4 Is Kyoto a good idea?

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Introduction

In 1997 the Kyoto Protocol ('Kyoto') was signed by 172 countries. It is by far the most ambitious international environmental treaty ever attempted, with the purpose of controlling emissions of greenhouse gases (GHGs) related to human activities, mainly carbon dioxide (CO_2) from carbon-based fuels. The regime intended to reduce emissions from industrialised countries so that during the period 2008–12, they are 5.2% beneath their levels in 1990.

Although there was agreement in principle to this regime, since 1997 the path has been extremely rocky. Though the USA decided in 2001 not to ratify the treaty, the other signatories have decided to forge ahead. Most of the participants, including the countries of the European Union, have now ratified the treaty, which will come into force if Russia ratifies in the autumn of 2003.

The Kyoto Protocol resulted from the concern that if humans exacerbate the greenhouse effect, the earth's climate and human living conditions will suffer. The intended benefit of the treaty is to prevent the potential negative effects of a warmer climate, such as extreme weather events and sea-level rise.

Kyoto attempts to achieve this goal by limiting human emissions of greenhouse gases in industrialised countries, which is currently provided by the burning of hydrocarbon-based fuels and therefore results in considerable emissions of GHGs. Such a policy does not come without costs to society – our economic production, prosperity and lifestyle depend on access to cheap and reliable energy. Therefore the agreement has significant costs for our everyday lives.

While Kyoto may be based on good intentions, good intentions do not make sound public policy. What matters for Kyoto is expected results. We do not know what will happen in the future, but it is worth asking 'Does the Kyoto Protocol appear to be a good idea given reasonable expectation of the future based on the best available current knowledge?'

The purpose of this chapter is to answer this important question, with an analysis of the expected costs and benefits of the Kyoto Protocol, amidst significant uncertainties and unresolved scientific issues. To achieve this, we ask: How significant are man-made emissions of greenhouse gases? Does the expected climate change pose a problem? How will Kyoto address this problem, and at what cost? Fundamentally, is the Kyoto Protocol the right approach to address climate change?

How significant is man-made warming?

Scientists are in broad agreement that human activities have some influence on global mean temperatures and climate, but they disagree about the extent of this influence. Even without the influence of humanity, the earth's climate would not be stable – it experiences extreme natural changes, and small man-made temperature increases are likely not to be a huge problem.

It is almost as uncontroversial that uncontrolled human emissions of GHGs will result in a rise in global mean temperatures – all other things being equal. This does not in itself justify political action in general or the Kyoto Protocol in particular. The earth's climate would not be stable without human influence. In fact climate has always changed and will always change. Therefore, small man-made temperature increases are not a problem.

To evaluate the Kyoto Protocol, it is important to establish by how much temperatures can be expected to rise over a relevant timescale because of the influence of human activities. The Intergovernmental Panel on Climate Change (IPCC) has attempted this exercise for the past fifteen years. 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:

> 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. The IPCC does not carry out research nor does it monitor climate related data or other relevant parameters. It bases its assessment mainly on peer reviewed and published scientific/technical literature.[1]

In its third assessment report (2001), the IPCC predicted that the global mean surface temperature would rise by 1.4–5.8°C[2] and came to the widely quoted conclusion that: 'There is new and strong evidence that most of the warming observed over the last 50 years is attributable to human activities.'[3]

The IPCC's conclusions are highly controversial. Its prediction depends on two sets of computer models, one of which predicts how much CO_2 and other greenhouse gases human activities will emit into the atmosphere, and the other of which predicts how the climate will react to such increases.

The quality of the predictions depends entirely on the ability of the models to produce reliable results – but in fact, there are two main uncertainties which hamper these models. We do not know how sensitive the earth's climate system is to increased levels of CO_2, nor do we know how much CO_2 we will emit.

How sensitive is the earth's climate system to CO_2?

It may seem surprising that this should be a controversial question since the basis of greenhouse theory rests on solid scientific knowledge. It is controversial because the expected effect of increased levels of CO_2 on climate can be divided into direct and indirect effects. The direct effect is a function of the radiative properties of CO_2 (its ability to trap infrared light), which are fairly well established. But this direct effect of increased CO_2 is relatively small. The IPCC estimates the direct effect of a doubling of CO_2 in the atmosphere would be on the order of 1.2°C with an accuracy of +/-10%.[4] The major part of the CO_2-warming predicted by computer models is based on indirect feedback effects.

The most important indirect feedback effects are caused by water vapour. According to the IPCC: 'In models, increases in water vapour … are the most important reason for large responses to increased greenhouse gases.'[5]

Water vapour is by far the most important GHG. Humans 'emit' water vapour, but in minute amounts compared to natural evaporation from oceans and the earth's biomass. This evaporation is not a problem, since water does not accumulate in the atmosphere like other GHGs. Unlike CO_2, methane and other GHGs, there is a limit to how much water vapour the atmosphere can carry – that is why water vapour turns into rain, fog or dew and carbon dioxide does not. But when temperatures rise, the atmosphere absorbs more water vapour, so an increase in CO_2 leads to a small rise in the global mean temperature. Higher temperatures increase humidity, and since water vapour in the atmosphere is itself a greenhouse gas there is a further rise in temperature. That is a feedback effect.

The problem for climate modellers is that, unlike the direct radiative effect of CO_2, indirect feedback effects are not well understood. To estimate the indirect effects, we need a detailed understanding of the climate system itself, but we lack that understanding because the climate system is extremely complex.

We know that there are both positive and negative feedbacks in the system. Water vapour forms clouds. Some types of cloud have a net warming effect, and others have a net cooling effect. Some clouds trap reflected infrared heat which is 'escaping' the atmosphere, so they have a warming effect. Others reflect incoming solar radiation back into space and thus have a cooling effect. To model the feedback effect of clouds, modellers need to know how clouds are formed and how they behave – but they don't. The IPCC admits in its latest assessment report that 'Clouds represent a significant source of potential error in climate simulations … The sign of the net cloud feedback is still a matter of uncertainty …'[6] and

> Probably the greatest uncertainty in future projections of climate arises from clouds and their interactions with radiation … increased physical veracity has not reduced the uncertainty attached to cloud feedbacks: even the sign of this feedback remains unknown.[7]

Thus, a huge degree of uncertainty surrounds climate modelling, which implies that the major part of the warming predicted by climate models is uncertain.

In fact, recent research indicates that the positive feedback effects from clouds may be vastly exaggerated in current models. A few years ago, Professor Richard Lindzen, meteorologist at the Massachusetts Institute of Technology, published with colleagues from NASA a peer-reviewed article which highlights the extent of uncertainty about clouds.[8]

The researchers found that the area of cirrus clouds over the equatorial Pacific Ocean correlated negatively with temperature. In other words, the production of cirrus clouds went down as temperature went up. The net effect of cirrus clouds is to trap heat, so if the statistical correlation represents a climate mechanism, Lindzen may have found a powerful negative feedback which current climate models do not account for. It would be so powerful that it would reduce the effect of a doubling of CO_2 from the current IPCC estimate of 1.5–4.5°C to 'a half degree or maybe one point-something', according to Lindzen.[9]

Most of the warming predicted by climate models results from built-in assumptions that positive feedbacks will considerably outweigh negative feedbacks. These assumptions are also uncertain, and they are contradicted by research conducted by Lindzen and other scientists.

Indeed, chapter 7 of the latest IPCC report deals extensively with the physical processes underlying the presumed feedback effects and points out many problems with the way computer models represent these processes. But in the 'Summary for Policymakers' this 35-page chapter is summarised in one sentence under the heading 'Confidence in the ability of models to project future climate has increased'. That sentence reads: 'Understanding of climate processes and their incorporation in climate models have improved, including water vapour, sea dynamics and ocean heat transport.'[10] While this is undoubtedly true, it is not the whole truth. Some quotes from the executive summary of chapter 7 put that sentence into context:

> While improved parametrizations have built confidence in some areas, recognition of the complexity in other areas has not indicated an overall reduction or shift in the current range of uncertainty of model response to changes in atmospheric composition.

> Probably the greatest uncertainty in future projections of climate arises from clouds and their interactions with radiation …
>
> … increased physical veracity has not reduced the uncertainty attached to cloud feedbacks: *even the sign of this feedback remains unknown*. [emphasis added]
>
> … significant deficiencies in ocean models remain.
>
> Uncertainty resides with the relative importance of feedbacks associated with processes influencing changes in high-latitude sea surface temperatures and salinities, such as atmosphere-ocean heat and fresh water fluxes, formation and transport of sea ice, continental runoff and the large-scale transports in ocean and atmosphere.
>
> There has been an increase in uncertainty in those aspects of climate change that critically depend on regional changes.[11]

How much CO_2 does humanity emit?

The IPCC emissions scenarios

The climate models calculate the consequences of increasing atmospheric GHG concentration – typically at a level equivalent to doubling of atmospheric CO_2 compared to the pre-industrial level. However, to forecast expected warming, modellers need estimates of the rate of increase of CO_2 to determine when CO_2 concentrations will double, which means that they need forecasts of human emissions of CO_2 throughout the 21st century.

The IPCC has carried out such long-range forecasting exercises for all of their three assessment reports since 1992. The latest results were published in 2000 in the Special Report on Emissions Scenarios (SRES).[12] The SRES working group produced 40 scenarios, out of which six were chosen as 'marker scenarios' and fed into the climate models. The emissions scenario exercise is a crucial step in creating the above-mentioned temperature growth range for 2100 of 1.3–5.8°C. In fact, most of the span in this temperature range is produced by the huge difference in emissions across the marker scenarios.

The scenarios are based on parameters which influence emissions, such as GDP per capita growth; population growth; energy efficiency (how much GDP does one unit of energy produce); composition of fossil fuel consumption (coal, oil, gas); and non-carbon fuels' share of total energy production (nuclear, wind, solar, etc.).

Use and abuse of scenarios

The quality of the emissions forecasts depends entirely on how these parameters are treated and their values in the different scenarios. Over a century, the degree of uncertainty for each parameter is enormous, and these uncertainties compound. However, this does not mean that anything should be considered plausible.

A variety of problems such as sloppiness and poor methodology plague the use of economic scenario methods in many applications, and the IPCC is no different. Unfortunately the Special Report on Emissions Scenarios, part of the IPCC, does a very poor job of creating plausible scenarios.

The IPCC treats the period 1990–2000 as part of the forecast period, without consideration for the actual data that exist for that period. Apparently the SRES reused data from previous scenario exercises, which have been proven wrong by time and real world observations.

For instance the scenario figures used for the increase in world GDP between 1990 and 2000 vary between 20.6% and 35.4%. However, IMF data for most of that period was available in 1999 and showed growth of 36.5%.[13] This error probably does not have a substantial impact on model results by 2100, but it is amazing that such sloppy practices are used as an input to a modelling exercise that involves the use of supercomputers and costs millions of euros.

The IPCC also suffers from poor methodology. One leading economic modeller, John Reilly of the MIT Joint Program on the Science and Policy of Global Change, calls the SRES approach to scenario building an 'insult to science'.[14] According to Reilly the scenario teams have worked backwards from a desired end result in terms of emissions and temperature increases. In other words, the IPCC has allegedly started with an emission projection, then made an estimate of the relationship between emissions and growth, and finally calculated the growth rate needed to achieve the desired emissions projection.[15]

Economists Ian Castles and David Henderson recently called attention to a specific deficiency in methodology, observing that the method for calculating future GDP was based on an inappropriate assumption about exchange rates between countries. This seemingly innocuous methodological sleight of hand led to an overestimate in future emissions.

Castles and Henderson concluded that: 'The SRES projections do not, as is claimed for them, encompass the full range of uncertainties about the future ... The SRES should not be taken as the accepted basis for the IPCC's coming Fourth Assessment Review.'[16]

The most serious objections to the SRES result from their use of scenarios as forecasts. The SRES states that they are 'images of the future or alternative futures' and should not be seen as predictions or forecasts, but then it feeds the emissions scenarios into a computer and produces an apparently concrete result about what the temperature will be. Though the SRES presents these scenarios as an exercise in 'free thinking' about the future, the IPCC relies on them as direct evidence for the need to drastically curtail global CO_2 emissions.

The SRES claims that the scenarios 'are not assigned probabilities of occurrence, neither must they be interpreted as policy recommendations'.[17] But since each scenario results in a figure, there is an implicit bias in favour of extreme scenarios, because they extend the temperature range.

The SRES scenarios are used to make forecasts – so the SRES team abuses the scenario method. In the real world, extreme outcomes are treated as less likely and therefore are assigned less importance. The SRES scenarios do not have assigned probabilities. This is a normal practice when working with scenarios, since such exercises are intended to cover a full range of possible futures. Yet it implies that scenarios should not be used as forecasts, because a forecast doesn't make sense without a discussion of probability. Meteorologists only make weather forecasts extending three to five days into the future. The reason why they don't make longer forecasts is that there is only a very small probability that they will be correct.

How much warmer will the climate be by 2100?

Table 2 summarises the basic steps that the IPCC goes through to achieve the expected warming interval (left-hand column). For each

Table 2 **IPCC's forecasting and uncertainties**

Forecast exercise	*Principal uncertainties*
Create scenarios for future emissions of CO_2	World GDP growth per capita and its distribution among low-, middle- and high-income countries
	Population growth
	Composition of different fossil fuels in total consumption
	Technological change, including shifts to non-carbon or low-carbon energy sources, energy efficiency, carbon sinks etc.
Convert emissions to atmospheric concentrations	The lifetime of different GHGs in the atmosphere
Model radiative forcing and convert this forcing to a projected temperature	The sensitivity of the climate system to increased CO_2 (feedback effects of clouds, aerosols etc.)
	Natural climate effects enhancing or counterbalancing man-made effect

step it lists widely considered uncertainties given current scientific understanding (right-hand column).

We simply do not know how much warmer the climate will be in 2100. In fact, the degree of (compound) uncertainty is so large that the mere exercise undertaken by the IPCC of providing temperature intervals is highly misleading and provides phoney confidence. For many of the parameters even the degree of uncertainty is controversial. Climate science is not yet capable of providing confidence intervals, especially one hundred years into the future. In fact even the term 'uncertain' is often misleading when it comes to climate science – many things are not uncertain but simply *unknown*. For all climate scientists know, climate might have cooled by the year 2100!

The National Academy of Sciences report concludes:

Because there is considerable uncertainty in current understanding

> of how the climate system varies naturally and reacts to emissions of greenhouse gases and aerosols, current estimates of the magnitude of future warming should be regarded as tentative and subject to future adjustments (either upward or downward).[18]

The climate sensitivity of the models is largely based on a number of positive feedbacks, whereas negative feedbacks are probably underestimated or completely ignored. The temperature range should be decreased because climate models almost certainly overestimate the sensitivity of the climate system to increased CO_2. On top of that, the emissions scenarios produce growth rates of carbon emissions which are not in line with recent history. Given this knowledge, downward adjustments seem to be the best option, but there are strong indications that the IPCC has a systematic bias in favour of exaggerated temperature increases.

Will warming be a problem for humans?

Advocates of the Kyoto Protocol often justify this policy on the basis that climate change will adversely affect human beings. So, from a human welfare perspective, what might be the effects of climate change?

Using a human-centred approach also implies using a dynamic approach. With the right incentives and institutional framework, people solve problems, they rise to challenges and adapt. They invent new technologies and new ways of doing things. And over the course of an entire century they will have plenty of time to do so. Some of the climate change models assume that people don't adapt to new conditions – that is not a reasonable assumption.

A rise in sea levels

The IPCC expects sea levels to rise 9–88 cm by 2100 – a wide-ranging figure, and, given scientific uncertainties, the high figure should be taken with a pinch of salt. Even if sea levels were to rise by as much as a metre, it would be a minor problem. In some parts of the world, people would have to adapt to avoid flooding. The IPCC predicts that damage to infrastructure in coastal areas would costs tens of billions of dollars. However, these estimates are based on the rather absurd assumption that people and countries will just idly sit by and watch. Instead countries would act to protect coastal areas – just as the people of Holland have done for centuries. This adaptation can be done with relatively low costs. The IPCC estimates that for most countries the costs of protection are in the region of 0.1% of GDP.[19]

The US Environmental Protection Agency has estimated that the cost of coastal protection against a whopping 1-metre rise in sea level would be just 1.5% of one year's GDP at current levels of output.[20] Since sea levels rise gradually, the investment could be spread out over 50 to 100 years. On top of that, most of the investment would take place in a future where the US GDP would be anywhere from five to ten times higher than the present. In other words, even a 1-metre sea level rise would have little impact on human welfare, even if developed countries were to finance all adaptive measures in developing countries.

Extreme weather events

This is one of the most popular misconceptions about the effects of climate change. Despite much media spin, there is no empirical evidence that hurricanes and storms are increasing in frequency or intensity.[21] The US has fewer hurricanes during hot El Niño years than during normal years.[22] Climate models do not predict these developments: '… climate models currently lack the spatial detail required to make confident projections. For example, very small-scale phenomena, such as thunderstorms, tornadoes, hail and lightning, are not simulated in climate models.'[23]

Although global warming is expected to cause increased rainfall in many parts of the world, increased problems with flooding are almost entirely linked to developments such as urbanisation, sewage systems leading rain water quickly into rivers, conversion of wetlands, deforestation etc.

The higher insurance costs of weather-related natural disasters are, according to insurance company Munich Re, caused not by global warming but by a growing world population. More and more people can afford insurance, and they have more property to lose and increasingly live in higher-risk coastal areas.[24]

Changes in agricultural output

If climate changes without farmers adapting their behaviour accordingly, global warming would be detrimental to agricultural output.

But it is not reasonable to assume that farmers would not adapt to changing conditions. If reasonable assumptions about adaptive behaviour concerning crops and technologies are included, global warming is expected to benefit agricultural output in industrialised countries, because a warmer and more humid atmosphere is good for plant growth and because CO_2 enhances the growth of plants.[25]

According to models used by the IPCC, the benefit in agricultural output will mainly be in developed countries in the cooler northern hemisphere. In the Third World, the models expect a negative impact because of the rise in (already high) temperatures. IPCC assumptions about adaptation seem far too conservative: 'These studies do not fully or adequately account for technological progress and adaptation ... which not only overestimates the potential negative impact but also *underestimates the potential gains from harnessing positive aspects of global warming*'[26] (emphasis added).

The IPCC uses a completely unrealistic worst case scenario,[27] with a 4.0–5.2°C temperature increase as early as 2060, in which only current technologies and crop varieties can be used, and no new technologies – crops, irrigation methods, pesticides or farm machinery – will be invented. But even this nightmare scenario produces an outcome where developing countries only lose 6–7% of agricultural output.

It seems likely that with adaptation and technological advances, less developed countries will not suffer a loss in agricultural output because of global warming. In fact, the models probably overestimate the negative effect from rising temperatures, because most of the actual warming is occurring at night.[28] This will extend the growing season, while the risk of drought and other heat wave damage is reduced.

Consequences for human health

Global warming is not likely to have a negative effect on human health. Humans have successfully adapted to varying climates. There is no general temperature level at which heat suddenly becomes dangerous to human health. On the contrary, heat-related mortality increases when the temperature rises above what the local population is accustomed to. In Finland heat-related mortality sets in at 17.3°C, in Athens at 25.7°C.[29]

Over the course of a century, humans will adapt to rising temperatures, or they will adapt their environment to the temperature, and they will suffer no adverse health effects. In fact, since death rates due to extreme cold are double those due to extreme heat, there might be a net benefit from warming in the number of lives saved.[30]

Some alarmists promote the idea that tropical diseases will spread because of global warming. However, the geographical spread of these diseases has very little to do with climate. In the nineteenth century, malaria, cholera and other diarrhoeal and parasitic diseases were prevalent around the world, including northern Europe. Malaria was endemic in England until the late 1800s and in Finland until after World War II. Today these diseases are problems 'only in countries where the necessary public health measures are unaffordable or have been compromised.'[31]

Wealth and a functioning public health system is what matters when it comes to combating tropical diseases.

The costs and benefits of the Kyoto Protocol

The Kyoto Protocol was adopted with the objective of establishing a regulatory framework that could tackle the threat of global warming. The main mechanism for achieving this is quantified emissions commitments. Only industrialised countries with high per capita emissions, listed in Annex 1 to the Treaty, are bound by the emissions agreement.

The Annex 1 countries include the USA, OECD countries in Europe, Japan, Canada, Australia, New Zealand and economies in transition: Russia, Ukraine, Poland and Hungary, amongst others.

These countries agreed to cut their emissions of GHGs. Each country agreed to achieve a specific percentage reduction by 2008–12 relative to 1990 (the base year) emissions. The USA agreed to cut emissions by 7% and the EU by 8%, and Japan agreed to a 6% reduction. The EU reduction was later divided internally among the EU countries. Some countries were actually allowed to increase emissions (especially poor southern European countries) while others took deeper cuts to compensate.

The negligible benefits of Kyoto

The benefit of the Kyoto commitments comes from the extent to which emissions reductions avoid the costs of global warming. Additionally there might be tangential benefits, for instance reduced air pollution. The costs of the Kyoto Protocol are the costs of limiting energy use. The expected benefits are virtually all in the long run, since global warming would happen gradually as GHGs accumulate in the atmosphere, but the costs are paid immediately.

The main expected benefit of Kyoto-type initiatives is that less CO_2 causes less warming. However, the size of this benefit is extremely uncertain because we do not know how much warming we will avoid (i.e. the benefit) from incurring the costs of Kyoto, nor do we know if the warming we are avoiding is actually detrimental. If Kyoto avoids the marginal effects of a small amount of warming (as seems almost certain – see below), it would probably not be beneficial at all, even if it could be implemented at no cost.

Given current (lack of) knowledge it does not even make sense to calculate the benefits of Kyoto: they are not just uncertain, they are unknown. They could be positive or negative. No one knows, and we cannot know until we achieve a better understanding of both climate and climate change.

The costs of Kyoto in the EU

It is an established fact that the Kyoto commitments will have little impact on emissions and global warming. There are two reasons for this. First, the agreed reductions amount to just 5.2% reduction below the 1990 level for the industrialised countries overall. This will not stop the accumulation of GHGs in the atmosphere. Second, and more significantly, although currently Annex 1 countries are responsible for most of global GHG emissions, this situation will change as populous Third World countries such as China and India grow richer. Over the next decades increasing emissions from less developed countries will completely drown out the small reductions achieved by Kyoto.

This has caused some critics of Kyoto to ridicule it as a futile exercise. But that misses the point: the Kyoto Protocol is far more than just a specific commitment to reduce emissions by a certain date. It provides a global mechanism for *future* commitments, and commits parties, for instance, to open negotiations on a second commitment period no later than 2005. It is the general understanding of government officials and academics participating in or following the Kyoto process that the Protocol is a mechanism which will progressively seek deeper cuts in carbon emissions, and that commitments will eventually expand geographically to include all countries.

There are two relevant periods for estimating the costs of the Kyoto Protocol – the first commitment period, until 2012, and then beyond 2012. While it is possible to estimate the costs of Kyoto during the first commitment period, those of a post-Kyoto regime are highly uncertain.

The first commitment period, 2008–12

The costs of the carbon reduction commitments depend on the extent to which the parties to the treaty are allowed to trade CO_2. Trading CO_2 implies that countries are allowed to sell or buy rights to emit CO_2. A market for CO_2 will evolve and CO_2 will be traded at a market price. Some economic agents will be able to cut CO_2 emissions cheaply – and they can make money by selling their extra emission rights on the market. Others, who face higher costs of cutting emissions, would happily buy these rights. This reduces the overall costs of curbing emissions, because the market allows for CO_2 emissions to be reduced where it costs the least.

In October–November 2001 the seventh Conference of the Parties in Marrakech agreed on a regime that allows emissions trading[32] and a carbon trading market is now evolving.[33] The consequences for total abatement costs are significant: several studies show that a regime allowing trade among all Annex 1 countries would reduce abatement costs between 50% and 75%.[34]

Trading is the most cost efficient way for EU countries to fulfil their Kyoto obligations – and the ultimate costs to them depend on whether or not they will use trading. During most of the negotiations, the EU countries were against trading, as were most environmental organisations. They feared that trading would lead to countries buying 'hot air' in Russia and eastern Europe instead of actually making an effort at home to save energy and develop more efficient technologies.

The 'hot air' issue arises because Russia and Eastern Europe have experienced dramatic economic collapses just after the 1990 base year. This resulted in decreases in energy consumption and emissions. Despite the fact that these economies have grown considerably over the past 6–8 years, emissions have not returned to previous levels.

Emissions in these countries have actually fallen far below their Kyoto commitment, which is a reduction of 0–8% (depending on country) relative to the base year (1990), so these countries have excess carbon to sell on the market. They may need this carbon in the future, but that does not seem likely (at least in the short term) given recent emission trends in these countries.

The price of carbon depends on the supply and demand. In 2001 three events drastically changed the supply and demand for carbon. First, the USA – by far the largest source of potential demand for carbon – withdrew from ratifying Kyoto. Second, Russia's energy projection was revised downward thus increasing their carbon surplus. Third, the Bonn/Marrakech negotiations introduced a CO_2 allowance of 'carbon sinks' into the Kyoto regime, which allows countries to subtract carbon absorbed by managed forests from their emissions. Russia's sink allowance was almost doubled, which further increased its surplus carbon.

The result of these developments was that the price of carbon plummeted. Recent price estimates range between US$5 to US$13 per tonne.[35] Assuming that European countries decide to fulfil their Kyoto obligations by buying carbon, and that the carbon allowance in Russia and eastern Europe is sufficient and traded, compliance with the Kyoto Protocol until 2012 would be very cheap, because actual emissions reductions will be minute. Kyoto 2008–12 is estimated to reduce global CO_2 emissions by less than one per cent relative to no policy.[36]

Such a reduction would have no measurable effect on climate whatsoever. Virtually all the emissions reduction has already taken place in Russia and eastern Europe during the transition from central planning to market economy, and the costs of this reduction have also been carried by these economies. The costs of Kyoto will not be incurred by efforts to cut emissions but will be a transfer of money from Europe (and Japan) to Russia and eastern Europe.

The EU as a whole would have to spend between €940 million and €2.6 billion if they were to comply with Kyoto today. In nominal terms that is a lot of money, but it is only 0.01–0.03% of EU GDP. However, it is a yearly cost, and it would increase as economic activity – and thus emissions 'demand' – increases.

This would be the cheapest possible scenario, but several factors are likely to increase the costs considerably.

It is uncertain that the complete allowance from Russia and eastern Europe will be available for trading, and economic models show that the future trading price is very uncertain. One study shows that increasing the assumed GDP growth rate in Russia by 1% for ten years would cause the carbon price to increase by 50%.[37] The fact that just one variable has such a large influence on carbon prices shows how vulnerable the carbon market will be. Also, eastern Europe and Russia could decide to bank their CO_2 allowance for use in the future. This could happen if the price becomes too low or if they collude to push up prices. In the latter case Kyoto compliance would become more expensive.

Carbon prices are vulnerable, but given the supply and demand situation, it is difficult to imagine carbon trading costs multiplying.

What could increase costs is if the EU countries decide to finance a major share of emissions cuts on their own. While the Kyoto Protocol does allow trading, article 6 (d) provides the following limitation on trade: 'The acquisition of emission reduction units shall be supplemental to domestic actions for the purposes of meeting commitments under Article 3.'

This provision is vague, which leaves it open to interpretation. In practice some countries are interpreting it strictly, possibly for ideological or political reasons. Holland and Italy have announced that they will fulfil only half their targets through trade.[38] In Denmark the government decided in early 2003 to use the trading regime to minimise costs of abatement.[39] However, this decision was ferociously criticised by the left wing opposition. At the time of writing legislation has been passed by the European Parliament which will allow an EU-wide trading scheme to go into effect in January 2005.

If the EU or individual countries choose not to utilise the trading regime, costs will increase significantly. This is because national measures would actually reduce CO_2 emissions rather than simply requiring businesses to buy 'hot air'.

A large number of economic models have estimated the costs of Kyoto under different assumptions. One of these assumptions[40] is a regime where no trade is allowed. This is similar to a situation where countries decide to curb CO_2 by using national measures despite the existence of a trade regime. The lowest estimate indicates a loss of 0.31% of GDP per year in OECD Europe. The highest estimate shows a 2.08% loss.[41] For OECD Europe this would be equivalent of €34–230 billion a year.

The probable outcome is that the 2008–12 commitment period will cost much less than expected before Marrakech and the US opt-out – probably less than half a percentage point of GDP. However, the effectiveness of the money spent in terms of carbon reduction will be very low. One of the leading economic modellers suggests that 'the overall assessment of the accord is that it pays a high price for very small reductions in carbon emissions.'[42]

Beyond 2012

Extending the current Kyoto regime into the future would be far more expensive in subsequent commitment periods than in the initial 2008–12 period. There are two main reasons for this. First of all, the large allowance of CO_2 in Russia and eastern Europe will gradually disappear as their economies grow and emissions rise. This will result in a steep increase in carbon prices. The expected low carbon price of the first commitment period is a result of unique circumstances – including the US withdrawal – which are unlikely to recur.

Secondly, the marginal costs of CO_2 abatement increase rapidly. The costs of cutting the first tonne of CO_2 are low but rapidly it becomes more difficult to find cheap reduction options. Denmark is a case in point. Its GHG reduction efforts have been relatively intense for about a decade, and its CO_2 emissions have nearly stabilised. A recent study concluded that: 'Denmark has … been focussing on CO_2 emissions reductions for some time now. As a result of this the measures that are possible today and lead to real reductions are relatively expensive.'[43]

Even if Kyoto is merely extended into the future, stabilising Annex 1 country emissions at 5.2% below the 1990 level, costs will increase exponentially. The reason for this is that, as economies grow, new ways of avoiding GHG emissions will have to be found in order to stabilise emissions, which is costly. Alternatively – and even more costly – economic growth would have to be avoided.

One study used a computer model to analyse a scenario where the Kyoto Protocol is extended forever (for the whole of the 21st century) in the Annex 1 countries.[44] The Protocol would permanently decrease European GDP through the 21st century. After ten years GDP would be approximately 0.1% below the 'no Kyoto' reference case. After twenty years the gap would be 0.35% and the gap would continue increasing for the first 50 years and reach a maximum of slightly over 0.5%.

Fractions of a per cent may not sound like a lot, but the actual amounts involved are astronomical. The study estimates net global costs of the Kyoto Protocol to Annex 1 countries to be between US$344 billion and US$1,507 billion in current value.[45] In comparison, global Third World aid amounts to approximately US$60 billion.

As mentioned above the IPCC estimate of the global costs of warming will be in the order of US$500–US$650 billion a year. Compared to this figure the Kyoto investment might seem a good idea. However, Kyoto is estimated to have a very small impact on climate and temperatures. Assuming IPCC level climate sensitivities would imply that Kyoto had the effect of lowering temperature by 0.15°C.

The 'Kyoto forever' scenario would, despite the high costs, have very little impact on total emissions. If we were to stabilise emissions or temperature, the cost would be much higher.

Given the mechanisms of the Kyoto Protocol and the current political agenda, it is possible that future commitment periods will imply deeper cuts in GHG emissions in order to stabilise CO_2 emissions or global temperatures at some future level by some future date. The costs of cutting GHG emissions beyond 2012 depends on the quantity, the methods for cutting them, and how fast.

Conclusion: How should we address climate change?

Dealing with climate change implies dealing with uncertainty. After all, we are discussing the effect of current actions and policies on society and climate almost a hundred years from now.

In fact, this paper concludes that the benefits of curbing emissions of GHGs are not just uncertain but *unknown* since we do not know the extent to which GHGs influence climate. Also, a small temperature increase is probably good whereas a large temperature increase is probably bad. Without any clear benefits, Kyoto could actually be bad for human welfare, even if it had no costs.

Current scientific knowledge suggests that the CO_2 sensitivity of the earth's climate is probably lower than suggested by computer models – at least the high-end models. This supports the possibility that by curbing emissions we might in fact be preventing something good. On the other hand, we cannot rule out the possibility that increasing GHG concentrations will result in large and detrimental temperature increases.

Turning from benefits to costs, estimates of future costs of climate mitigation rely on assumptions about future economic and population growth, and about future technologies, which have implications for the carbon intensity of energy use and the energy intensity of the economy

Beyond 2020 the assumptions about these factors are even more uncertain, especially for technology. The main technological uncertainty is not *if* low-carbon or non-carbon energy technologies will become economically competitive, but *when*.

McKibbin and Wilcoxen, two leading economic modellers and both professors of economics, point out 'the importance of the inherent uncertainty about the future that should be at the heart of the design of a sustainable climate policy.'[46] They criticise Kyoto's rigid emissions targets on a fixed timetable, which results in highly uncertain costs for countries. As mentioned above, the authors demonstrate how changing just one factor (the assumed GDP growth rate in Russia) would cause the carbon price to increase by 50%.

Over the long run costs could explode if expected new technologies were delayed by a few years. Countries would have to comply with the treaty obligations, though the rational course might be to postpone emission reductions until new technologies are in place. Such a policy would free economic resources for further cuts, or for other uses.

According to McKibbin and Wilcoxen, imposing rigid targets and timetables implicitly assumes 'that the risks posed by climate change are so great that emissions must be reduced no matter what the costs. However, too little is known about the dangers posed by climate change, and about the costs of avoiding it, to draw that conclusion.'[47] Given the uncertainties about the costs of both climate change and abatement strategies, we need to balance the risk of doing too much with the risk of doing too little. Current scientific knowledge about climate change does not warrant the Kyoto-style approach of 'reductions at any cost'.

But on the other hand GHG concentrations may possibly entail some adverse effects. Since climate change is (presumably) irreversible, it makes sense to avoid causing more of it than necessary, at least until the potential risks are better understood.

An appropriate policy response to climate change would be one that encourages all low-cost efforts to slow GHG emissions. The policy should provide an incentive to reduce GHG emissions but should avoid imposing unknown or very large costs. A strong economy is important for dealing with any kind of change, and costly policies can create a drag on the economy. Moreover, a strong economy will provide the means for research into less carbon-intensive technologies. The main reason why Third World countries are more vulnerable to global warming than industrial nations is because they are poorer and their societies sometimes do not encourage appropriate responses to change. Thus, poor countries are less able to control their environment.

Others have observed that Kyoto's rigid approach is much less efficient than alternative regimes. A study by William Nordhaus, one of the leading modellers of the economic effects of Kyoto, concludes that: 'The emissions strategy is highly cost-ineffective, with the global temperature reduction achieved at a cost almost 8 times the cost of a strategy which is cost-effective in terms of "where" and "when" efficiency.'[48]

The 'where' efficiency of Kyoto is low because only Annex 1 countries participate, despite the fact that most of future emissions – and the cheapest abatement potential – will come from Third World countries. The 'when' efficiency is low because rigid targets and timetables impose 'too much abatement, too soon'. The IPCC favours early action: 'The greater the reductions in emissions and the earlier they are introduced, the smaller and slower the projected warming and rise in sea levels.'[49]

The IPCC failed to add in its advice to policy makers that the greater and earlier the reductions, the higher the costs.

In the long run the key to addressing climate change is technology. We need to develop new low-carbon or non-carbon energy technologies and we need to increase the energy efficiency of our economies. It is almost certain that we can develop cheap non-carbon energy alternatives by the second half of the 21st century. But in order to do this we need prosperous economies that can afford to invest in research and development. We also need to minimise uncertainty.

The Kyoto Protocol is the wrong approach to addressing climate change. While it does provide an incentive for developing new decarbonising technologies, it is highly inefficient, because its rigid targets and timetables demand cuts at any cost. Furthermore, Kyoto actually maximises uncertainty – the future price of carbon, future commitments and the number of participating countries are all unknown factors. This regime of uncertainty is not conducive to creating a long-term strategy for future energy technologies.

Notes

1 http://www.ipcc.ch/about/about.htm
2 http://www.grida.no/climate/ipcc_tar/index.htm
3 IPCC (2001a), p. 5.
4 IPCC (2001d), chapter 1.3.1.
5 Ibid, Chapter 7, executive summary.
6 IPCC (2001c), section D.1.
7 *Ibid.*, Chapter 7, executive summary.
8 Lindzen *et al.* (2001).
9 Nature News Service, 7 March 2001, http://www.nature.com/nsu/010308/010308-9.html
10 IPCC (2001b), p. 1.
11 IPCC 2001, Working Group 1, Chapter 7, Executive Summary.
12 IPCC (2000).
13 Henderson (2003).
14 Corcoran (2002). See Webster *et al.* (2001) for a more in-depth analysis of projected emissions of carbon dioxide.
15 *Ibid.*
16 Castles and Henderson (2003).
17 IPCC 2000, Summary for Policymakers, p. 3.
18 NAS (2001).
19 Lomborg (2001), p. 290, citing IPCC (1998), p.7.
20 Titus *et al.* (1991).
21 IPCC (2001e).
22 Lomborg (2001), p.293, citing Bove (1998); Pielke and Landsea (1999).
23 IPCC (2001b), p. 15.
24 See Chagnon *et al.* (2000) and Kunkel *et al.* (1999).
25 See Gouk *et al.* (1999), Fernandez *et al.* (1998).
26 Goklany (2000), p. 198.
27 Lomborg (2001), p. 288, Table 7, citing IPCC (1996), p. 451, Rosenzweig and Parry (1994), p.136.
28 'Night minimum temperatures are continuing to increase, lengthening the freeze-free season in many mid- and high-latitude regions.' IPCC (2001), Executive Summary, Chapter 2, 'Observed Climatic Variability and Change', available at http://www.grida.no/climate/ipcc_tar/wg1/049.htm
29 Keatinge *et al.* (2000).
30 Goklany (2000), p. 197.
31 *Ibid.*, p. 196.
32 See http://unfccc.int/cop7/
33 See http://www.ieta.org, especially: http://www.ieta.org/Documents/New_Documents/StateandTrendsoftheCarbonMarket2002.pdf
34 Nordhaus (2001), Global Warming Economics, *Science*, vol. 294, 9 November 2001.
35 Grubb (2003).
36 Nordhaus (2001), Global Warming Economics, *Science*, vol. 294, 9 November 2001.

37 McKibbin and Wilcoxen (2003).
38 Institut for Miljøvurdering, 'Danmarks omkostninger ved reduktion af CO_2' (October 2002). Link: www.imv.dk
39 The Liberal and Conservative Party form a coalition minority government backed by the nationalist Danish Peoples Party.
40 Weyant and Hill (1999).
41 IPCC (2001g), Chapter 8.2.2.1.1, table 8.4.
42 Nordhaus (2001).
43 Institut for Miljøvurdering, 'Danmarks omkostninger ved reduktion af CO_2' (October 2002), p. 23. My translation. Link: imv.dk
44 Nordhaus and Boyer (1999).
45 *Ibid.*, p. 33 – The model run assumes US participation. This is a reasonable assumption since Kyoto could not survive US non-participation in the long run.
46 McKibbin and Wilcoxen (2003).
47 *Ibid.*
48 Nordhaus and Boyer (1999).
49 *Ibid.*, question 6.3, p. 19.

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