CLIMATE CHANGE

Reply to Byatt et al.

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Ian Byatt and his co-authors, in their critique of my OXONIA speech and paper on the economics of climate change,[1] focus largely on the science of climate change and some well-known criticisms of IPCC (Intergovernmental Panel on Climate Change) projections. They do not come to grips with the more difficult economic analysis which is at the heart of the problem and which is central to the approach adopted by the Stern Review team. Nevertheless, the criticisms merit a response, not least to correct the authors' misapprehensions about the implications of uncertainty for policy and to re-assert the need to apply the tools of modern economics to the problem. So I will comment on the science, the role of uncertainty, and on the type of economics the issues demand.

First, the science. In common with the authors of the critique, I am not a climatologist, but my team—which includes staff with knowledge of scientific as well as economic aspects of the issues—has had the benefit of discussions with a wide range of experts here (e.g. the UK Met Office's world-renowned Hadley Centre) and at research universities and institutes in the rich and in the developing world. Those discussions and our assessment of a broad literature have convinced us that the evidence supporting the hypothesis of anthropogenic climate change is compelling.

A number of theoretically plausible criticisms of the majority scientific view have been investigated empirically—just as they should be—and have been found wanting. For example:

- Professor Lindzen of MIT has long suggested that water vapour could act as a negative feedback on warming, because the upper atmosphere would dry out as it warms, reducing the amount of water vapour (a strong greenhouse gas).[2] That is a reasonable

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[1] "The Stern Review 'OXONIA Papers': A critique", by Ian Byatt, Ian Castles, David Henderson, Nigel Lawson, Ross McKitrick, Julian Morris, Alan Peacock, Colin Robinson and Robert Skidelsky, in this issue pp. 145–151. I am grateful for the assistance of members of my team in preparing this reply. There are a number of details where Byatt et al.'s note is misguided but we do not want to burden the reader with a point-by-point account. The Review will cover many important aspects of the economics of climate change that could not be covered in a preliminary lecture.

[2] For example, Lindzen (1990), "A skeptic speaks out", *EPA Journal* 16: pp. 46–47.

hypothesis that merits investigation. Re-analysis of satellite measurements published just a few months ago[3] has shown that in fact the opposite is happening. Over the past two decades, the air in the upper troposphere has become wetter, not drier, casting doubt on Lindzen's theory and confirming that water vapour is having a *positive* feedback, i.e. an amplifying effect on global warming.

- Similarly, some have pointed to recent increases in ice sheet growth in the interior of the Greenland ice sheet as evidence of inconsistencies between model projections and observations.[4] The interior of the Greenland ice sheet is gaining mass because of increased snowfall, but the edges are getting thinner. These changes match predictions from computer models of global climate change. The net effect of these changes is a release of 20 billion tonnes of water to the oceans each year, contributing around 0.05mm/yr to sea-level rise.
- Some have claimed that the observed warming could be due to increasing urbanisation. That is not now seriously considered. Weather stations in isolated areas show a similar warming trend as those near urban areas, and the effect is not diminished on windy nights (when the urban heat island effect is weakened or destroyed). The urban heat island effect is not sufficient to explain large-scale warming patterns.[5]
- One remaining controversy is the attribution of current weather events to human-induced climate change. The world has been experiencing more extreme weather events—heat waves, droughts (e.g. in the Horn of Africa at present), floods and storms (e.g. Hurricane Katrina). While it is certainly true that any particular weather event cannot be confidently attributed to climate change, the overall trend is consistent with predictions. For example, new, stronger evidence has emerged linking increasing hurricane intensity with rising sea surface temperatures.[6]

The overwhelming body of evidence leaves no doubt that the threat of climate change is real and serious. Counter-arguments or hypotheses have been undermined and discredited as new evidence has come in. Increasingly, apparent inconsistencies in the evidence are being reconciled. This is not a theory that is fraying at the edges. On the contrary, it is sound basic science building on ideas from the nineteenth century which have stood the test of time, and for which the evidence, already strong, is becoming still stronger.

[3] Soden et al. (2005), "The radiative signature of upper tropospheric moistening", *Science* 310: pp. 841–844.

[4] Johannessen et al. (2005), "Recent ice sheet growth in the interior of Greenland", *Science* 310: pp. 1013–1016. Accumulation in the interior of ice sheets is a response to global warming and the associated increases in rainfall predicted by several models. In one of the most comprehensive studies of its type, published in December 2005, satellite data were used to plot changes in the ice sheets over the past 10 years. The survey documents extensive thinning of the West Antarctic ice shelves, but a thickening in the east of the continent (though not by as much as some other studies show).

[5] Parker (2004), "Large scale warming is not urban", *Nature* 432: pp. 290.

[6] Hoyos et al. (2006), "Deconvolution of the factors contributing to the increase in global hurricane intensity", *Science* 312: pp. 94–97.

Indeed, science has moved on since the IPCC report of 2001. In fact, the latest science suggests that the risks could be substantially greater than previously seen. The Exeter G8 conference on avoiding dangerous climate change, held last year under UK government auspices, highlighted the potential for a range of extreme events and amplifying mechanisms, i.e. effects that magnify the problem and that could be triggered by temperature changes in the upper part of the range of possibilities.[7] One possible such mechanism is the projected weakening of natural sinks for carbon as the world warms—a phenomenon observed in all climate models that explicitly include land–ocean–atmosphere carbon feedbacks.[8] This occurs because soil respiration is sensitive to warming and reduces the amount of carbon stored on the land. In an extreme case, the land sink could become an additional source of carbon dioxide by 2050, leading to 50% more warming by the end of the century.[9] Another possible mechanism is the melting of permafrost and the consequent release of methane. The current store of methane is greater than all historical emissions of greenhouse gases—although there remains uncertainty about how much would be released.

Second, the role of uncertainty. The authors stress the pervasive uncertainty around projections of climate change. In fact, the uncertainty is no longer so much about the fact of anthropogenic climate change but about its future extent. It is not clear from their critique that the authors appreciate the implications of this uncertainty about model forecasts for climate change policy. Policy-makers need to take into account the risks of greater dangers, as well as central expectations, because the consequences if these risks were to materialise would be very serious. For example, extreme, abrupt and dangerous climate-change scenarios based on loss of carbon sinks and melting permafrost may not accord with climate scientists' central expectations, but their possibility must be recognised when considering the appropriate vigour of policy responses. This prudential approach is common in other areas of policy, from defence to financial stability, and warrants more public action to mitigate climate change, not less. Risk aversion on the part of policy-makers—which many would argue is appropriate in the face of the danger of major and irreversible global shocks—would warrant even greater weight being given to the more adverse possible outcomes. And in practice, decision-makers at the sharp end, for example, considering the future of London's flood defences, do test their options against a range of scenarios, including those at the higher end of possible damage.

The work of the Hadley Centre and others[10] to explore this uncertainty by

[7] For more details, see http://www.stabilisation2005.com/ and *Avoiding Dangerous Climate Change*, edited by Schnellnhuber et al., Cambridge University Press.

[8] Friedlingstein et al. (2006), "Climate-carbon cycle feedback analysis: results from C4MIP model intercomparison", *Journal of Climate*, in press.

[9] Cox et al. (2000), "Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model", *Nature* 408: pp. 184–187.

[10] e.g. Murphy et al. (2004), "Quantification of modelling uncertainties in a large ensemble of climate change simulations", *Nature* 430: pp. 768–772 and Stainforth et al. (2005), "Uncertainty in predictions of the climate response to rising levels of greenhouse gases", *Nature* 433: pp. 403–406.

means of ensembles of computer runs has been very helpful in drawing attention to the risks of still greater climate change, for instance, if clouds and their formation make the climate more sensitive to greenhouse gases. No model is ever going to capture completely the complexity of the real world, but models are necessary in order to make (probabilistic) projections of possible future developments. Climate models attempt to do this for a wide range of phenomena, not simply mean global temperature. They can be assessed by the extent to which they embody accepted physical relationships and explain past observations. Models such as the Hadley Centre's do just that—if the role of anthropogenic greenhouse gas emissions is recognised. And the temperature increase of the past 40 or 50 years cannot convincingly be explained without this recognition. The models further predict that global temperatures will rise above the levels of the past couple of centuries.

This argument for prudent action does not rely on the 'hockey stick' temperature chart attacked by Byatt et al. (models predict a range of variables not just temperature); nor is it inconsistent with recent evidence suggesting greater climate variability in the past than previously thought; nor does it rest on spurious claims for the precision of central estimates. Also, it is important to recognise that the scientific models follow a different modelling strategy from standard econometrics. The physics and quantitative chemistry constrain the model parameters, so specifying such models is not simply a curve-fitting exercise; in any case, the complexity of the models, the number of variables of interest that they try to explain, and the number of possible criteria by which to judge goodness to fit preclude choosing the value of uncertain parameters to obtain the best fit.

This brings me to my third point: the need for serious economic analysis. Assessing the merits of policies entailing different degrees of mitigation and adaptation requires the comparison of very different possible paths for economic development. This is a problem in non-marginal dynamic stochastic cost–benefit analysis quite different from the usual project appraisal approach to cost–benefit analysis that treats macroeconomic parameters such as growth rates and discount factors as given and known.

Let me explain this in the context of scenarios for future greenhouse gas (GHG) emissions. The key points are that, in the absence of an appropriate policy framework, first, global economic growth is likely to lead to rising GHG emissions and, second, incentives to develop and adopt less carbon-intensive technologies are and will remain absent.[11] This gives rise to a substantial risk of adverse impacts on economic growth and human development, particularly in developing countries, in the future. This risk should be reflected in the policy-maker's growth modelling and approach to evaluating future benefits in the 'business as usual' scenarios. Generally, where

[11] Incentives to reduce emissions of GHGs are not equivalent to incentives to increase energy efficiency, although they may often work in the same general direction.

extra benefits accrue in more difficult circumstances, they should have higher weight than on more attractive paths.

In the absence of policies to correct the externalities and market imperfections associated with the emission of GHGs and with innovation, markets cannot be expected to deliver efficient or desirable outcomes. Further, fossil fuels, particularly coal, are available in sufficient abundance to make the 'business-as-usual' scenarios feasible. Trajectories of GDP and emissions can, and should, be very different from 'business-as-usual'. This could, we shall argue, be achieved with fairly modest net initial costs relative to 'business-as-usual' but very large benefits from avoided damage later in the century. Thus appropriate analysis must be non-marginal in the sense that it must be able to compare possible paths some of which perform very badly later in the century (i.e. those involving 'business-as-usual' now) with paths that take corrective action now and that allow continued growth.

That is the type of analysis that the economics of climate change must grapple with. And it must go on to look at the policies and market structures that could support these very different trajectories; it is in this area of the difficult microeconomics of public policy that much of the hard work lies. The remarks of Byatt et al. show little awareness of the importance of getting to grips with these vital issues.

These arguments do not turn on the precise definition of the 'business-as-usual' scenario, so the authors' criticisms of the IPCC SRES are largely beside the point of our argument. The statement that, without radical change, emissions will be such as to take us at least to 550 ppm CO_2 equivalent by mid-century and probably well above is robust to a very broad class of model assumptions. Simply continuing at the current rate of GHG emissions (a conservative assumption in the light of energy demand forecasts) is enough to generate a scenario in potentially dangerous territory (i.e., close to 550 ppm by mid-century—see original paper for discussion of possible consequences). Of course, emissions projections can be helpful in establishing the extent of action required, so the IPCC's decision to take another look at how scenarios are formulated is to be welcomed.[12] But there is a danger that the debates about the realism of the various SRES could obscure the basic argument that, in the absence of concerted action, the stock of GHGs in the atmosphere is likely to reach a level a lot higher than any policy-maker seriously concerned with the world's future would want.

If the major market failure of GHG emissions, and the real dangers it embodies, are to be overcome, collective action has to be taken on a global scale to induce non-marginal changes in technology choices and development paths. If progress is to be made, a shared understanding of the nature of the challenge and the uncertainties surrounding it is necessary. I hope that my Review will play a useful part in building that understanding.

[12] See: http://www.ipcc.ch/mandate.pdf

What do you look for in a leading indicator?

"There are a huge number of monthly indicators we use to try to predict ECB rate changes…….we found the whole-economy PMI (the weighted average of the manufacturing and services indices) was the best leading indicator of ECB rate decisions."

Dario Perkins, Economist
ABN Amro