Why controlling climate change is more difficult than stopping stratospheric ozone depletion

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The euphoria that greeted the signing of the Kyoto Protocol in December 1997 has all but evaporated. The Annex-1 or developed countries will not achieve even the modest 5% average reduction that they agreed to in Kyoto from their 1990 emissions by 2012. The developed countries have postponed meeting their targets by 10–15 years without penalty, worsening climate impacts and pressures on developing countries[1]. The feeling of despair that mankind may be unable to come to grips with climate change is exacerbated by tedious diplomatic posturing that goes on at each annual conference of the parties to the United Nations Framework Convention on Climate Change, such as the most recent ones at Bali and Poznan, and the several intermediate meetings held at Bonn.

Before giving in to despondency at our collective inability to solve this global problem, it is useful to recall that we are well on the way to solving another global problem, that of stratospheric ozone depletion. Ambassador Richard Benedick, the Chief Negotiator for the US at the Montreal Protocol has hailed the agreement as 'one of the great international achievements of the 20th century'[2]. Tim Flannery, the famous Australian author goes even further: 'the Montreal Protocol marks a signal moment in human societal development, for it represents the first ever victory by humanity over a global pollution problem'[3]. The resolution of stratospheric ozone depletion problem led many analysts, including a recent editorial in *Nature*[4], to believe that similar success would be forthcoming in the climate change arena. In this paper, we examine the similarities and differences between the two problems to see what the ozone problem can teach us, and the factors that make the climate problem a harder nut to crack.

A convention or a treaty is a binding agreement between two or more sovereign states. When a treaty is a statement of broad principles, it is called a framework convention. Conventions allow for more specific agreements to be negotiated later. These are called protocols. Both conventions and protocols are often named after cities where negotiations are concluded. Each international agreement is separately negotiated, signed, and enters into force 'only when it is ratified' (usually by federal legislatures) by a specified number of signatory countries. Both the ozone and the climate change problems have their governing framework conventions and protocols. Table 1 shows the history of the international agreements on the two problems.

While the time difference between the signing of the Vienna Convention and the UNFCCC was 7 years, that between the Montreal Protocol and the Kyoto Protocol was 10 years and that between the two sets of agreements in Copenhagen will be 17 years, reflecting the more difficult nature of the climate problem.

A brief history of the science of stratospheric ozone depletion and climate change

The primary gases involved in both global problems are gases prized for their inertness, with the exception of methane. Chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs) are primarily responsible for ozone depletion, and carbon dioxide (CO_2) for climatic change. While CFCs are manufactured products, in most instances CO_2 is generally a waste product (except in carbonated drinks). Generations of engineers have been taught that in order to maximize combustion efficiency obtained with a carbonaceous fuel, it is best to ensure that all carbon is converted to CO_2. Both CFCs and CO_2 were initially thought not to pose environmental pollution problems because in addition to being inert, they are neither toxic nor flammable. They do not easily react or break down. But because of that stability, once released they last a long time in the atmosphere. As Flannery has written, 'it is their stability that is a key factor in the damage they cause'[3].

Sherwood Rowland, Mario Molina and Paul Crutzen were the first to link in 1974 CFCs to depletion of ozone. As is commonplace in science with most new theories, there was no early agreement among the scientific community. Ozone science, until the late seventies, was more disputed than climate science of today[2]. However, because heterogeneous reactions involving stratospheric ice particles at temperatures below –75°C had been disregarded[5], the detection of the ozone depletion over the Antarctic in May 1985 came sooner, and was much larger than anyone, including Molina and Crutzen, expected[5]. It was the American NASA satellite team that coined the

Table 1. International agreements on stratospheric ozone depletion and climate change

Governing agreements	Stratospheric ozone depletion: Agreement	Year negotiated	Year entered into force	Climate change: Agreement	Year negotiated	Year entered into force
Framework Convention	Vienna Convention on the Protection of Ozone Layer	1985	1988	UN Framework Convention on Climate Change	1992	1994
Protocols	Montreal Protocol	1987	1990	Kyoto Protocol	1997	2005
Amendments	London	1990	1992	–	–	–
Amendments	Copenhagen	1992	1994	Copenhagen	2009	–

evocative phrase 'Antarctic ozone hole'. This expression played a large part in grabbing media and public attention. More accurately, 'there was a depletion of ozone rather than an actual hole in the ozone layer'[6]. Later in 1995, Crutzen, Molina and Rowland were to share equally the Nobel Prize for Chemistry.

In 1988, four assessment panels (scientific, environmental, technology and economic) were established under Article 6 of the Montreal Protocol, whose terms of reference were approved by countries in 1989. A year later, the Technology and Economic Assessment Panels were merged. These three panels provide independent, technical and scientific assessments to the countries of the Montreal Protocol. There was early consensus that all the identified impacts of ozone depletion, such as increased incidence of skin cancers or cataracts, affected all regions adversely.

The origins of scientific studies of the enhanced greenhouse effect go back almost two centuries. In 1824, Joseph Fourier of France calculated that the earth would be a colder place if it lacked an atmosphere. We owe the discovery that greenhouse gases block outgoing infrared to the Irish-British scientist John Tyndall who in 1859 also suggested that changes in their concentrations could change climate. The Swedish scientist, Svante Arrhenius published the first estimate in 1896 of how much the globe would warm with a doubling in the concentrations of CO_2. Arrhenius won the Nobel Prize for Chemistry in 1903. Arrhenius thought that he was dealing with a very long-term problem. Extrapolating from then essentially European rates of consumption of fossil-fuels, he estimated that it would take 3000 years for the global pre-industrial CO_2 concentration of 280 ppm to double. He was wrong by a factor of almost 20. In the absence of concerted action, a doubling somewhere in the middle of this century can be expected.

For the next 60 years or so, the significance of Arrhenius's calculation remained by and large unrecognized. The International Conference on the Assessment of the Role of Carbon Dioxide and Other Greenhouse Gases in Climatic Variations and Associated Impacts, organized by the International Council of Scientific Unions, the World Meteorological Organization, and the United Nations Environment Programme at Villach, Austria in October 1985 was a turning point. Assessing the painstaking scientific work of the past three decades, this conference reiterated the consensus amongst scientists about the inevitability of global warming. The discovery that other trace gases add to the warming caused by carbon dioxide meant that significant changes could be expected within a lifetime rather than in some distant future. Abandoning their characteristic caution, scientists from 29 countries at this conference concluded that 'human releases of greenhouse gases could lead in the first half of the 21st century to a rise of global temperature . . . *greater than any in man's history*'. They also urged 'active collaboration between scientists and policymakers to explore the effectiveness of alternative policies and adjustments.'

Inter-governmental efforts

Governments in the United Nations General Assembly decided in 1988 to establish the Inter-governmental Panel on Climate Change (IPCC), a joint programme of the WMO and UNEP, to provide 'policy-relevant but not policy-prescriptive' advice. It was around this time that the term 'global warming' or the scientifically more correct term 'enhanced greenhouse effect' were dropped in favour of the more neutral 'climate change'[7]. The IPCC published its first report two years later in 1990, establishing that emissions of greenhouse gases resulting from human activities were substantially increasing their atmospheric concentrations and that under a business-as-usual scenario, the 21st century would witness an increase in global mean temperature greater than any seen in the past 10,000 years. As a result of this assessment, the UN General Assembly established the Intergovernmental Negotiating Committee in December 1990, which drafted the UNFCCC. More than 140 countries with differing interests participated in the negotiations. It was signed by 154 heads of states at the Earth Summit in Rio in 1992 and came into force in 1994 (see Table 1). To date, 188 countries have ratified the convention.

Since the convention had 'only the vaguest of commitments regarding stabilizing of concentrations and no commitments at all on reductions', the first Conference of the Parties to the Convention in Berlin agreed to negotiate a protocol to define more precisely the emission reduction commitments of developed countries. It took two years to negotiate the Kyoto Protocol (1995–97) and another 8 years for it to come into force, when countries representing 55% of the developed country emissions had ratified (Table 1). The US declared its intention not to ratify the protocol in 2001. The protocol specifies that countries should initiate in 2005 (and conclude by 2009) the consideration of commitments for the post-2012 period.

Because the IPCC formation preceded the convention, unlike the panels of the Montreal Protocol, it is outside the formal convention process. The IPCC too has three panels called Working Groups, the first dealing with science, the second dealing with impacts and the third dealing with response measures. While there are many indications of changing climate due to human actions, there is no clinching 'smoking gun', as in the case of the annually recurring Antarctic ozone 'hole'. This is one reason why some continue to be skeptical about the timing and the extent of climate change and many policy makers refuse to commit to costly immediate action. The skeptical group does not represent scientific mainstream consensus and its views are consigned more and more to the fringes. In policy making circles, however because the required mitigation strategies are often fraught with risks as large as the problem itself[8], gingerly response is still the mainstream view.

The role of the United States

International agreements rarely fructify without some countries assuming leadership positions and nudging the agenda forward. In the ozone negotiations, despite a conservative administration, the US had assumed a leadership position. In the 70s the US accounted for almost one-half of the global CFC use, most of it in aerosol sprays. In less than two years and without any government regulation, adverse publicity about harm to the ozone layer had caused the market for such sprays to drop by two-thirds[9]. The US Senate ratified the Montreal Protocol 83–0 in March 1988. A combination of factors was responsible for this lopsided vote. A US company (DuPont) had substitutes in the pipeline, the US had already reduced its consumption, and wanted other competing countries (mainly European) to do the same, and the developing countries then accounted for only a very small fraction of global consumption. Also, the Reagan administration in its second term was worried about its environmental legacy[10].

Until very recently, the US was also the highest emitter of greenhouse gases, responsible for a quarter of the total emissions (rather than half as in the case of CFCs). After the US Vice President Al Gore's personal intervention to break the deadlock in negotiations in Kyoto in December 1997, the US more or less ceded the leadership of the climate issue to the European Union. Even before the Kyoto Protocol, the US Senate passed in July 1997 the even more lopsided and bipartisan Hagel-Byrd Resolution 95–0 stating that the United States would not be a signatory to any protocol which would mandate commitments to limit its greenhouse gas emissions, unless the protocol also mandated commitments to limit greenhouse gas emissions from developing countries within the same period. Partly because the Kyoto Protocol was not in consonance with the US Senate's resolution, it was never submitted to it for ratification.

The costs of responding and burden sharing

Only a half a dozen or so chemicals cause stratospheric ozone depletion. Chemical companies were working on the development of substitutes even before the reduction targets of the Montreal Protocol were announced. In the end, substitutes ended up costing much less than forecast as the impending controls forced many industries to change entire processes and find more ingenuous, efficient and productive ways of doing things than they did before. CFCs were only one small segment of the worldwide chemical industry.

Only 20 countries negotiated the Vienna Convention and thirty countries the Montreal Protocol. Most developing countries were uninvolved and uninterested as initially the reduction targets were firm with tight deadlines, but provisions for technology transfer and the coverage of incremental costs were vague. The subsequent history of Montreal Protocol shows that developing countries accepted 'limitations on their CFC consumption only when they were assured of equitable access to new technologies'[2]. Participation of India and other developing countries came with the London Amendments when the firmer provisions for technology transfer and the payment of incremental costs by developed countries were agreed. These costs were thought to be small (and proved to be smaller) and developing countries were not yet widely perceived to be competitive threats at the beginning of the nineties. These positive incentives were coupled with the threat of trade sanctions against countries not joining or complying with the protocol. Some developing countries, such as India, became even more enthusiastic participants when the initial agreement requiring per cent reductions were tightened and replaced by phase-out requirements. This earlier reluctance was coloured by not wanting to determine who could continue to emit and who could not, and an inadequate capacity to enforce that determination.

In the climate arena, again there are only a handful of gases that significantly affect radiative forcing, but most of the emissions come from the energy sector which is far more pervasive in modern societies. Again, the search for renewable energy substitutes dates to at least the seventies, a decade earlier than the initial calls by scientists to curtail the emissions of greenhouse gases. Despite impressive recent growth, renewable energy systems still generate globally a miniscule fraction of electricity and provide a miniscule fraction of liquid fuels used in transportation systems. Although the cost of power generation from renewables is declining, their levelized per unit prices for base load remain higher than those from their fossil competitors.

In the case of ozone, in the first decade 1987–97, the world in total had spent approximately US$ 235 billion to contain the problem. The cumulative amount of north to south transfers were relatively modest, of the order of US$ 2 billion[4]. To reasonably address the climate problem, the total bill could potentially be relatively large, estimated by the Stern Review to be of the order of one per cent of gross world product[11]. Spending US$ 500 billion a year for say, 40 years makes it a US$ 20 trillion problem. The transfers to developing countries have been variously estimated to be of the order of US$ 20–200 billion per year for the next 40 years or so[12]. Thus the climate problem is at least a hundred times more expensive problem to tackle than the stratospheric ozone depletion and north–south transfers could be a thousand times greater, something that the *Nature* editorial does not mention[4]. The Multilateral Fund of the Montreal Protocol does offer a good model for the estimation of incremental costs in a technically competent fashion within the Montreal Protocol process. Therein, the clearly defined nature of ozone-friendly technologies eligible for funding and the level of funding for earth technology, have provided both predictability and transparency to developing countries. There is now a marked unwillingness in developed country legislative bodies to pay for all the incremental costs or to transfer technology without strings. Within a decade, there has been a change in the perception of developing countries from clients, customers and aid recipients, to potential and actual competitors. Table 2 summarizes our discussion of the differences between the two problems.

Of course, given the collective dependence on fossil fuels, a phase-out is currently off the table, only reductions are being negotiated.

Concluding remarks

The success of the ozone negotiations, coupled with the glacial pace of climate negotiations in the last decade, has caused some analysts to recommend agreements between a smaller group of major emitters[2]. Recent industrial history has shown how easy it is for manufacturing to move from one country to another. For example, various estimates claim that 75% of China's manufacturing is export-related and that a third of its GHG emissions may be attributable to exports[13]. Therefore only a truly global agreement will ensure that there is no 'leakage' or 'gaming'.

Eager and active participation of the US and China will be essential to the success of any global regime negotiated to tackle this problem. The current administration in the US promised in its electoral campaign to undo many of the climate-related policies of the previous administration. Progress is still expected to be slow, in the absence of a catastrophic event such as the Antarctic ozone

Table 2. Differences between the stratospheric ozone and climate change problems

Stratospheric ozone depletion	Climate change
20 countries were involved in the original negotiations	~180 countries participate in climate negotiations
Clinching scientific evidence in the form of 'Antarctic ozone hole'	No smoking gun; evidence is incremental and cumulative
Term 'ozone hole' is evocative	Term 'climate change' is neutral
All countries expect to lose	Both losers and (at least initially) winners
Three scientific assessment panels inside the formal Montreal Protocol process for advice	Three IPCC Working Groups outside the formal Convention Process provide advice
US (and UNEP) leadership	EU leadership
US Senate ratified Montreal Protocol 87–0	US Senate opposed Kyoto Protocol 95–0
Costs of developing substitutes reasonable	Substitutes to fossil fuels for electricity and transport currently expensive
Developing countries were perceived by northern countries to be aid recipients	Developing countries perceived to be competitive threats
Northern legislatures willing to transfer technology and resources to developing countries	Northern legislatures unwilling to transfer technology and resources to developing countries

hole. Scientists have identified several potential candidates of such 'tipping elements' in the Earth's climate system where tiny perturbations can qualitatively alter the state or evolution of the system[14]. Monsoon is one of the well-known 'tipping elements'. Burns *et al.*[15] have shown that monsoon transitions from dry to wet have occurred very rapidly in the Indian Ocean about 50,000 years ago. Data from the Socotra Island in the Indian Ocean have shown that the transition from weak to strong monsoon can occur in less than 25 years. This shows that concerns about abrupt climate change in the 21st century are serious[16].

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Soil fertility in physically degraded lands: are we overestimating?

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During the green revolution, intensive agriculture increased food production on one hand and decreased soil fertility on the other. But reduced soil fertility is currently threatening the total food production of the country by stagnating or reducing productivity. It is now obvious that if high productivity has to be sustained, not only should the productive capacities of cultivated lands be increased, but hitherto uncultivated, physically degraded lands (henceforth referred as degraded lands) should be brought under cultivation. All this has to be achieved without compromising soil fertility. This is especially relevant in the wake of discussion on launching the second green revolution. Improving soil health is possible only when soil fertility is accurately estimated and suitable corrective measures are adopted. In our opinion, the present methodology for soil fertility estimation may be unsuitable for degraded soils. Here, we explain this methodological problem and highlight the possible consequences of adopting the present method for degraded soils.