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A Perspective Paper on Adaptation as a Response to Climate Change

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The author is Research Fellow, College of Asia and the Pacific; and Deputy Director, ANU Climate Change Institute. This paper was prepared as part of the 2009 Copenhagen Consensus process. It aims to provide a counterbalance to the Assessment Paper 'Adaptation to climate change: the role of market and policy driven responses', by Bosello, Carraro and De Cian (2009). The author thanks the Assessment Paper authors for their detailed response to my review of their initial paper. Thanks also go to presenters and participants at the session "Economics of climate change adaptation" that I convened at the Copenhagen Climate Change Congress in March 2009, and which provided valuable insights.

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PREFACE

ABSTRACT

Adaptation to climate change impacts will be necessary, and may require substantial economic resources. Economic analysis of adaptation, including costs and benefits, is subject to similar complications and limitations that beset quantitative economic analysis of climate change mitigation. To make such analysis relevant for policy decisions, the analysis must incorporate three factors that define the economics of climate change. The first is uncertainty, in particular the risk of abrupt climate change, which is a major reason for urgency in addressing climate change. The second is improved calibration of economic climate change impacts, and the inclusion of non-market impacts. The third is equity and differential climate impacts at the fine scale, which will define adaptation actions in practice. Hence, there is a long road ahead in improving the tools for economic modelling of adaptation, and the mitigation-adaptation nexus. Meanwhile, the crucial question for policymakers is not the benefit-cost ratio for adaptation in aggregate, but whether and where specific adaptation actions are beneficial, what new policies are needed to support adaptive action, and what existing policies need to be changed or scrapped.

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The Copenhagen Consensus Center has commissioned 21 papers to examine the costs and benefits of different solutions to global warming. The project's goal is to answer the question:

"If the global community wants to spend up to, say $250 billion per year over the next 10 years to diminish the adverse effects of climate changes, and to do most good for the world, which solutions would yield the greatest net benefits?"

The series of papers is divided into Assessment Papers and Perspective Papers. Each Assessment Paper outlines the costs and benefits of one way to respond to global warming. Each Perspective Paper reviews the assumptions and analyses made within an Assessment Paper.

It is hoped that, as a body of work, this research will provide a foundation for an informed debate about the best way to respond to this threat.

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1. INTRODUCTION

Climate change is highly likely to have substantial impacts on natural and human systems in decades and centuries to come, and has the potential to severely disrupt economic activities. It is likely to force the relocation of large numbers of people between and within countries, and change the location, extent and nature of economic activities including agriculture. In some cases, adaptation to changed climatic conditions could be feasible simply through changed practices, not necessarily incurring significant economic costs. In others, it will require expansion and remodelling of service systems such as public health; and necessitate the early retirement of existing and construction of new infrastructure including in housing, transport, water supply, energy and so forth.

These facts drive a demand for qualitative and quantitative economic analysis on optimum degree of climate change mitigation (that is, reducing greenhouse gas emissions as the driving force of human induced climate change) and adaptation to the effects of climate change, the optimal timing of such actions, and their optimum distribution between countries and sectors.

This paper discusses what is possible for economic modelling in this field and what is not. It makes specific reference to the Copenhagen Congress 'assessment paper' on the economics of climate change adaptation by Bosello, Carraro and de Cian (2009), and aims to give a counterbalance to that paper. It addresses, in turn, some of the broad questions for quantitative economic modelling of climate change and some of the results presented by Bosello et al; three facets of modelling that are prerequisites for detailed quantitative modelling to be relevant to policymaking namely uncertainty, economic impacts and their valuation, and equity and impacts at fine scale; and concludes by arguing that the most urgent policy relevant questions regarding adaptation are about specific localised assessments and about the design and reform of policies.

2. THE USES AND LIMITS OF QUANTITATIVE CLIMATE CHANGE MODELLING

The likely costs of climate change adaptation are beginning to be estimated in detailed sector-by-sector studies (as an example among many, see Ciscar et al 2009). Only some of the cost studies include an explicit assessment of the benefits from adaptive action, and thus make it possible to assess benefit-cost ratio of adaptation. Where they do, the result is typically that the costs of adapting are far smaller than the economic losses that would be incurred without adaptation. This result is unsurprising, because it depends on the selection of adaptation options for evaluation. There would obviously be instances where a specific course of adaptive action will pay large dividends (think of expanded water storage and improved fire prevention in areas that become drier with climate change), just as there would be adaptive investments that are economically wasteful (an example might be sea walls to shield existing infrastructure from sea level rise when it would be cheaper to re-build at a higher elevation). The latter would typically be excluded from studies.

At the other end of the spectrum of quantitative economic analysis, aggregated models of the economy overall, in particular Computable General Equilibrium (CGE) models, are beginning to be used for the analysis of climate change impacts as well as the analysis of adaptive responses. Where both mitigation and impacts/adaptation are modelled together, these models are referred to as 'integrated assessment models' (IAMs). The specific example of an application of such a model, discussed here, is the study by Bosello, Carraro and de Cian (2009).1 Such modelling, in principle, has decisive advantages over micro-level, partial-equilibrium modelling: it gives an integrated representation of benefits and costs adaptation over many different sectors and countries; a representation of economic flow-through effects such as changes in relative prices, trade, production and consumption patterns that may result from climate change impacts, mitigation and adaptation actions; and it can be used in simultaneous analysis of mitigation and adaptation. But IAM modelling also brings great abstractions, generalisations and reliance on assumptions about parameters that drive the aggregate results but are difficult or impossible to estimate or determine.

The relationship between mitigation and adaptation is one of the most important 'aggregate' question for policy to deal with climate change. It is clear that some degree of mitigation action is economically beneficial, although debate is lively (and is unlikely to ever be resolved) over what the optimal amount of mitigation is – see for example the conflicting conclusions reached by Stern (2006) or Garnaut (2008) on the one hand, and Nordhaus (2007) and Tol (2002) on the other. Similarly, it is clear that adaptation will be economically beneficial in many circumstances, but not in others, as outlined above. But the theoretically optimal amounts of mitigation and adaptation are also interlinked. If more effort goes into limiting the extent of climate change, then this will change the options and needs for, and payoffs from, adaptation. The exact nature of the relationship however cannot be theoretically defined, and instead needs empirical analysis.

Some results in the Assessment Paper

Bosello et al make an important contribution on this question, showing that the optimal policy mix for the world entails both mitigation and adaptation, and that an increase in mitigation action reduces the optimal level of adaptation action. Other key findings by Bosello et al are that both market and policy driven adaptation is needed; that mitigation action needs to take place earlier than adaptation; and that the degree of climate change damages as well as time preferences affect both the extent of optimal adaptation and mitigation, as well as the optimal mix.

They also present quantitative estimates of costs and benefits of mitigation and adaptation by country groups, and the benefit-cost-ratios of different scenarios of adaptation and mitigation. Some of their results are discussed below, in the context of critical assessment of model features and assumptions. The Copenhagen Consensus project places significant emphasis on benefit-cost (BC) ratios, and a number of these computations are provided by Bosello et al, though (perhaps tellingly) the authors do not emphasise these in their conclusions. In my view, and for reasons laid out below, it is not possible to compute robust cost-benefit ratios for climate change adaptation or mitigation within standard modelling frameworks such as that applied by Bosello et al, or indeed in any existing modelling framework.

1 In the interest of brevity, the modelling framework used by Bosello et al is not reiterated here. Please refer to the original paper.

Nevertheless, here and later in the paper I offer reflections on some of the quantitative results presented in the Assessment Paper.

The estimates of benefits and costs, and their ratios, are most usefully compared in their broad magnitudes and changes between different scenarios, for example as in Table 9 in Bosello et al. This shows, firstly, the overwhelming role played by the discount rate. Under the 'low discount rate' scenario, both benefits and costs of adaptation, and in particular joint mitigation and adaptation, are greatly higher than for high discount rates. This is of course a familiar result, especially in the wake of the Stern Review, and is a core difficulty with benefit-cost analysis in climate change. Along with the overall magnitude of benefits and costs, the absolute difference between them increases greatly under a lower discount rate. The benefit-cost ***ratio*** however is lower with low discount rates. Hence, considering only the BC ratio could lead to the fundamentally wrong impression that greater concern for the future ***reduces*** the desirability of climate change adaptation and mitigation compared to other investments.

Using higher damage functions greatly increases both the absolute size of benefits and costs, and the BC ratios. This is intuitive, if climate change is more of a problem, then the payoff from addressing it is greater. However, the stark differences in BC ratios between the 'low' and 'high' damage scenarios show that to a great extent, these ratios are driven by the assumptions about climate change damages. As discussed below, leaving out the risk of extreme or catastrophic climate outcomes biases the damage estimates downward, perhaps severely. Leaving out non-market values and equity impacts will bias the results generally in the same direction.

A fundamental point to note in assessing the benefit-cost ratios and other quantitative results is the damage cost estimates and functions, in particular after market-driven adaptation assumed in Bosello et al's model. Figure 2 in their paper shows modest GDP impacts even at temperature increases around four degrees, which is now commonly regarded as carrying a significant risk of large-scale, highly disruptive and possibly catastrophic climate change. The damage function is in line with some comparison studies, and lower than others. When market driven adaptation is considered, OECD countries as a group ***benefit*** from climate change (and presumably net benefits are even greater when taking into account government driven adaptation). This result could be seen to imply that OECD countries' interest, as a group, is in increasing global emissions, not reducing them, and that only the developing world has an interest in mitigation – which is in obvious conflict with observable actions by countries on climate policy. The result can again be traced to the climate change damage functions used in the model, combined with the fact that the risk of abrupt or catastrophic climate change is not considered in the modelling. In the real world, these concerns are likely to be a key driver of EU climate change concerns.

The paper makes interesting points about the time dimensions of mitigation and adaptation. A key conclusion is that mitigation action needs to come first, and little adaptation action is needed until the middle of the century, when climate impacts are assumed to begin. However, it stands to reason that many adaptation actions would need to take place ahead of time, to manage the risk of future climate change. This relates in particular to long-lived infrastructure, including for transport. A current real-world example are desalination plants, which in Australia and elsewhere are now being planned and in some cases built, to come on line if and when drought and water shortages become worse.

Limitations

Any such quantitative analysis is defined and limited by the choice of features of reality that are represented and ignored, and the calibration of parameters, for which empirical evidence is often scarce. I argue that the aggregated modelling tools at the disposal to the economics community, and including those applied by Bosello et al, are not nearly sophisticated enough to yield quantitative answers that are useful to policymakers. They may be able to give important qualitative indications, such as about the complementarity of mitigation and adaptation, but the quantitative results are under a heavy cloud of doubt even for broad aggregate results, and are generally not of use as a guide to policy at a disaggregated level.

The present paper looks into three aspects that would need to be included in quantitative economic modelling of climate change, in order for the quantitative results to usefully speak to policy. The first is uncertainty, in particular the risk of abrupt climate change, which is a major reason for urgency in addressing climate change, but difficult to capture in economic models. The second is improved calibration of economic climate change impacts, and the inclusion of non-market impacts, which motivate much of public concern about climate change and for which adaptation options are typically much narrower than for market impacts. The third is equity and differential climate impacts at the fine scale, which will define adaptation actions in practice, but cannot be represented in aggregate models.

3. UNCERTAINTY

Most modelling of whole economies, in particular that using CGE models, takes places in a deterministic framework. CGE models consist of a set of parameters that describe observed economic data and relationships (such as inputs to production processes, and trade flows), and fixed assumptions for behavioural responses (such as responses to changes in prices). In typical applications, including Bosello et al, the model is then subjected to 'shocks' in the form of sets of changes in exogenous variables. In modelling of climate change, a set of assumptions about the impacts of climate change is imposed, for example through changes in the productivity of certain sectors of the economy; and a price (tax) on emissions is imposed which results in shifts in production and consumption away from emissions intensive processes, goods and services. The myriad effects and interactions in the model can then be presented in an aggregate measure such as GDP or consumption. It is generally thought that responses in an economy to changes in relative prices, for example through changes in taxation or tariffs, can be modelled in this way with at least some degree of confidence.

The extension to the modelling of climate change impacts however brings hugely more complex issues into play. The nature and extent of future physical climate change impacts is unknown. Climate change science increasingly indicates that there may be strong feedback mechanisms in the system, making the correlation between greenhouse gas emissions, temperature increase and physical impacts highly non-linear (Richardson et al 2009). In other words, there is a wide probability distribution for the possible climate impacts (and their economic effects or damages) of any given level of emissions or global temperature increase. Consequently, modelling that deterministically maps emissions to climate change damages lacks the crucial dimension of uncertainty about what the actual effect might be, and in particular risk of very strong damages.

The risk of extreme climate change is in fact the main reason why the mainstream of climate change scientists urge fast and strong action to reign in emissions, and the key reason why a range of governments pursue urgent global mitigation action. A central objective of climate change mitigation, already evident in the 1992 UN Framework Convention on Climate Change, is to reduce the risk of extreme climate change in an expression of societal risk aversion.

It has been shown that under assumptions about the probability distribution of climate change damages that appear plausible given current knowledge, the (low) probability of catastrophic climate change alone could be the single overwhelming factor in an economic analysis of climate change, and for considerations relevant to economic decision-making about mitigation (Weitzman 2009). Thus avoiding the risk of very large scale economic damage dominates the effect even of the choice of discount rate, traditionally seen as the main variable driving the optimal level of mitigation.

Similar arguments, though likely to a lesser extent, also apply to the modelling of adaptation. Abrupt climate change could necessitate very different adaptation responses, and at a different timescale, including requiring a greater extent of anticipatory adaptation to achieve greater readiness for possible climate change impacts.

Furthermore, it must be questioned whether current assumptions about behavioural parameters built into economic models are an accurate guide to what may happen in the future, particularly under scenarios of significant change in the structure of economies.

The upshot for economic modelling of climate change, its economic effects and policy responses is that stochastic modelling is needed. In the first instance, this would involve the modelling of a large number of different scenarios of climate change impacts, ranging from very small to catastrophic changes according to a probability distribution. The difficulty in practice is that there is not just risk, but also uncertainty: climate science cannot define the shape of the probability density function.

The required modelling response to such uncertainty is not (as is typically done) to only use the median of the presumed probability distribution, as this creates the illusion of certainty. Rather, climate modelling becomes useful where it explores a range of possible outcomes across a range of possible climate outcomes. Such stochastic modelling was undertaken for example by the Stern (2006) Review, and conflated into an aggregate measure of expected economic impacts from climate change. Such stochastic modelling has however been applied in only few other economic climate change modelling exercises to date.

Bosello et al give a small glimpse of what a stochastic analysis might yield, in the comparison of ‘low’ and ‘high’ climate damage scenarios, and these show strongly differing quantitative results. A comprehensive stochastic analysis would explore these over a much broader range, and over a combination of stochastic parameters.

4. ECONOMIC IMPACTS AND VALUATION OF CLIMATE CHANGE IMPACTS

A second set of fundamental issues for economic modelling of climate change and adaptation options relates to the likely economic effect of environmental change, especially if and where such change is large in scale; and the inclusion and valuation of non-market impacts. Most current modelling exercises, Bosello et al included, rely on highly aggregate climate change damage functions that may underestimate feedback effects within economies, and do not represent non-market impacts such as the loss of species or natural icons.

CGE models typically assume a strong degree of substitutability in both production and consumption structures, and aggregate welfare measures such as GDP and consumption are driven much more by assumed underlying growth in productivity, than by changes in productivity because of a shift in structure away from the optimum. Physical factors, such as the need to produce and consume a certain amount of food per person, are oftentimes not or inadequately represented. Similarly, and using a related example, possible feedback effects such as escalating food prices during times of shortage are generally not well represented. Hence, even large scale physical impacts from climate change tend to be translated into only small changes in welfare, especially when compared to the assumed increase over time.

A striking result from Bosello et al (Figure 17) is that adverse impacts on tourism are the approximately equal largest category of economic damages, alongside agriculture. By contrast, the impacts from sea level rise and health are almost insignificant. Total net climate change damages are less than half a percentage point of GDP at 2050, compared to GDP typically expected to more than treble over that time span. This is in a scenario of a 3 degrees increase in mean temperatures, which now generally regarded to herald unacceptable risks from climate change for humanity.

These damage estimates originate in the damage functions taken from other studies, in interaction with the data and assumptions in the models. While it is impossible to confirm or refute any particular pattern of climate change damages, this particular result provokes doubts over the damages functions used. At a minimum, alternative specifications need to be explored that accord with notions that impacts on coastal infrastructure, health and agriculture and so forth would be serious to an extent that they would likely far outweigh economic impacts on the tourism industry.

A well-understood, yet extremely difficult to address shortcoming of standard economic modelling of climate change is the omission of non-market impacts of climate change, including amenity value to people and existence value of natural and cultural icons. These aspects are difficult to quantify, and leaving them out is in the mainstream modelling tradition. Nevertheless, an analysis that speaks to actual policy decisions on climate change cannot afford to set aside non-market impacts. In an illustration from Australia, it appears that the possible or indeed likely loss of the Great Barrier Reef, the world's largest coral reef, is a major factor in public concern about climate change. While it will be impossible to reliably quantify the amenity and existence value of such natural icons, they must figure in the overall evaluation of mitigation and adaptation strategies.

Adaptation options will typically be more restricted for issues revolving around non-market values, than for market impacts. The coral reef example is obvious in that there are no apparent adaptation options. The situation may be similar if somewhat different for issues such as the survival of species, where assisted relocation may be an option in some instances. Overall, the inclusion of non-market values in the analysis is likely to shift the balance towards more mitigation, rather than adaptation.

5. EQUITY AND SCALE

A third set of issues critical for the modelling relates to the distribution of impacts of climate change, and the costs and benefits of mitigation and adaptation.

Mainstream modelling exercises, including Bosello et al, aggregate welfare measures across countries, and implicitly within countries, and derive optima over the globally aggregated result. The implicit assumption is that an extra dollar of income provides the same utility to each person in the world. Given stark differences in income and living standards between and within countries, this is obviously not true. Again, the point is generally recognised in the climate policy debate, where there is heavy emphasis – at least in the rhetoric of international negotiations and domestic politics – on shielding the poorest countries and people from climate change damages.

One way to deal with this in a modelling context is to give equity weighting to welfare results. In a multi-country model, this would result in a different global optimum, namely one that gives greater emphasis to the best outcome in poor countries. On the basis of the numbers reported by Bosello et al, this would probably mean a greater optimum amount of both mitigation and adaptation, and a changed mix between the two.

A final issue relates to the scale of the modelling. The sectoral and regional detail in economic models used for climate change analysis is much coarser than the likely pattern of damages and benefits from climate change and adaptation. For example, a net loss within agriculture in one country could in fact consist of gains in some regions and for some types of agriculture, offset by larger losses in other areas. Similarly, there would be pertinent and highly cost-effective adaptation options in some activities and regions, whereas none may exist elsewhere. The design and implementation of policy must and will take the fine scale into account, and data from much coarser aggregate economic modelling will be of limited value in guiding such policy.

CONCLUSION: NUMBERS TO SHUN, QUESTIONS TO ASK

The relevance of economic modelling as a guide to climate change adaptation policy depends on the level of aggregation and detail, and the distinction between qualitative and quantitative results.

Modelling such as that by Bosello et al can provide powerful qualitative insights, for example about the respective roles and broad interactions between mitigation and adaptation, and as drawn out in their conclusions and alluded to in Section 2 above. However, the more detailed quantitative results from such studies are subject to such strong limitations as to be virtually irrelevant as a guide to policy. The Copenhagen Consensus exercise places heavy emphasis on benefit-cost-ratios. These ratios come about as a result of highly contestable assumptions about climate change impacts, economic damage functions, societal valuations and preferences, with interactions between them shaped by assumptions about behavioural relationships in economies decades in the future.

As an unavoidable result, the estimated ratios are highly contestable, and arguably not a useful guide for policy. Of course, similar caveats should apply to estimates of benefit-cost ratios for other long-term and uncertain investments in public and private goods, though it is clear that climate change adaptation as well as mitigation are particularly difficult areas for benefit-cost analysis.

The type of quantitative analysis that will be most useful for policymakers in getting to terms with climate change adaptation is not aggregate estimates of economic benefits and costs. Rather, it is detailed and localised benefit-cost estimates that take into account actual preference structures, including for equity, non-market valuations and aversion to risk. This is because decisions about adaptation will not be taken in aggregate for whole economies (as will typically be the case for mitigation), but sector by sector and locality by locality.

Finally, arguably the most pressing need for understanding in the policy community relates to the effect of policy settings on adaptation. Existing policies can support adaptation, or be counterproductive and hinder adaptive responses. This implies that many aspects of the existing policy framework in any country will need to be examined for their likely effect on climate change adaptation. New policies will be needed in some areas, to support types of adaptive behaviour that would otherwise not come about, and some existing ones will need to be scrapped. Much work will need to be done to understand where these needs are and how they would best be met. This will include quantitative work about benefits and costs, but rarely at a highly aggregated level.

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The science is clear. Human-caused global warming is a problem that we must confront.

But which response to global warming will be best for the planet? The Copenhagen Consensus Center believes that it is vital to hold a global discussion on this topic.

The world turned to scientists to tell us about the problem of global warming. Now, we need to ensure that we have a solid scientific foundation when we choose global warming's solution. That is why the Copenhagen Consensus Center has commissioned research papers from specialist climate economists, outlining the costs and benefits of each way to respond to global warming.

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