Global climate change/variability: Action or adaptation to increasing greenhouse gases? - Lessons from the past

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by

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Abstract

Recent remarkable findings in Greenland ice core data have suggested that the climate of the last interglacial (the period between ice ages) 115,000-135,000 years ago was not as stable as that of our present interglacial climate (the last 10,000 years). Rapid transitions were found to occur between climates which were similar to, warmer than and colder than today. The transitions between these states were very rapid (several decades) although the climatic system could remain in any given state for hundreds of years. While there is still some concern as to the reliability of the ice core data corresponding to the latter half of the last interglacial, recent modelling studies have now provided a possible theory to explain the ice core observations. The last interglacial was known to be, on average, slightly warmer than our present interglacial. Associated with this warmer climate is an enhanced *hydrological cycle* (low latitude evaporation and high latitude precipitation) which induces dramatic shifts in the strength of the North Atlantic ocean heat conveyor and hence the North Atlantic climate.

The last interglacial period may offer us a glimpse of the type of variability which we might expect in a climate warmed through the release of anthropogenic greenhouse gases. The possibility of future climatic "regime changes" has, however, been largely ignored by economists and public policy makers as the probability of their occurrence has usually been deemed to be very small. Estimates of economic damages from global warming have implicitly assumed relatively smooth, gradual changes in climate, with damage estimates sufficiently small relative to the costs of mitigation to favour a policy of *adaptation*. Here we suggest that policy makers should not be solely focussing on *adaptation* to a slowly warming climate, but rather should be *acting* to ensure that we prevent its arrival. We emphasize that it is not so much the warmer mean climatic state which we must concern ourselves with, but rather the potential variability associated with this new state.

Background

Over the past few years increasing public, political and scientific concern has been directed towards potential climate change associated with increasing greenhouse gases. The most recent and sophisticated climate forecasts[1] have suggested that global warming will occur at a rate of 3.5°C per century associated with a 1%/year increase in atmospheric CO_2 (close to the IPCC Business as Usual Scenario for atmospheric greenhouse gas emissions[2]). In the high latitudes of the northern hemisphere, the climate forecasts for a doubling of atmospheric CO_2 further suggest an amplification of the warming (~8–9°C versus ~3°C for low latitude regions[1,3]) due to the reduction of sea ice cover and the accompanying decrease in surface albedo (amount of incoming solar radiation reflected back to space). In the region around Antarctica, very little change (or even slight cooling) is predicted over the next few centuries, due to the efficient absorption of heat by the ocean there.

Predictions of global climate change pose a public policy problem: what, if anything, should be done to head off the threat created by emissions of greenhouse gases? In answering this question, the most widely accepted approach (at least among economists) is to weigh the benefits of a given action against its costs. The benefits of actions taken to head off (prevent or mitigate) global climate change are the damages thereby avoided. These are the damages that would occur in the absence of policy actions taken to limit the build-up of greenhouse gases in the atmosphere. Since some climate changes may already be in the pipeline, as a result of past emissions of greenhouse gases, not all damages may be avoided.

Economists are able to provide a quantitative measure of benefits by focusing on the *economic* damages avoided. Typically this requires an in depth analysis of the impact that climate has on the various sectors of economic activity. Of necessity such measures ignore the existence "value" some human beings place on the earth's present climate, independent of any economic damages that might accompany a changed (presumed warmer) global climate.

The costs of policy actions are also measured in economic terms. These costs are quantified as the reductions in output that are estimated to occur if greenhouse gas emissions are reduced below the level that would occur in the absence of policy action. Since a large fraction of greenhouse gas emissions, especially CO_2, are released as a result of energy production and use, cutbacks in emissions imply cutbacks in fossil-fuel energy use. With 85% of the world's energy provided by fossil fuels, and with non-fossil fuel energy substitutes (other than nuclear energy, which has its own environmental problems) currently incapable of meeting baseload energy requirements, reduced CO_2 emissions imply reduced energy use. In turn, reduced energy use is likely to result in a reduction in economic output (or gross domestic product [GDP]). A reduction in output or output growth is inevitable if the reduction in energy use exceeds the rate at which technological improvements make possible the long term decline in fossil fuel energy input per unit of economic output. Economists have estimated that simply stabilizing global emissions at 1990 levels (which would slow but certainly not prevent climate change) will reduce global GDP by approximately 2% per annum by 2040 and 4% per annum, plus or minus 1%, by 2100[4].

The comparison of the benefits and costs of actions in preventing/mitigating climate change requires a scientifically based climate change scenario and numerous economic assumptions. The most important of these assumptions are those underlying projections of the long term rate of output growth and those relating to (a) the rate of induced technological changes that affect energy use per unit of output and (b) the development of non-fossil fuel energy alternatives. The most widely employed scenario is based upon IPCC modelling, which projects that "business as usual" (no policy action taken to control emissions) would produce a 3 to 6°C global warming in 2100 (relative to 1900), with a best guesstimate being 4°C[5]. This scenario is based on atmospheric general circulation models (GCMs) that project a relatively smooth path of rising global average temperature. As a result, estimates of economic damages are implicitly based on the assumption of relatively smooth, gradual changes in climate. The possibility of climatic "regime changes", such as those which we shall discuss below, are all but ignored. Suffice it to say that the economists' benefit-cost calculus, already hard pressed to deal with the long term and uncertain nature of climate change has not yet been, and perhaps cannot be, fruitfully applied to the far more catastrophic possibility posed by climate regime changes.

The Oceans & Climate Change

The ocean is well known to have a moderating effect on climate through several mechanisms. It is the buffer which moderates temperature fluctuations during the course of a day, from season to season and even from year to year. One only has to compare the maritime climate of Victoria, British Columbia (48°25'N, 123°22'W), with average temperature of 4°C in January and 16°C in July, with the continental climate of Winnipeg, Manitoba (49°54'N, 97°14'W), with average temperature of –18°C in January and 20°C in July, to see the moderating effect of the ocean. The ocean also acts as a large-scale conveyor that transports heat from low to high latitudes, reducing latitudinal gradients of temperature.

Much of the oceanic heat transport is thought to be associated with the *thermohaline circulation* (that part of the ocean's circulation which is driven by fluxes of heat and freshwater through the ocean's surface). In the North Atlantic, intense heat loss to the overlying atmosphere causes deep water to be formed in the Greenland, Iceland and Norwegian Seas. These sinking regions are fed by warm, saline waters brought by the thermohaline circulation from lower latitudes. No such deep sinking exists in the Pacific. Again, if one compares the climates of Bodö, Norway (67°17'N, 14°25'E), with average January temperature of –2°C and average July temperature of 14°C, to that of Nome, Alaska (64°30'N, 147°52'W), with average January temperature of –15°C and average July temperature of 10°C (both of which are at similar latitudes and on the western flanks of continental land masses), one directly sees the impact of the poleward heat transport of the thermohaline circulation. The ocean can also regulate climate through its ability to store both anthropogenic and natural greenhouse gases.

Due to the ocean's role as a thermal buffer, greenhouse gas climate forecasts predict that the warming over the ocean is smaller than that over the land. A question that has only recently begun to be examined[1,6] is how changes in the ocean's circulation associated with the increasing greenhouse gases might feed back upon the climatic response.

Adaptation vs Action

According to economic theory the least cost methods of reducing greenhouse gas emissions are carbon taxes and tradable emission permits[7]. These are policies which rely mainly on the market mechanism rather than the command and control powers of direct government regulation. Nevertheless, almost all benefit-cost analyses of programs which would reduce carbon emissions are found to have costs that substantially outweigh their benefits. There are three reasons why even an efficient and effective program of carbon taxes, one with the relatively modest goal of stabilizing emissions (at, say, their 1990 levels), is found not to be cost effective (more ambitious programs are found to be even less cost effective):

1. Most economic activity, especially in developed countries, is insulated from climate change. This includes manufacturing, underground mining, and most services. Vulnerable sectors such as agriculture make up a relatively small share of the GDP in developed countries, although often a much larger share in developing ones.

2. There is an assumed human ability to adapt to changes in the environment, including climate, and the presumed progress of technology in making food supplies and other climate-vulnerable commodities more adaptable to climate change.

3. A positive discount rate, even one as low as 1%, substantially reduces the value of benefits (damages avoided) that are received several decades hence. Given the long term nature of climate change, any damages it will produce may be negligible prior to the middle of the next century. However, avoiding damages in 2040 requires undertaking substantial (costly) programs (or investments) now. At a 1% discount rate, one billion spent today requires damage avoidance in 2040 of 1,584 billion dollars simply to break even in benefit-cost terms. Or to put it another way, one billion dollars in benefits (damage avoidance) in 2040 has a present value (worth) of 630 million dollars today. At a discount rate of 3%, one billion dollars in benefits received in 2040 is worth 246 million dollars today. Of course, damage avoidance is not limited to that in 2040 but to all future years. But, by the same token, the costs of programs undertaken today affect GDP not only today, but into the foreseeable future.

For all three of these reasons, Nordhaus[5,8] suggests that the optimal (from a benefit-cost standpoint) carbon tax is one that rises from $5 per ton of carbon to around $20 at the end of the next century. To put these very modest figures in perspective, a carbon tax of $100 per ton would increase coal prices by about $70 per ton (or 300%) and oil prices by $8 per barrel, or approximately 50%. For emission stabilization (at 1990 levels), the carbon tax would rise from $40 per ton of carbon currently to between $400 and $500 per ton late in the next century[5]. In effect, the optimal (from an economic standpoint) carbon tax is one which would only slightly reduce the expected rise in greenhouse gas emissions. The impact of economically-justified carbon taxes on the course of climate change would appear to be marginal. Less efficient methods of emission control, such as regulatory or other command and control methods, would appear to be even less economically desirable.

The economics of global climate change (greenhouse warming) thus comes down on the side of adaptation as opposed to prevention (an exception is Cline's analysis[9]). There is, however, a caveat noted earlier. Economists' estimates are based on a relatively smooth progression toward a globally warmer climate — albeit with local-regional idiosyncrasies and with somewhat harder to predict impacts on rainfall, soil aridity, temperature extremes and (violent) storminess. Climatic "regime changes" pose problems for economic analysis and renders existing benefit-cost analyses vulnerable to the criticism that they have failed to factor in catastrophic possibilities, albeit they may have only small probabilities of occurring.

In summary, based on early IPCC projections of global warming[1,10] many governmental agencies developed a policy of *adaptation* instead of *action*, arguing that if climate were to change, it would do so slowly. If the globe were to warm 3.5°C over 100 years (at an undetectable rate of 0.035°C/year) then both resource- and industrial-based economies, as well as the environment could perhaps adjust. Indeed, paleoclimatic data which was available at the time of these policy decisions suggested that interglacial (the period between ice ages) climates were relatively stable and so one might expect anthropogenic effects only to cause small perturbations to the climate system. The policy of *adaptation* therefore appeared reasonable as *action* would require enormous short term financial investment.

Lessons from the Past

Recent remarkable findings from the Greenland ice core project[11,12] have added a new twist to the global warming debate. It has been known for a long time that the glacial periods and the transitions to/from these glacial periods were marked by intense climate swings (regime changes) which occurred over very rapid times (order decades). The last such cooling event, *the Younger Dryas Event,* ended about 10,000 years ago. This event concluded the transition from the last ice-age to the present interglacial period (known as the *Holocene*). Prior to the publication of the new ice core findings, the existing coarse temporal resolution paleoclimatic data suggested that interglacial periods were free of such intense climate variability. What the Greenland ice core project has revealed is that the climate of the last interglacial (referred to as the Eemian period) was characterized by three climatic states. A state very much like today's climate and states significantly warmer and colder than today's climate. It was also found that the transition between these states occurred very rapidly and that the climate system never remained in one state for more than about 2,000 years (we have been in a stable climatic state for about 10,000 years). While there is some concern as to the reliability of the ice core data corresponding to the latter half of the Eemian[11,13,14], our understanding of interglacial climates has nevertheless suddenly been questioned: It was thought that interglacial climates were relatively stable — now it appears that it is only our present interglacial which has a stable climate and we are left with the question of why this is so.

Some recent modelling results[15,16] have provided us with a possible answer. The Eemian interglacial was, on average, slightly warmer than the present Holocene interglacial. Associated with this warmer atmosphere would be enhanced low latitude evaporation and, through poleward atmospheric water vapour transport, enhanced high latitude precipitation. This enhanced *hydrological cycle* would cause a destabilization of the ocean's conveyor belt (thermohaline) circulation which could then rapidly, and unpredictably, switch from one mode of operation to another, with catastrophic changes in northern hemisphere climate.

Global Warming & Rapid Climate Variability

Rapid northern latitude climate swings of > 10°C over a few decades would clearly have profound effects on western economies, especially, but not exclusively, those that are resource-based. Industries such as fisheries, forestry, agriculture, energy, recreation and tourism etc would find it difficult to adjust to these climate transitions, yielding potentially enormous economic problems. In addition, there could be large migrations of people that would create potentially costly economic and social dislocations for origin and destination communities alike. One danger is that policy makers might use the Greenland ice core data as evidence that rapid climate fluctuations are inevitable and hence once more advocate a policy of *adaptation*, arguing that if the climate were to suddenly change it would do so on its own accord. Below we address this argument through a simple analogy shown schematically in Fig. 1.

Suppose there is a small valley between two hills (above) which represents the present climate. The black ball in the figure illustrates where the earth's climate might have been at any time over the last 10,000 years (slightly colder than normal to the left of the middle of the valley; slightly warmer to the right). The two precipitous drops portray the rapid transitions to either colder or warmer climates. The present interglacial climate is clearly susceptible to natural variations which we represent as the ball being lightly kicked up either side of the hill and rolling back down to the valley. Eventually we suspect (from the Greenland ice core data) that there will be an unusual kick to the climate system which would be sufficiently strong to knock the ball over the crest of a hill and hence irreversibly to either a warmer or colder climate (we of course have no ability to predict such an event as yet). What we as humans don't want to do is give the ball an extra nudge to help it over a hill in a case when it would not have made it naturally. Specifically, if we continue to increase our concentrations of atmospheric greenhouse gases then the projected increase in global mean temperatures will push us past the mean temperature of the Eemian period. As discussed earlier, the warmer climate would have a significantly enhanced hydrological cycle which modelling studies[15,16] have suggested could cause rapid transitions between different modes of operation of the oceanic conveyor.

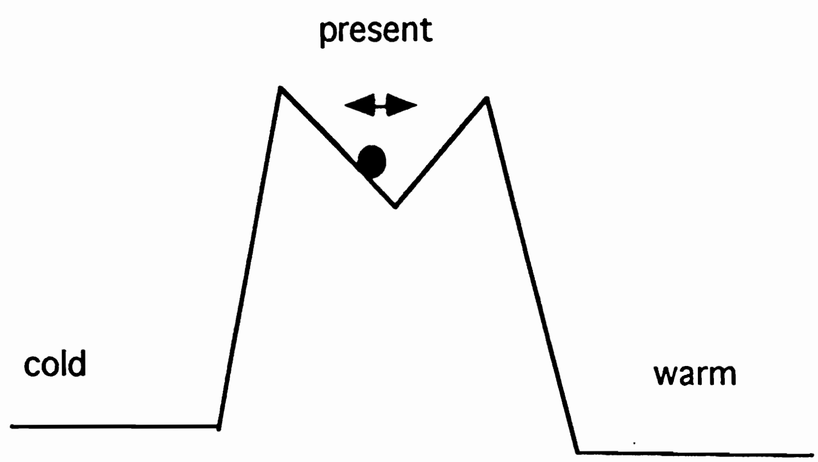

Figure 1: A schematic diagram of our climate system.

Summary

The advances in climate science, discussed above, pose a predicament for policy analysis. The starting point of policy analysis relating to climate is scientific understanding of climate and what can cause it to change. Until recently, this understanding combined careful measurement (only a few decades old) of atmospheric trace gases with the analysis of output from three-dimensional atmospheric GCMs. Atmospheric GCMs are complicated in their own right and suffer from a variety of problems. However, climate scientists have been aware of the fact that global climate change involves the even more complicated interaction between atmosphere, ocean, cryosphere (ice), and biosphere. In the past few years the development of coupled atmospheric-ocean GCMs and other models have not only altered scientific predictions of the time paths of global climate change, but in some cases have indicated the possibility of "regime changes". At the same time, paleoclimatic investigations, especially those based on evidence from ice cores, have indicated the possibility that earlier climates were far less stable than our own.

It is predictable, then, that the progress of climate science will enhance our understanding of the probable consequences of climate changes that are initiated as a result of human's economic activities. As the scenarios change so will the outcomes of policy analysis. Actions that are economically non optimal given current understanding may turn out to have been desirable after all. Likewise, costly actions taken now could turn out to be unnecessary on the basis of enhanced understanding of climate and its determinants.

In conclusion, we suggest that the Eemian interglacial may offer us a glimpse as to the type of rapid climate variability which we might expect in a warmer climate. If we continue to increase our emissions and simply maintain a policy of *adaptation* then we may be in for a big surprise. To reduce the likelihood of surprise, policy makers should not only be focussing on *adapting* to a warmer climate but should be *acting* to ensure that we reduce our greenhouse gas emissions in order to prevent its arrival. It is not so much the new warmer mean climatic state with which we must concern ourselves, but rather the potential variability associated with this new state. But even the choice of *action* involves hard decisions. For example, it could even turn out that there is already enough anthropogenic effects in the pipeline to set off climatic regime changes. If so, costly attempts now to prevent further emissions would be irrelevant: it would be much more sensible to invest resources in means of enabling most of humanity to withstand (survive) rapid regime change, albeit, at what may turn out to be a substantially reduced average level of economic well-being.

Notes:

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