-2008, seeks to reduce carbon emissions by 2050 by at least 60% from 1990 levels.

In the United States:

In the US, a federal carbon cap-and-trade scheme is likely to be implemented

- Particular emphasis will be placed on technological solutions, through:
 - more incentives to encourage the development of renewable portfolios; and
 - more incentives, and possibly public private partnerships, to technologies such as carbon capture and storage (CCS);
- At the level of Federal policy:
 - it is unclear that Federal legislation will pass by 2008;
 - with political pressure building, the new Administration is likely to play a strong role in 2009-10;
 - the industries likely to be the most affected are: utilities; cement; ferrous metal production and processing; and pulp and paper; and
 - automobile (CAFE) standards may either be revisited, or replaced by other forms of regulation (e.g. carbon fuel standards, upstream cap-and-trade on fuels, tail-pipe standards, etc.);
- A carbon cap-and-trade scheme is likely to be at the core of future climate change policy:
 - Progressively more states will join in market-based greenhouse gas limitation schemes in the coming two years;
 - With traction for auctioning increasing, the proportion of auctioning will be higher than that currently prevailing in Europe.

After a technological push, Japan will implement price-based policies

In Japan:

- Japan, which is already a low emitter in terms of intensity, will commit to further reduction in greenhouse gas emissions, perhaps by 50% by 2050;
- In the first instance, emphasis will be put on technological solutions, with:
 - A further push to nuclear power generation, which is likely to account for around 40% of total electricity supply by 2020, as nuclear is already today supplying around 30% of total Japanese electricity; and
 - Further development of innovative technologies, such as solar power and fuel cells;
- Japan will, however, likely also have to implement price-based policies, to go along with other G7 countries. Although a carbon tax has already been discussed, Japan will probably take part in a carbon trading scheme.

In China, regulatory measures will be invoked first

In China:

- In the coming year or two there will be a reluctance to commit to any commitment to quantified emissions reduction targets, not least on the equity argument that China was not responsible for the bulk of past emissions;
- However, China's authorities will become increasingly concerned at the domestic political implications of the country's growing air, water, and soil pollution problems, and administrative resolve to tackle these issues will strengthen;
- Increasingly, regulatory measures will be invoked and, in the process, legislation will also likely be introduced to improve energy efficiency (by, say, 20% by 2010); as well as to encourage renewable energy sources (to, say, 10% of total power supply by 2010);
- Furthermore, emphasis will be placed on research into energy-saving technology, improvements in water resource management, and public education campaigns to raise awareness of the issue;
- However, these measures are likely to prove inadequate. Longer term, say by 2009, China will in our judgement have no viable option but to introduce price-based policies, quite possibly a carbon trading system; and
- In this eventuality, it will have little substantive reason not to join in what by then stands to be an already near-global policy.

But price-based policies will have to be implemented afterwards

In India:

India may lag China in implementing climate change policies

- Well aware that India stands to be heavily affected by climate change, India's authorities will progressively engage constructively in international negotiations;
- However, there will not be any commitment to cutting carbon emissions, at least in the next several years;
- More emphasis will be placed on: energy efficiency in the use of coal and oil by industry; a greater use of renewables; improving air quality; and subsidising clean technologies and forestation;
- Specific measures will be announced in October 2007 and will provide a roadmap for climate change and a long-term strategy to reduce glacier melting; and
- However, India may well lag China, and be amongst the last of the major emitters to enact policy that seriously bears down on greenhouse gas emissions.

Share prices will increasingly be affected by environmental performance

Companies

While share prices will continue to be driven by the usual macroeconomic, sectoral and company-specific determinants, they will also increasingly be affected by companies' environmental performances, including their emissions of greenhouse gases. Specifically:

- Relative share prices will, over years rather than months, tend to move significantly *across* sectors, in accordance with (relative) carbon emission intensities; and
- Relative share prices will also tend to move substantially *within* sectors, again in accordance with (relative) carbon emission intensities.

Investors

- Carbon-light funds will, over a run of years, tend modestly but continually to outperform otherwise similar carbon-heavy fund; and
- Investor interest will grow in funds that track recognised indexes but comprise companies with a lighter carbon footprint. ■

Evaluating the EU ETS

Written with assistance from Eva Karra (ekarra@lehman.com)

The European Union Emissions Trading Scheme (EU ETS): a young carbon market

The EU ETS, which came into effect in January 2005, was constructed on the basic premise that setting emission caps and allowing them to be freely traded would enable companies to seek emission reductions wherever and however it was cheapest to do so. It is the world's most ambitious cap-and-trade scheme to date, covering 25 countries, each with authority to issue emission allowances. The sectors included in Phase I (2005-07) are: power generation; ferrous metal production and processing; chemical processes; mineral industry; and pulp, paper and board. These account for approximately 45% of EU CO₂ emissions. In its very first year of operation, the value of allowances issued across the EU reached more than €60bn¹²⁶.

Phase II (2008-12) expands the scope of the market to cover all greenhouse gases and adds further sectors, including aviation. And Norway, Iceland, Liechtenstein, and Switzerland will all join, even though they are not EU member states. Some economists have dubbed the EU ETS as "... by far the most significant accomplishment in climate policy to date"¹²⁷.

Has the EU ETS achieved its mission?

The EU ETS is sometimes said to have failed because the Phase I carbon price has fallen almost to zero. This situation arose because, at the outset, the European Commission had no reliable information about companies' emissions, and was therefore obliged to use figures provided by installations themselves. In the spring of 2006, it became evident that in fact actual emissions were below the initial allowances. This led to some of the most volatile days in the market as prices fell close to zero.

This issue was addressed in the Phase II National Allocation Plan decisions: the Commission both significantly reduced the allocated volume of permits, and limited the use of external credits. As a result, the price of future emissions under Phase II (starting in January 2008) is far from zero: the current price is around €20/tCO₂ (equivalent to €70 per tonne of carbon.)

The EU ETS has thus succeeded, and fairly quickly, in imposing a price on carbon. In 2006, €22.4bn worth of allowances were traded¹²⁸ – a substantial increase from the 2005 figure of €9.4bn. Furthermore, by opting for a market system, the EU has already succeeded in encouraging the private sector to invest in carbon-reduction projects. Significant capital has already been invested in emission-reducing projects in developing countries under the Clean Development Mechanism (CDM). Such projects generate emission credits that European companies can use to comply with the EU ETS via the Linking Directive¹²⁹.

The EU ETS' basic market design has enabled companies, across the EU and across different sectors, to trade in a relatively transparent market where price movements reflect evolving perceptions about scarcity and abatement costs. Within a year of its introduction, most installations established trading relationships and, by the first surrendering date, there were few cases of non-compliance. This was reflected in the exponential increase in traded volume, as well as in the diversity of active participants. By end-July 2007, daily volume had increased to an average of 6.5m EU Allowances (EUAs). The CDM/JI market is now evolving similarly. This year saw the development of the secondary CER market, which attempts to standardize the CDM market and allow market participants to access the credit market without exposing themselves to the primary market.

What next?

Debate seems to be shifting from "Is a cap-and-trade scheme the best solution?" to "How should a global cap-and-trade scheme best be implemented?" From a market perspective, the continuation of the EU ETS into a third phase is a fact, and both private and corporate players are pre-positioning with regards to that next phase. It will probably not be long before the market place attempts to price this future scenario. Whatever the decision beyond 2012, we judge that the EU ETS provides a credible first framework from which governments are gaining significant experience. ■

¹²⁶ Carbon Trust (2006).

¹²⁷ Ellerman, A.D. and Kuchner, B.K. (2007).

¹²⁸ Point Carbon.

¹²⁹ With the Linking Directive, carbon credits from Clean Development Mechanism and Joint Implementation projects under the Kyoto Protocol are able to be imported for use in the EU ETS.

KEY TERMS

Abatement. Action to reduce greenhouse gas emissions and thereby the extent of climate change. The word “mitigation” is also used in this sense in some of the literature. We use “abatement” throughout.

Adaptation. Adjustment to the consequences of climate change. The term refers both to actions in anticipation of climate change and to actions in response to it.

Annex I countries. The 40 countries plus the European Economic Community listed in Annex I of the United Nations Framework Convention on Climate Change (UNFCCC) that have agreed to limit their greenhouse gas emissions and to submit an annual greenhouse gas inventory.

Anthropogenic emissions. Emissions of greenhouse gases resulting from human activity.

Auctioning. The process whereby emission permits are sold, at the prevailing market price, to those who need to emit greenhouse gases and are required to have a permit to do so.

Carbon dioxide equivalent (CO₂e). An internationally accepted measure that, by means of agreed conversion factors, expresses the global warming capacity of different greenhouse gases in terms of the amount of carbon dioxide that would have the same global warming potential (GWP).

Carbon price. The level of the carbon tax in a tax regime and the market price of carbon in a trading regime. In an optimal regime, the ‘social’ cost of carbon, the optimal carbon price and the carbon price are all equal.

Certified Emissions Reduction (CER). A carbon credit developed by carbon offset providers that is certified as being equivalent to one tonne of CO₂ under the United Nations’ Clean Development Mechanism (CDM).

Chlorofluorocarbons (CFCs). Synthetic industrial gases composed of the elements chlorine, fluorine and carbon. They have been used as refrigerants, aerosol propellants and cleaning solvents. Their use has been prohibited by the Montreal Protocol because of their harmful effect on the ozone layer.

Clean Development Mechanism (CDM). An arrangement under the Kyoto Protocol whereby industrialised countries with greenhouse gas reduction commitments (Annex I countries) may invest in projects that reduce emissions in developing countries.

Climate change. The term generally refers to long-term, persistent, changes in the average climate.

Cost-benefit analysis. An economic tool, designed to quantify the feasibility of a project or a plan by comparing its costs and its benefits – including, often importantly, costs and benefits whose prices cannot be obtained from market information.

Discounting. The process that reduces future costs and benefits to reflect the time value of money and the (common) preference for consumption now rather than later.

Emissions Reduction Unit (ERU). A reduction of one tonne of CO₂ equivalent, particularly under the Joint Implementation (JI) mechanism.

Emissions trading. The market mechanism which allows emitters to buy emissions from, or sell emissions to, other emitters.

European Union Emissions Trading Scheme (EU ETS). The world’s largest multi-country, multi-sector, greenhouse gas emission trading scheme. The scheme, in which all 25 member states of the European Union participate, started operations on 1 January 2005.

Externality. In the context of climate change, a cost or a benefit that is neither paid for, nor received by, the company, person, or other entity which gives rise to it.

Grandfathering. An allocation method whereby emissions permits are issued to emitters free of charge, on the basis of each emitter’s past emissions.

Greenhouse effect. The process whereby infrared radiation emitted by earth is reflected back down from the atmosphere, thereby raising earth’s equilibrium temperature.

Greenhouse gas. Any gas, such as carbon dioxide (CO₂), methane (CH₄) or water vapour (H₂O) that gives rise to the greenhouse effect.

Hydro fluorocarbons (HFCs). Synthetic industrial gases, which do not contain chlorine, and which are primarily used in refrigeration and semi-conductor manufacturing as commercial substitutes for chlorofluorocarbons (CFCs). They do not have any known effect on the ozone layer, but are greenhouse gases and hence do cause global warming.

Intergenerational equity. The issue of the fairness of the distribution of the costs and benefits that are borne by different generations. In the case of climate change policy, for example, action or inaction today has impacts not only on the present, but also on future, generations.

Intergovernmental Panel on Climate Change (IPCC). The IPCC was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The role of the IPCC is to "... assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation."

Joint Implementation (JI). An arrangement under the Kyoto Protocol whereby industrialised countries with a greenhouse gas reduction commitment (Annex I countries) may invest in emission-reducing projects in another industrialised country, as an alternative to reducing emissions in their own.

Kyoto Protocol. An international agreement adopted in December 1997 in Kyoto (Japan). The Protocol sets binding emission targets for developed countries that would reduce their emissions on average by 5.2% below 1990 levels.

Montreal Protocol. The Montreal Protocol on Substances that Deplete the Ozone Layer is an international treaty designed to protect the ozone layer by phasing out the production of a number of substances believed to be responsible for ozone depletion. The treaty was opened for signature in September 1987, and entered into force on 1 January 1989.

National Action Plans (NAPs). Under the European Union Emissions Trading Scheme, each Member State must propose a NAP, which is submitted to the EU Commission for acceptance. NAPs have to fulfil 12 criteria set out in the Emission Trading Directive. The first and foremost criterion is that the proposed total quantity is in line with the Member State's Kyoto target.

Optimal carbon price. The price at which the marginal cost of reducing carbon emissions and the marginal benefit of reducing climate-change-induced damage are equal.

Parts per million (ppm). The number of unit parts of a substance contained in a million unit parts of another substance.

Positive feedback. A process that, by 'feeding on itself', amplifies the initial response of a system to an external shock. For example, the release of methane by rotting vegetation that has become exposed as a result of ice melting increases the atmospheric concentration of methane, a greenhouse gas. This in turn further warms the planet, resulting in further melting of ice, the release of more methane, and so on.

Revenue recycling. The return to the economy, for example by a lowering of income or value added taxes, of revenues accruing to government from the taxing of emissions or the auctioning of emission permits.

Social cost of carbon. The damage value of an additional tonne of carbon emissions.

United Nations Framework Convention on Climate Change (UNFCCC). A treaty, signed at the 1992 Earth Summit in Rio de Janeiro, which calls for the "...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

FIGURES

Motivation: Why climate change matters to business

Figure 1. Climate change headline hits

Figure 2. 10-year German and Italian government bond yields

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