Ethics, Equity and the Economics of Climate Change*

Paper 1: Science and Philosophy

Nicholas Stern

London School of Economics

August 2013

ABSTRACT:

This paper examines a broad range of ethical perspectives and principles relevant to the analysis of issues raised by the science of climate change and explores their implications. A second and companion paper extends this analysis to the contribution of ethics, economics and politics in understanding policy towards climate change. These tasks must start with the science which tells us that this is a problem of risk management on an immense scale. Risks on this scale take us far outside the familiar policy questions and standard, largely marginal, techniques commonly used by economists; this is a subject that requires the full breadth and depth of what economics has to offer and a much more thoughtful view of ethics than economists usually bring to bear. Different philosophical approaches bring different perspectives on understanding and policy, yet they generally point to the case for strong action to manage climate change.

INTRODUCTION:

The principal purpose of the two papers in this series is to set out a framework for combining economic and ethical analyses of the issues raised by the science of climate change and to do this in a way that can inform the economics and politics of practical policy discussion and negotiation. All too often one or more of the disciplines of science, philosophy, economics and politics are excluded

* My thanks to Christopher Bliss, Alex Bowen, Nancy Cartwright, Raj Chetty, Janet Currie, Angus Deaton, Peter Diamond, Simon Dietz, Ottmar Edenhofer, Cameron Hepburn, Dale Jamieson, Kirit Parikh, Mattia Romani, Amartya Sen, Ioanna Sikiaridi, Michael Spackman, Chris Taylor, Bob Ward, Martin Weitzman and Dimitri Zenghelis for helpful guidance and comments. John Broome has given generously of his guidance on moral philosophy and I am very grateful to him. I am especially grateful to James Rydge for his work on this paper. The editor and referees gave very valuable advice for which I am very grateful. The opinions and views expressed, and any errors, are my own. Some of the ideas were discussed at a meeting of The New York Institute of Philosophy in their project, "New Directions in Political Philosophy" at New York University organised by Samuel Scheffler – I am very grateful for the valuable comments and discussion at that meeting (on 13th October 2012).

or treated simplistically and the usefulness and persuasiveness of the analysis for making policy are undermined.

Paper 1 examines the *science* of climate change, the scale of the risks, and a broad range of underlying *ethical* perspectives and principles, arising from moral or political philosophy, which are relevant to the analysis of policy towards climate change. Paper 2 considers important *economic* questions in the context of the ideas generated by the science and the ethics, and concerns specific equity and distributional issues, both inter- and intra-temporal, that arise strongly in the context of climate change, including national and international *political* discussions. Each of the papers can be read separately but the links between them are strong and important.

This paper starts with the science which tells us that this is a problem of risk management on an immense scale; business-as-usual implies risks of temperatures not seen on the planet for tens of millions of years, with consequences that could lead to the movement of hundreds of millions of people and thus possibly severe and prolonged conflict. Risks on this scale take us far outside the familiar policy questions and standard, largely marginal, techniques commonly used by economists; they raise deep questions about ethical perspectives beyond those traditionally captured in analyses of Pareto efficiency or standard social welfare functions. The challenges raised by the science are not questions of minor disturbances of some simple underlying growth story. Attempting to shoe-horn a problem involving the management of risk on this scale into an economic framework with modest perturbations in a narrow, often one-good growth model, together with taking a blinkered and overconfident view of the information that markets can provide on related ethical values and possible outcomes, carry profound risks of suggesting ill-founded, misleading and dangerous policies. This is a subject that requires the full breadth and depth of what technical economics has to offer and a much more thoughtful view of ethics than economists usually bring to bear.

The second part of this paper is devoted to an examination of ethical perspectives, which could be helpful and relevant in thinking about the problems indicated by the science. From moral philosophy, the perspectives include: Kant and his emphasis on duty and categorical imperatives; social contract approaches in the tradition of Hobbes and Rawls; Aristotelian and virtue ethics; and J.S. Mill and the potential ways in which values are informed and formed by public discussion. From political philosophy, we examine issues of liberty, rights and justice which arise in an intense way for these issues. There are important insights from all of these philosophical approaches, although I suggest some are more directly helpful than others. Arguments are advanced in favour of a pluralistic

approach in the tradition of Isaiah Berlin both in terms of the relevance of different perspectives and of the challenge of creating decisions in complex polities. These different philosophical approaches bring different perspectives on understanding and policy and may differ in their attractions to different people, yet they generally point in a similar direction, i.e. the case for strong action to manage climate change.

The social and political questions at issue are first, whether strong action is necessary; second, how strong should that be; and third, the nature of that action.[1] I note that this formulation is broader than the question in the form posed by some philosophers who focus on how much should we pay now and who should bear the costs (see, e.g. Caney, 2005; Gardiner et al, 2010). The reason I put it more broadly is that the narrow formulation often appears to take simplistic and rather static economic, technological and physical structures as given, with only modest scope for dynamic gains from learning, experience and discovery. Thus they speak the language of burden-sharing associated with zero-sum games rather than of an equitable approach to sustainable development.

A central point of these papers is to examine the decisions we do take as individuals, groups or societies and contrast with the decisions which could or should be understood as ethical. Such scrutiny can nurture reflection, discussion and change. For example, our political and social decision-making systems have often led to outcomes that are discriminatory and unethical; slavery and denying the vote for women were unethical but were strongly defended at the time. In the analysis of climate change, some argue strongly, for example, that people actually do discriminate between individuals by date of birth and so a high rate of pure-time discounting is ethically justified. These two papers attempt to structure and promote an examination and discussion of such issues. This paper is in part about the "is", in other words, the way decisions, implicit or explicit, are argued and taken. Thus, economic and other arguments and analyses around the relevant issues are examined, so that we can discuss whether the ethical bases can be viewed as clear and defensible. But it is also about how we "should" do things based on the guidance from examining a wide range of ethical perspectives.

[1] The third question is examined in the second of this pair of papers, and in more detail in Stern (2009) and (2012).

PART 1: THE SCIENCE AND THE SCALE OF RISKS

1.1 The Science

Understanding policy towards climate change, and its foundations in ethical and economic analysis, requires a basic understanding of the science when determining the processes at work: these processes and possible resulting impacts have a profound influence on the ethics, economics and politics. Of particular importance in shaping the required analysis are: the scale; risk and uncertainty; the long-term, global and distributional nature of impacts; and the "publicness" of a key cause of the problem, emissions. These four features arise directly from the science and thus the science must be the point of departure.

The problem of emissions and anthropogenic climate change starts with people and ends with people. The logic, to keep it very simple (and thus ignore some subtleties), is, in five steps, as follows: (i) people emit more greenhouse gases, as a flow, than the planet can absorb; (ii) stocks or concentrations therefore rise; (iii) more infra-red energy from the surface of the earth is prevented from passing out through the atmosphere and global temperatures increase; (iv) the local and regional climates and weather patterns change; (v) these changes have impacts on the lives and livelihoods of people. The impacts operate in large measure through water, or its absence, in some shape or form: storms, floods and inundations, droughts and desertification, sea-level rise. Changing temperatures and growing seasons also affect people directly.

The patterns and combinations of rainfall, wind, and temperatures across the year all influence what people can do. We have adapted to conditions as they are, and those conditions, in terms of global temperatures, have been fairly stable for around 8 thousand years or so. The impacts concern what happens to us if these change. It is the *change* that is crucial. Thus we must examine the science to see what it can tell us, to guide the ethical and policy analyses, about the processes and possible outcomes of change.

That the atmosphere was trapping the exit of energy was inferred by the French physicist and mathematician Joseph Fourier in the 1820s, when he examined heat-balance equations for the earth and found it to be substantially warmer than these equations indicated. He suggested that something was preventing the outflow of energy. John Tyndall, from Carlow in Ireland (at that time under British rule), discovered in the middle of the 19th century, by experimentation, some of the atmospheric gases trapping the outflow. At the end of the 19th century, Svante Arrhenius, the

Swedish chemist, provided preliminary calculations of the possible magnitude of the effects. By the 1940s, quantum mechanics (e.g. through the work of Walter Elsassar) had helped understand the mechanisms at work – in particular, showing that the oscillations of the greenhouse gas molecules were at frequencies/wavelengths which interfered with the infra-red energy.

The main greenhouse gas (GHG) at issue for policy is carbon dioxide (CO_2). There are others such as methane, nitrous oxide, and fluorinated gases such as hydro fluorocarbons (HFCs). Other GHGs are usually measured in terms of the equivalent in radiative forcing to CO_2 and the total measured as CO_2 equivalent or CO_2e. CO_2 constitutes around 60-65% of emissions (flow) of CO_2e and 85-90% of concentrations (stocks) of CO_2e since CO_2 lasts much longer in the atmosphere (for up to 1000 years or more) than most of the other main GHGs (CH_4, N_2O).

Rising CO_2 concentrations cause an increase in global temperatures by trapping more heat within the atmosphere. But this initial warming also triggers many feedbacks in the atmosphere that act to amplify or suppress the initial warming effect. Of substantial importance amongst these feedbacks is water vapour. A warmer atmosphere holds more water, and water vapour, as a potent greenhouse gas, traps more heat, amplifying the initial warming caused by increasing CO_2. Another important positive feedback is the 'albedo' effect – where warming melts ice at the poles meaning that less solar radiation is reflected and the atmosphere warms. There are cloud feedbacks – where more clouds have a net warming effect through trapping more heat (an effect which seems stronger than any reflection of heat). There are also negative feedbacks, such as the lapse rate feedback, where it is thought that the change in the vertical temperature profile of the atmosphere will have the effect of increasing the amount of heat that escapes the atmosphere – having a cooling effect. There is strong and consistent evidence, from both observations and models, that the net effect of all these feedbacks is strongly positive – that is, they amplify the warming effect of increases in levels of CO_2.

Empirical observations on the relevant variables, from direct temperature measurement over 150 years, from ice-core data where carbon dioxide (CO_2) and temperature can be inferred from crystal structure, now back to 800,000 years or so, and from paleo-archaeology over tens of millions of years, have provided extensive evidence to support the basic logic and theory outlined above. The data on temperature, greenhouse gases and other variables are not observations or correlations in search of a theory: the theory has been carefully built by scientists from different disciplines within science and across many countries over 200 years and is supported and confirmed by very extensive empirical work.

Each of the five steps of the chain of causation described involves risk and uncertainty as do forecasts of incoming solar energy. Often in this paper we do not distinguish between risk and uncertainty, but when we do, speaking of uncertainty, we use the Knightian sense of unknown probabilities.[2] We cannot precisely forecast emissions, or the absorptive capacity of the planet (the carbon-cycle), or how big is the effect of increased concentrations on temperature (climate sensitivity), or the impact on global temperature and local climates/weather, or their impacts on people. Thus this must be a story of risk management. The nature of the risks and uncertainties vary: some involve randomness in the process themselves, others difficulties in formulating formal models, others difficulties of calculation within models, others imprecision in parameter estimates (see Smith and Stern, 2011, for an examination of the different types of risk and uncertainties and their potential influence in policy discussions).

However, the risks look potentially immense. To illustrate: we now (2013) have concentrations around 445 parts per million (ppm) CO_2e. As a world, we are adding at a rate of over 3ppm per annum, a rate which was 0.5ppm per annum 70 years ago. That rate is rising; thus with unmanaged climate change the 445 could grow to around 750 or much more in a century. Some climate models suggest a median temperature increase over the next one or two centuries in the region of 4°C or warmer, with substantial probabilities of well above 4°C (see, e.g. IEA, 2012 and 2013; Stern, 2013; Rogelj et al, 2012).[3]

Global mean temperatures regularly exceeding 4°C above pre-industrial have likely not been seen for at least 10 million years, perhaps much more (e.g. Zachos et al 2008). The last time CO_2 levels exceeded 750 ppm, with surface temperatures well beyond 4°C above pre-industrial, was likely about 35 million years ago during the Eocene Epoch when the planet was entirely ice-free, which today would drive a sea level rise of the order of 70 meters. It appears that we have not seen temperatures equivalent to increases of more than 3^{o}C for around 3 million years. We have been here as *homo sapiens* for probably no more than 250,000 years (Stewart and Stringer, 2012).[4] Our current civilisations are much younger, 8,000 or 9,000 years, and date from the time after the last ice age when we had climate conditions favourable to the cultivation of grasses/cereals and thus a settled agriculture which provided both surplus and storage. During this period temperatures have stayed in a band of plus or minus 1 or 1.5^{o}C and we are now at the top end of that band. The planet has been at temperatures 4^{o}C or so below current periods fairly recently – the last ice age, which

[2] See e.g. Smith and Stern (2011).
[3] References to the science can be found in Stern (2012) and (2013), and National Academy of Sciences (2010).
[4] See: http://www.worldmuseumofman.org/hum.php

came to an end around 12,000 to 7,000 years ago. The conditions radically affected where people could live; in particular, given where the ice-sheets were, in the northern hemisphere they lived mostly closer to the equator than latitudes corresponding to London (if you will excuse a co-ordinate chosen by an Englishman). For more detailed references see Stern (2009), (2012), and (2013).

At 4^{o}C and upwards we are also likely to see the necessity for huge movements of population – some areas now comfortable will probably be deserts, others probably inundated, and others probably subject to hurricanes. Monsoons in Asia, crucial to the occupation and location of so many, are likely to change radically and so, too, are patterns and flows of rivers. Many of the features that explain where we are living would likely be redrawn. Mass movements of population, probably in the hundreds of millions, possibly billions, would likely result in severe and extended conflict. For more details on the possible consequences and dangers of 4^{o}C and upwards, including on migration and conflict, see: Hsiang et al (2013); Gemenne (2011); Royal Society (2011); Steinbruner, Stern, Husbands (2012) (Box 1-2 and the section on disruptive migration); Licker and Oppenheimer (2013); Oppenheimer (2013); Gilmore et al. (2013); and the January 2012 Special Issue on Climate Change and Conflict in the Journal of Peace Research.

None of these possible outcomes can be stated with certainty. But the lessons from the science suggest that the perils could be immense and the probabilities could be large, i.e. 20+% of 4^{o}C or more a century or so from now, under business-as-usual (see IEA, 2012, and 2013, and Stern, 2013). These are not tiny probabilities of inconveniences but substantial probabilities of catastrophes.

There are, of course, many potential sources of oscillations and random effects around the strong trend identified. There are the "high frequency" oscillations, every decade or few years, of El Niño/La Niña, where warmer or colder water comes to the surface of the oceans. The fraction of incoming energy flows absorbed in the lower ocean levels can vary. Solar activity can change, both in cycles and randomly. Volcanoes may erupt and result in the emission of particulates which screen out some energy from reaching the earth's surface. Variations in orbits around the sun with cycles of tens of thousands of years can play a role too. But the logic of the flow-stock process of emissions accumulations points to a powerful trend of temperature increase, very rapid in historical time, around which these oscillations and random effects will occur.

The flow-stock process makes delay dangerous. Once concentrations are there they are very hard to remove: particularly for CO_2 which lasts in the atmosphere for very long periods, much of it for a

hundred or more years, and some of it for a thousand or more years. And capital equipment and infrastructure for power, industry, buildings, transport and agriculture can lock-in techniques and the use of hydrocarbons. Indeed about 80% of the world's energy infrastructure for 2020 is already with us (IEA, WEO, 2012). Twenty years of inaction during which we add 3ppm or more per annum would take concentrations close to or above 500ppm CO_2e (with CO_2e around 450ppm) and, together with locked-in infrastructure, would make temperature increases of 3^{o}C (or more) likely, even with very radical action thereafter.

This flow-stock process and the difficulties associated with emissions reductions has led some to support "geo-engineering". This involves, for example, creating particulates on a massive scale to prevent energy arriving, or treating the oceans with iron to increase their absorption of carbon. Such methods are likely to involve all sorts of known and unknown hazards, possibly on a huge scale. For example, stopping energy from arriving would not prevent the acidification of the oceans arising from high concentrations of CO_2. Geo-engineering raises a host of ethical questions, including who decides on action. It is not the main topic here but it should be recognised as potentially significant, and better information on the possibilities has value. Weak action or inaction on emissions reductions may make it difficult to avoid being confined, in a few decades time, to choices between very risky strategies, one of which might be geo-engineering in some shape or form. For a review of geoengineering see The Royal Society (2009) and Reekie and Howard (2012). Allowing the regeneration of degraded forests looks to be a promising route for reducing atmospheric concentrations of CO_2e.[5]

How much to reduce emissions raises major questions. Many scientists have argued, and it is widely accepted in international discussions (e.g. the Cancun agreement at the UNFCCC, COP16[6] meeting in December 2010), that temperature increases above 2^{o}C would be "dangerous". The reasoning includes the concern that beyond these levels positive feedback effects, such as the possible collapse of the Amazon forest, thus releasing the carbon stored in the trees, the changing structure of oceans and their absorptive capacity, and the emission of vast amounts of methane from a thawing

[5] See, e.g. Righelato and Spracklen (2007).

[6] Discussions and meetings around international action on climate change began in 1992 with the establishment of the United Nations Framework Convention on Climate Change (UNFCCC), four years after the Intergovernmental Panel on Climate Change (IPCC) was established to report on the science. The parties to the UNFCCC have met annually in Conferences of the Parties (COP). In 1997 the Kyoto protocol was adopted, which set mandatory emissions targets for developed countries, and entered into force in 2005 following Russian ratification. These targets expired at the end of 2012. COP18 in Doha at the end of 2012 agreed a modest extension of the Kyoto Protocol with a small group of countries involved, largely from the European Union.

permafrost become more likely and, could set off unstable or run-away effects. Given the probabilistic nature of the forecasts and processes, the target is often taken as a 50-50 chance of a 2°C increase. A 50% chance of going above "dangerous" levels would itself be worrying, but it is one benchmark.

To achieve "two degrees" in this sense would involve radical reductions in emissions as illustrated in Figure 1 (from Bowen and Ranger, 2009).[7] There will be a number of relevant paths because, as this is a flow-stock process, one can do more now and less later, or less now and more later, but the paths look roughly as shown in the Figure. We essentially have to go from around 50 billion tonnes CO_2e per annum as a world now (2013)[8] to well below 35 in 2030 and well below 20 in 2050. Or in per capita terms, from 7 tonnes per capita per annum now to around 4 in 2030 and 2 in 2050. Given that the US is around 20 tonnes per capita, Europe/Japan 10-12, China around 7, India below 2, and many African countries between 1 and 2, it is clear that there are difficult issues, which involve, *inter alia*, equity, around who reduces and by how much. These issues are also influenced by the fact that the rich got rich on high-carbon growth and are responsible for around 75% of CO_2 emissions since the mid-19th century (CAIT-WRI, 2013). Yet it is poor people who will be hit earliest and hardest. The cross-country and intergenerational equity issues are explored in Paper 2.

We could think of there being only a certain amount of total cumulative emissions 'remaining', or a limited 'carbon space', if the 2°C objective (in the above sense) is to be attained. Figure 1 points to figures (the area under the curve) in the region of 1,000-1,500 billion tonnes of emissions remaining – around 25 times current annual world emissions (see also the work of Myles Allen on cumulative emissions, e.g. Allen et al., 2009). Should those who have consumed more of the 'carbon space' in the past have less right to consume later? There are many difficult issues to consider here, e.g. should we consider past emissions from when we began to understand the consequences of our actions? When was this? Or are we responsible anyway (e.g. as with asbestos in buildings) whether or not we understood the consequences? We examine the concept of allocation of the remaining 'carbon space' in Paper 2.

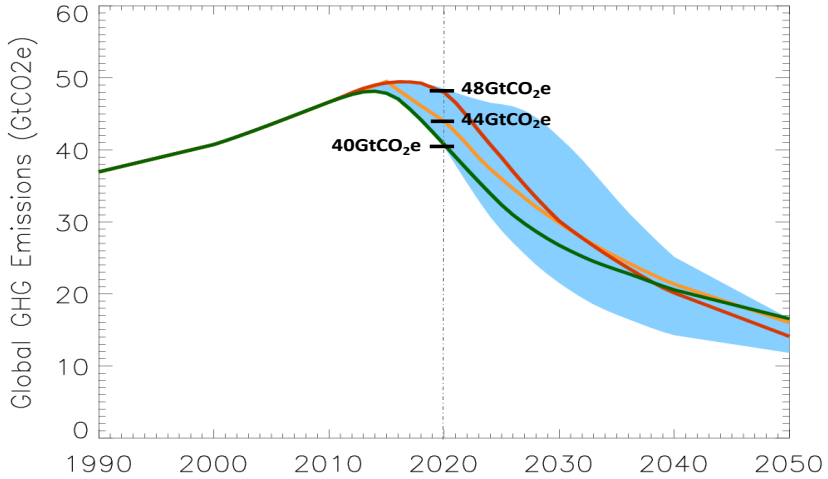
The scale of the necessary change essentially involves a new energy-industrial revolution which covers the whole economy. Fostering that change raises fascinating questions in dynamic public

[7] Precise statements of probabilities and paths are not possible and estimates are subject to revision, but the overall scale of necessary reductions as depicted in the Figure are robust.
[8] Numbers based on Ecofys (2013) for 2010.

economics. Those policies are not the primary object of this paper (see, e.g., Stern 2012, Lionel Robbins Lectures; we return to the idea of the energy-industrial revolution in Paper 2).

The above is a brief summary of the basics of the science. It, in large measure, determines how we understand and frame an economic analysis of policy and how we formulate the ethical issues. It is a crucial foundation for the next part of this paper and Paper 2.

Figure 1: Paths for global annual emissions that lead to a reasonable chance of a temperature rise of no more than 2°C.



Note: the shaded area represents the range of emissions paths that are consistent with a reasonable (50-50) chance of the 2ºC goal and the three lines show specific paths within this range.

Source: Based on Bowen and Ranger (2009).

This is not the place for a detailed discussion of the attacks on the science. I simply note that the science has developed in a systematic, thorough and detailed way with the usual interplay between theory and evidence. In this case the story started with a straightforward application by Fourier of a theory, concerning heat-balance, and as the evidence came in there has been ever-stronger support for the theory based on the greenhouse effect and on the temperature and other changes it indicates. In recent years the modelling has developed to the point where it can speak explicitly about some of the relevant probabilities, a crucial input into economic analysis. Remember that the key conclusion concerns risk: there appear to be substantial probabilities of catastrophic risks from unmanaged climate change and suggested probability distributions point to substantial weight around a range of temperature increases that involve very difficult or disastrous consequences.

There have been numerous and vociferous attacks on the science. These usually take one or more of the following forms, stylised for simplicity. (i) Because we have to speak mainly in terms of

probabilities and thus cannot speak with certainty about specific outcomes, we may as well assume very small or zero effects until proved otherwise. This line of argument involves either or both of a travesty of the empirical and theoretical evidence on the risks and ignorance of basic decision theory under risk. (ii) Because there is uncertainty, let us wait until more issues are resolved. This overlooks the fact that we have the ratchet effect of a flow-stock process and lock-in of capital and infrastructure. Thus delay is likely to be dangerous and expensive. (iii) Because there are oscillations it is impossible to discern a trend. This is clearly wrong, the trend is clearly visible, its causation is understood, and the mechanisms are likely to continue or accelerate without strong action. Economists, of all people, should surely not confuse oscillation and trend. (iv) Anthropogenic change may be present but other influences may be bigger. This is usually unquantitative, when other influences are examined the claim does not stand up; it often makes the same confusions as that of oscillations-trends. (v) Water vapour is important. Yes it is and, as we have noted, it amplifies effects of other greenhouse gases because warmer atmospheres hold more water vapour. More clouds also may trap more heat than they reflect, amplifying the impact of water vapour (Dessler 2010) (vi) Because a few papers in a body of thousands have errors, we cannot trust any of it. Clearly most sets of thousands of papers will have a few, or more than a few, with errors. The issue is whether, if those incorrect papers are deleted, the argument is still overwhelming. It is. (vii) Because a few scientists (in particular, from the University of East Anglia, UEA) have written emails which can be construed as suppressing evidence, the whole story of 200 years of science is a conspiracy. If all the work ever done at the University of East Anglia (around 50 years old) in whatever subject were deleted, there is a great body of evidence from researchers in many other parts of the world that comes to similar conclusions on temperature histories.[9] Interestingly, in the autumn of 2011 a further study, the Berkeley Earth Surface Temperature study, which conducted a new analysis of the surface temperature record (in part funded by those hostile to the current science) came to similar conclusions.[10]

Outcomes which can provide tests of the theory are not confined to surface temperatures. The vertical structure of the warming in the atmosphere and other changes to the climate are very difficult to explain other than by the action of greenhouse gases. A warming world will cause ice to melt and sea levels to rise but will also mean, for instance, a more intense water cycle, with more

[9] Further, a number of independent enquiries, including from the UK Parliament and one in which the Royal Society (the leading scientific society in the UK) was involved, have indicated that the work of the UEA scientists was sound. See the following UEA website for details: http://www.uea.ac.uk/mac/comm/media/press/CRUstatements/independentreviews

[10] See: Rohde (2013) and Berkeley Earth Surface Temperature (BEST) http://berkeleyearth.org/

floods and more droughts, because a warmer atmosphere holds more water vapour: again when we go beyond temperature to other predictions the evidence supports the theory.

One could go on. Readers who are interested in how the appearance of controversy has been manufactured when there is broad scientific agreement both that the basics of the scientific processes at work are understood and that the risks may be very large and with substantial probabilities, may wish to consult two recent books: "Merchants of Doubt" by Oreskes and Conway and "Doubt is their Product" by Michaels. *Inter alia*, they draw analogies with supporting evidence, between the assault by vested interests on the scientific analysis and demonstration of links connecting smoking and health, and the assault on the science of climate change. Indeed, some of the same people have been involved in both assaults: the book titles reflect an internal email from the tobacco industry in their attempt to undermine the evidence on tobacco and health: "doubt is our product".[11]

Those who want to learn more about the science should consult their learned scientific societies, such as the US National Academy of Sciences and the UK Royal Society. In countries round the world, scientists have examined the work of their climate scientist colleagues and come to similar conclusions: the science is sound and the risks very large. No national academy has taken a different view. Those interested in, or charged with making, policy should try to understand the science and should ask probing questions. They should also ask non-climate scientists for their assessment. The national academies have great experience in reviewing other science from both within and outside their particular research area: the answers of the academies around the world are consistent and clear.

Part 2 : ETHICAL PERSPECTIVES

2.1 Broad approaches to moral philosophy

The science forces us to go beyond the narrow formulations of economic modelling and of values and ethics, which are standard in economic appraisals of policy. These generally focus on a description of the consequences of policy based on marginal changes around some given path and exogenous future populations. That formulation of consequences of action often leads to ethics narrowly based on small Pareto improvements and Bergson-Samuelson social welfare functions. It also often goes with the claim that “social values" can be read off from markets, without necessarily being clear about the strong assumptions concerning markets, behaviour and ethics which are

[11] See these volumes for references and evidence.

required for the validity of such a claim. Such approaches to ethics are hard to sustain as the only or overwhelming perspective for the policy analysis of changes of the magnitude we have described and where millions of lives are at stake. Thus, we should examine a range of possible perspectives on the ethics.

We begin with moral philosophy, which emphasises on individual behaviour, but we shall discuss the issues in a way that links also to policy-making and thus to political philosophy – the next sub-section is on liberty, rights and justice.

I will not try to espouse, or urge the adoption of, one particular perspective. Indeed, my own inclinations are to follow Isaiah Berlin on the importance of maintaining a pluralistic view: no single perspective has a monopoly of insight or moral suasion. The first task here is to assess the traction and relevance of the most prominent perspectives in moral philosophy in connection with the issues that arise in climate change. The second is to examine what these different perspectives have to say about directions for policy on climate change. I shall argue that strong action on climate change would seem to follow from most of the perspectives considered. Each approach makes the case for strong action in different ways and brings different important and relevant issues and values to the discussion. That they point the same way not only helps to build a strong ethical case for action but also enhances the chances of gaining agreement to act.

Most approaches to moral philosophy assess or evaluate actions or policies in one of two ways: first we might examine whether or not they are wrong or unacceptable in relation to some basic set of principles; second we might examine whether they have consequences which are attractive or unattractive relative to criteria for assessing consequences. The latter is the "consequentialist" approach, of which the Bergson-Samuelson, or Paretian, welfare analyses are special cases familiar to economists. A number of versions of both the former and latter will appear at different points in subsequent parts of the paper(s).

Some are attracted by an attempt to be as "objective" as possible in using reason to justify moral codes, in the sense that they search for rules or propositions whose justification does not depend on the beliefs or feelings of any person or group. Whilst recognising that attraction, I do not wish to insist on that position and it is not necessary for my arguments here.[12]

[12] On issues concerning "objectivity", see David Wiggins' book "Ethics: twelve lectures on the philosophy of morality", Cambridge University Press, 2006.

Let us begin by looking at some important examples of the first type of approach; we consider four very briefly, which we crudely label Kantian, Contractarian (such as Rousseau or Rawls), Aristotelian,[13] and "common-sense pluralism". At the heart of Kant's framework is a 'categorical imperative' which gives a criterion for judgement of moral behaviour in oneself or others. Essentially, it invokes the notion of "duty" and examines its bases. Kant's formulation of categorical imperative is, "Act only according to that maxim whereby you can, at the same time, will that it should become a universal law". It is an approach to guide the individual. It focuses on the source of action – the will – as the object of moral evaluation, rather than on the possible consequences. For Kant it reflected a strong reaction to utilitarianism, the prime form of consequentialism at his time. There are difficulties in thinking about "universal law" when central to the class of 'others' are generations, some of whom have not yet been born, and whose actions are unlikely to affect ourselves in any direct way other than our interest in their welfare. Further, and of importance in this context, it is unclear who they are and whether they will exist.

Nevertheless it is hard to avoid the suggestion that a universal law that allowed each person to emit as much as she or he chooses, including at the levels we see in, e.g. the USA (around 20 tonnes per capita CO_2e), would be disastrous for the climate. In that case, total emissions would be currently around 150 billion tonnes, compared with the 50 billion we see now and the less than 20 billion we need to see by 2050 to avoid dangerous climate change (defined as a 50-50 chance of holding below 2°C). Thus a Kantian conclusion could be that individuals should radically reduce their emissions. Kant's second formulation of categorical imperative is never to treat humanity as a means to an end. Knowingly harming the prospects and livelihoods of the others by polluting their environment would seem to be using those others as a means to an end. But perhaps these lines of reasoning are too consequentialist for some Kantian philosophers, which may explain why they appear to have written little on issues related to climate change.[14]

Approaches based on Contractarianism, such as Rousseau or Rawls, have a similar problem to that of Kant. With whom is the social contract? In particular, what should be the role of those not yet born

[13] This brief discussion of Kantian, Contractarian, and Aristotelian ethics draws, *inter alia*, on Dale Jamieson (2010), in ed. Gardiner et al. "Climate Ethics", OUP, 2010. And I have benefited greatly from discussions with John Broome, the White's Professor of Moral Philosophy, at Oxford University, Nancy Cartwright, Professor of Philosophy at the London School of Economics and Amartya Sen, Lamont University Professor of Philosophy and Economics at Harvard University, and Cameron Hepburn and Dimitri Zenghelis, my colleagues at the Grantham Research Institute at the LSE. I have also benefited from the comments on these issues of Stephen Gardiner and Dale Jamieson and those from a meeting on “New Directions in Political Philosophy” at New York University on 13th October 2012, organised by Samuel Scheffler.

[14] A rare example of economists basing their analysis on Kantian ethics is Greaker et al. (2013).

who could not be present to participate in it other than if we act on their behalf? And we may be, indeed are likely to be, uncertain as to who and how many will exist in the future and how their presence or absence depends on our decisions. Interestingly, Rawls largely avoided the issue of future generations in his analysis of social contracts based on an "original position".[15] Notwithstanding this reservation, a contractarian approach would likely lead to a strong emphasis on the rights of future generations, for example someone in a Rawlsian "original" position would be ignorant of which generation she or he would join and would wish to avoid contracts which discriminate against them.

The Aristotelian approach, or virtue ethics, suggests that we can recognise, discuss and comment on "good behaviour" as we might recognise good playing of the violin. Aristotle in his Nicomachean Ethics pointed, for example, to courage, temperance, and magnanimity as key aspects of a virtuous life.[16] If we apply these ideas to say, drunken driving, we would probably agree that this is irresponsible or unvirtuous behaviour. Similar examples would apply to behaving in a way that ravaged the environment and put at risk the lives and livelihoods of many in the future.

"Common-sense pluralism" embodies the view: "the role for moral philosophy is primarily to explain and justify our everyday moral beliefs and attitudes rather than seriously to challenge them" (Jamieson, 2010). Unfortunately, such an approach does not help us very much if everyday or standard behaviour has arisen as a result of ignorance of its broader consequences, in this case of the long-term impact of greenhouse gas emissions. The ethical question on which we are seeking guidance concerns how we should act collectively, collaboratively or individually in response to the potentially immense risks of unmanaged climate change. Everyday behaviour in relation to everyday issues can often or usually allow us to understand consequences in a direct and observable way, so that our actions and the moral beliefs that might underlie them are informed by shared experience. All this is surely much less true of climate change.

Everyday behaviour may have arisen in an evolutionary way in terms of producing the kinds of codes and attitudes which allow societies to function better. But in the case of climate change, we simply have not experienced the scale of consequences which might arise from our collective behaviour.

[15] See, e.g. the volume edited by Gosseries and Meyer (2009) for a thorough examination of the issues and challenges around approaches to intergenerational justice, with a focus on Rawls and the fundamental difficulties with contract theory, including its limitations when applied to climate change. See also Gardiner (2011a,b).

[16] He also emphasised the avoidance of extremes, such as in the notion of courage which avoids recklessness and timidity.

And the global nature of the causes and effects, the long-lags, and the uncertainties make anticipation difficult. Our ability to reason about the consequences may be tested in ways for which evolution has given us limited experience and faculties, other than, crucially, the ability to reason itself, in terms particular of science, and thinking ahead.

That leaves, in terms of the broad approaches in the mainstream of western moral philosophy, consequentialism and its special cases such as utilitarianism, or the Bergson-Samuelson approach. The consequentialist approach, to express its statement of ethics in a simple way, embodies the idea that we should act to produce the best outcomes or consequences relative to some criterion or criteria which measure overall goodness and badness of consequences.[17]

In the case of climate change, acting together and on scale is crucial to having an effect commensurate with the problem. Thus Jamieson (2010) argues that the utilitarian (the argument is also relevant to the broader consequentialist approach just described) must ask how best to influence others towards a good outcome. He suggests that a utilitarian might be more persuasive and effective by eschewing detailed calculation and simply acting in a way that is virtuous, in this case in relation to the environment and climate change, in a similar way as choosing not to buy a carpet made with child labour. Thus someone who is virtuous in this Aristotelian sense of behaving in a way that appears right and responsible as a human being might in fact be very effective relative to a utilitarian calculus. Thus an approach to behaviour and policy based on 'virtue ethics' could look consistent with a utilitarian approach and indeed might be an effective way of pursuing that approach.

The ethical perspectives and approaches examined in this paper are drawn from traditions which are largely European. It is important to recognise that notions of merit, virtue, rights, duty, and responsibility for consequences of actions are also key elements of other great philosophical systems of the world (for example Sen 1997 and 1998 on Asian philosophical traditions; Wong 2011 on Chinese philosophy; and Taber, 1998 on Indian philosophy). Dahlsgaard et al. 2005, and Scharfstein 1998 write specifically on some of the commonalities or the similarities between European and non-European philosophies and traditions.

Many non-European religions and philosophical systems pre-date the “Occidental” tradition: Buddhism originated in around 600 B.C. and the roots of Hinduism, as expressed in the Upanishads,

[17] While some think of utilitarianism with an individual focus, it is more common to think of it as a way of evaluating states of affairs, where the link to individual action is a distinct issue.

pre-date Buddhism by many centuries, perhaps millennia. European philosophical systems we consider here begin with Aristotle and Greece around 350 B.C, although the focus in this paper is on the enlightenment tradition of the 17th and 18th centuries A.D. There is a literature on the influence of the Upanishads on both the Greek and enlightenment traditions (see for example: Conger 1952; Lomperis, 1984; Hebbar, 2009).

Respect for nature is a prominent theme in a number of non-European philosophical systems (for example: Watling 2009; Callicott et al. 1989; and Rolston 1987). Nature is firmly at the centre of many ancient cultures and religions: the Australian Aboriginal *Dreaming*[18] considers humankind as part of nature, where plants and animals have their own spiritual existence (Charlesworth 1992); for native Americans (in both north and south America) care of the land and respect for nature is at the foundation of the belief system of many tribes;[19] and for central equatorial African communities, a complex and holistic interaction and understanding of the environment enabled the development of a rich knowledge and understanding that went beyond the purely utilitarian (see Peterson 2004 and Selin 2003).

A duty and responsibility to nature remains central in some modern non-European societies. The constitution of Ecuador, for example, states that the people of Ecuador "Celebrating nature, the Pacha Mama (Mother Earth), of which we are a part and which is vital to our existence… Hereby decide to build a new form of public coexistence, in diversity and in harmony with nature."[20] This commitment to nature is further enshrined in Title 1, Chapter 7. "Nature, or Pacha Mama, where life is reproduced and occurs, has the right to integral respect for its existence and for the maintenance and regeneration of its life cycles, structure, functions and evolutionary processes."[21] And Title 1, Chapter 9 frames this commitment in terms of obligations and duties. "Ecuadorians have the following duties and obligations…to respect the rights of nature, preserve a healthy environment and use natural resources rationally, sustainably and durably."[22]

[18] Dreaming tells of the journey of Ancestral Beings who created life and the natural world. Dreaming stories pass on knowledge, cultural values and belief systems. http://australia.gov.au/about-australia/australian-story/dreaming

[19] http://www.indians.org/articles/native-american-life.html; http://www.pantheism.net/paul/history/native-americans.htm

[20] Preamble, Constitution of the Republic of Ecuador.

[21] Chapter 7, Rights of Nature, Constitution of the Republic of Ecuador.

[22] Chapter 9, Responsibilities, Constitution of the Republic of Ecuador.

2.2 Liberty, rights and justice

The previous discussion has focused for the most part on different perspectives from moral philosophy on what is or what is not moral behaviour by an individual.[23] There is a closely-related set of perspectives in political philosophy concerning liberty, rights and responsibilities which goes beyond the assessment of individual behaviour and which is highly relevant in this context: it will help shape the analyses of the next two parts of the paper on intergenerational and intragenerational issues. These perspectives concern the liberty or freedom an individual should have to take decisions as she or he would wish, in relation to what she or he desires or values, and in relation to the effects these decisions might have on others. The relevance of this approach to the impacts of climate change is clear. For much of this approach the questions are usually framed in terms of how far state or political structures do or should define and provide those freedoms. Many of the issues which arise straddle the (fuzzy) borders between moral and political philosophy. It is of no great concern to us where that border might be deemed to lie: what matters to this analysis is the guidance the different perspectives can provide for policy.

Perhaps the most widely discussed of these perspectives in political philosophy is the treatment by Isaiah Berlin of negative and positive liberties. To assert the importance of negative liberty is to assert that the state or other individuals or groups should not constrain or place obstacles in the way of key liberties such as the exercise of a vote or whom to choose as a partner. Its relevance to climate change is reflected in Berlin's famous remark "total liberty for wolves is death to the lambs" (Berlin, 1990): our emissions now potentially place severe limitations on the lives and liberties (for example where people can live) of those living later; indeed our actions can affect who may perish and who may exist.

Positive liberty concerns the ability to realise individual potential and thus concerns the presence or absence of constraints. Negative and positive liberty overlap but are not the same. The former is often read, for example, to imply strong limitations on state action and the role of the state more generally in relation to protecting individual freedom from state interference. The latter can sometimes be argued to require strong state intervention, for example to ensure that good education and health care are available to enable individuals, or to enhance their ability, to shape their lives. In development economics, versions of positive liberty have played a strong role, see e.g. Sen (1999) on capabilities or Stern et al. (2005) on empowerment.[24]

[23] We have noted that discussions of utilitarianism, for example, can and do treat rules and structures.
[24] The literature on international justice, e.g. Shue (1996) and Singer (2010), includes discussion of the positive/negative distinction as applied to rights and duties.

Similarly on the environment and climate change, the distinction between positive and negative liberties is reflected, sometimes very strongly, both in political discussion and in implied ethics. There are some, misguided in my view, who would argue that individuals have a right, and the state should not be able to restrict them, to do whatever they like, unless there is an overwhelmingly powerful case that what they are doing is inflicting serious damage on others: a focus on negative liberty. And to bolster that argument, there is a temptation to rubbish the evidence that their actions do actually damage others. For discussion of ways in which scientific evidence on climate change has been attacked and who has carried out and financed the attacks, see Michaels (2008), McCright and Dunlap (2011), Oreskes and Conway (2010), and Stern (2009, ch. 2). On the other hand, in the spirit of negative liberty, one can argue that the rights of a young person now to enjoy life and property in the future are being violated by the emissions of the current generation.[25] Arguments for limiting the role of the state, or for example, libertarianism as a political philosophy, are not the same as arguments that each group or generation has the unfettered right to damage the opportunities and freedoms of others.

Relatedly, there are some who argue that if the current generation of voters attach small weight to future generations then that should, as a matter of democracy, be decisive. That position, of course, would violate rights of future generations and would amount to asserting that one group, if it has power to do so, is entitled to damage others as it wishes.

Those who might emphasise positive liberty, might speak of a right to development, or they may see development objectives, as in Sen, in terms of the expansion of potential. They would thus argue that to fail to manage climate change is unacceptable because such failures would restrict the opportunities and rights to development of future generations. Arguments from the perspectives of negative and positive liberties are not necessarily in conflict, but they can be. In the case of climate change, I think they point the same way, and they should, in my view, be seen as of central relevance in the discussion of the ethics of and policy towards climate change.

Ideas of rights also appear in relation to "division of carbon space" – see Paper 2 (also below on justice). They might also appear in the context of e.g. wind farms where individuals might object to the "damage" to their local environment. And they can appear in policy reform which might force firms to bid for carbon permits when they made earlier plans on the basis that such permits might

[25] Those who speak of climate justice are often drawing attention to current damage in the developing world as a result of previous rich country action, see below and paper 2.

not exist: some might argue that investments or commitments made in good faith under previous rules establish some right to continue on the same basis. For example we often hear strong objections to “retrospective taxation”. Thus some emissions rights are sometimes “grandfathered” in the sense of some free allocation.

The pluralistic perspective, as argued by Berlin, is one which greatly broadens the economist's normal approach to the ethics of economic policy and decision-making. That is not to try to diminish or blur the economists' positive/normative distinction which is often key to the clarity of what we are doing when we try to offer policy analyses. But tying our normative analyses down to a narrow Paretian or Bergson-Samuelson approach in which individuals are fully aware of their preferences, and those preferences have a particular structure, is akin to tunnel vision and should not be seen as defining the "economists' approach", still less as defining "rigour". Indeed, in Amartya Sen's book "The Idea of Justice" (2009), in the spirit of Berlin, he sees pluralism as a step towards "objectivity". If a set of actions can be plausibly argued to be right relative to a range of ethical perspectives we can be more confident in suggesting the rightness of those actions than if it 'fits' with one perspective but conflicts with a number of others.

Policy analyses by economists should, and many do, contain basic calculations of gainers and losers from policy reform, and these calculations will generally be of great value for a whole range of political or ethical approaches. Such calculations are also crucial to an analysis of the political economy of vested interests. But we are much more productive in assembling and structuring analyses and presenting conclusions if we are aware of the broad range of political and ethical perspectives which might be brought to bear. And we can contribute strongly to public discussion if we can show how these different perspectives might complement, contradict or contrast with each other.

Some of those working on climate change have emphasised the idea of *climate justice*.[26] Amongst moral philosophers, the notion of justice has often been seen in terms of the realisation of a legitimate or moral claim on some object, opportunity or right; injustice is then seen as the inability to realise that claim. Thus justice and rights are closely linked ideas.

[26] This language was used by the environmental campaigner and Nobel peace prize laureate Wangari Maathai (who died in 2011). Mary Robinson, the distinguished former President of Ireland, has established the Mary Robinson Foundation for Climate Justice.

The discussion then turns to what constitutes, and what are the criteria for, a legitimate or moral claim. Amartya Sen's (2009) book gives the example of three girls who might be given one flute: child A is the only one who can play the flute; child B is the only one who, because of poverty, has no other object which could entertain or occupy her; and child C made the flute. Who has the most compelling claim? Solomon, in adjudicating between potential mothers or guardians for a child, rules on grounds of the love for the child which is revealed by the women who would choose to forgo her claim on the child rather than accept the division of the child into two; in the Merchant of Venice, the "judge" ruled that Shylock could have his pound of flesh as in the contract but could not shed a single drop of blood as the latter did not appear in the contract. These are all different perspectives on the notion of the legitimacy or moral foundation of a claim. The idea of justice forces direct consideration of these issues.

In climate, justice issues are usually centred on notions of rights to emit, to carbon space, to energy, to development. These are examined in Paper 2, Part 2, which focuses on "rights" to emit or to carbon space and suggests that such claims have a flimsy ethical basis. A right to energy as essential to living is different, although energy does not require greenhouse gas emissions. Many would regard a right to development, as the opportunity to change one's life, and in particular find a way out of poverty, as fundamental.[27]

We follow here, in the main, the approach proposed by Amartya Sen in terms of seeing the idea of justice in relation to public action, in terms of the identifying and overcoming of examples of injustice, where injustice is defined along the lines described above. He contrasts this with approaches which are intended to describe a just society as a whole, for example, the social contract approach of John Rawls, who sought to define justice in terms of the rules and objectives for society that might be proposed by a potential participant who is in an "original position", in the sense that she does not know what role she might have as a participant or, in a sense, who she will be in the society (Rawls, 1971). In the sense of the formal language of theories of social choice, Sen argues that we can tackle many key issues with partial orderings and do not necessarily have to insist that we must have complete orderings.

The outcome of this inevitably brief review is that consequentialism/utilitarianism, i.e. the starting point for much of economics, virtue ethics, rights-liberty approaches and ideas of justice are all highly relevant as ethical frameworks here, both for understanding moral behaviour and for the

[27] If our actions, here emitting, deprive a future generation of its ability to exist, then different justice questions arise, including whether people have rights to exist. (See Parfit, 1984).

principles of policy. For all of them, and we shall develop the consequentialist approach in the next sub-section, wreaking severe damage on the prospects and lives of future generations would likely be regarded as immoral.

The relevance of the Kantian and contractarian approaches, are qualified by the difficulty of incorporating in them the consequences of our actions for the possible *existence* of others in the future, thus making difficult an idea of "universalism" or "society" when the membership of the society is directly influenced by our actions. Nevertheless, notwithstanding that qualification, both of these approaches would indicate the immorality of being casual about the lives and livelihoods of future generations.

We return to the possible scale of the risks and damages at the end of this part of the paper and argue that there is a great deal we can do to limit the risks: we have choices. Delay is dangerous and alternative paths carry attractions beyond the fundamental limitation of climate risk. Given these choices, the different ethical perspectives would all appear to point to strong action.

2.3 Applying consequentialism

In the remainder of Part 2, we consider ethical and related analytical issues which arise in applying the consequentialist approach in the context of climate change: sustainability; population; Pareto efficiency; ideology and attempts to dodge the ethics. We also examine how the science and ethics together structure the economic analysis, thus establishing the framework for the second paper on intergenerational and intragenerational issues. But, as a foundation for these analyses, let us begin by reminding ourselves how standard theory deals with policy in terms of market failures and conventional cost-benefit analysis. The criteria invoked in such standard theory require us to examine how much the welfare or utility of the individuals involved, directly or indirectly, rises or falls, with utility increments usually added across individuals using a procedure for the social weighting of increments in utility or income.

If my actions damage the prospects of others and I consider in choosing my actions only my own welfare then I will push the damaging action “too far” in the following sense. I push it to the point where on the margin the net benefit to me is zero (e.g. the benefit to me on the margin is just equal to the price I pay or the costs I incur for the last unit). Then a small reduction in that activity has zero net marginal effect on my welfare but increases the welfare of the people damaged by the activities. Thus a small reduction in the activity results in a Pareto improvement, in the sense that one person

is better off and none is worse off. The state of affairs without the corrective action to reduce the activity on the margin is described as “Pareto inefficient” in the sense that it is possible to make someone better off without making anyone worse off. The damage to others from the activity is the externality and the misallocation or inefficiency reflects the failure of the market to signal the damage. I have argued elsewhere (Stern Review, page 27) that the emissions of GHGs and climate change represents the biggest market failure the world has seen because of the potential magnitude of the damage for so many people and the involvement of almost all in causing the externality.

In policy towards climate change there are other important potential sources of market failure: ideas are public goods and technological innovation is important; networks including public transport and electricity grids; the ability of capital markets to handle risk; asymmetric information; and unpriced benefits such as biodiversity and energy security. These are examined in more detail in Stern (2012, Lionel Robbins Lectures): it is a serious analytical and practical mistake to speak and act as if correcting the greenhouse gas externality itself is all that is necessary. Of course, that externality is absolutely central and its correction has to be at the heart of policy.

It is interesting to note that in some applications, e.g. to crime, (see Becker, 1968; Carr-Hill and Stern 1976 and 1979) there are issues concerning which benefits should be counted and which included in any social evaluation. In particular, should the pleasure of a sadist count as a benefit in assessing crimes of violence? Perhaps relatedly, we should note that some think it is wrong to be able to buy the right to pollute (Sandel, 2012 provides a recent example of the expression of this position).

Project appraisal, cost-benefit analysis or the evaluation of net benefits on the margin for an investment programme or set of policies, generally compares the world without the programmes and the world with. If the programme creates only marginal changes around some future specified path and markets work reasonably well, then standard procedures proceed on the basis that the value of an extra unit of a good or service is reflected in its market price. Variants of market interest rates or rates of return are often used as a basis for discounting future benefits. Non-marketed goods are often ignored, or receive just a mention. Sometimes, but far from always, income distribution is brought in by attaching "welfare weights" in the sense that gains or losses to poorer people have a higher weight. Welfare weights can be set to be equal on one of two grounds: by direct assumption, thus the ethics of income distribution is effectively ignored; or by suggesting that

transfer policy has set them to be equal[28] – that would formally involve an optimum set of lump-sum transfers, which on informational grounds is generally impossible (hence we have the theory of optimum income taxation à la Mirrlees, built on asymmetry of information between individuals and those doing the taxation). Taken together, the description of this paragraph characterises the framework or method that we take as the meaning of "narrow standard cost-benefit analysis".

In this context climate change impacts are non-marginal, there are many relevant market imperfections, the future path depends strongly on our actions, market rates of interest are poor guides (see Paper 2) and there are many important unpriced effects. These are the reasons we have described the standard approaches as misleading. We turn now to a set of issues which are often or usually excluded from standard approaches, but which may loom large for climate change.

Sustainability

There are ways of assessing consequences which do not necessarily proceed as we have just described i.e. by doing the evaluation of programmes, solely or primarily, in terms of whether and by how much the welfare of different individuals or households rise or fall and then aggregating in some way. There are many who would wish to argue or assert that this generation has an obligation to provide for "sustainability" formally defined as enabling the next generation to be no worse off than ourselves, in such a way that the same can also be true of subsequent generations in relation to their predecessors (see, e.g.: Arrow et al., 2012; Asheim, 2010; Asheim, 2007; Pezzey and Toman, 2002; Toman, 1994). They may make a mess of their own decisions but we should leave them with opportunities no worse than we had.

One way of assessing whether sustainability has been made possible by this generation is to look at the set of capital goods passed on (built, created, environmental, natural, human, social, etc.) to see whether they can sustain standards of well-being no worse than our own. That does not necessarily mean more capital on every dimension, but that taken together the set of capital goods which we leave them allows opportunities for the new generation at least as good as ours. Sometimes the definitions in formal models is that of non-decreasing "utility" from one generation to the next (see, e.g. Asheim, 2010; Buchholz, 1997). There is some formal discussion in the literature (e.g. Asheim, 2010; Basu and Mitra, 1983) relating sustainability to two axioms, Paretianism and anonymity, together with an assumption on the productivity of investment. And there has been a related

[28] Sometimes it is argued that income distribution should be tackled elsewhere. Often one can indeed argue that more should be done to redistribute income via tax and transfer methods but that still leaves the issue that, on information grounds, tax/transfer policies would not equalise welfare weights.

discussion of theorems that show that, in infinite horizon models, adopting these two axioms implies that related social orderings may be incomplete. This result is connected to the issue of discounting of lives and discrimination by date of birth (violating the anonymity assumption), as well as to model structures and assumptions concerning technical progress, and is examined in Paper 2, Part 1.

The broad definition of sustainability is sometimes made tighter, for example via notions of stewardship, in terms of specific aspects of our natural environment or biodiversity, which should be left to future generations as we find them ourselves, or indeed we should try to restore to what we know they were prior to our damage. The creation of national parks is in this spirit.

These notions of sustainability can be derived from some of the ethical perspectives discussed above. They could be seen as part of a version of rule-utilitarianism,[29] based on the idea that there may be a systematic failure to understand as individuals the consequences of our actions for future generations, so that a rule which binds us all might lead to gains for future generations much larger than any loss we might suffer. A Paretian perspective can lead to an argument and conclusions which are close in spirit, although not identical as discussed below.[30]

Sustainability could be seen as a part of virtue ethics which views a behaviour which recognises and acts on the idea of sustainability as part of the make-up of a virtuous citizen, just as an individual or society might feel that it is right or virtuous to educate children, or create human capital for them similar or better than our own. Or it might be seen as part of a social contract with future generations, although as we remarked above, the argument encounters the difficulty of applying this approach to "citizens" who do not yet exist or may not exist.

Because the idea of sustainability is, I think, derivative of the more general approaches, albeit an interesting idea which is widely embraced, it is presented here as an application or example of logically prior viewpoints, such as rule-utilitarianism, or virtue ethics, rather than as a broad perspective in its own right.

Population

One key application of the above discussion of ethical perspectives is population: climate change can, and does, kill people, either directly or through the conflict it can cause. It can also prevent people from coming into existence, such as the 'lost children' of those who might be killed or otherwise die

[29] For a discussion of rule and act utilitarianism see, e.g. Sen and Williams (1982).
[30] And see Asheim (2010) for a discussion of formal results on sustainability and Paretianism as just mentioned.

prematurely. And these premature deaths are likely to be very unpleasant, e.g. from conflict, starvation, dehydration, inundation, etc. The scale of the potential consequences means that those, including economists, who think about policy cannot avoid the issues. The first question we have to face here is trying to value premature (and very unpleasant) deaths and the prevention of future lives. A second question concerns population as a determinant of climate change in that more people imply more emissions. Thus we should examine arguments concerning the limitation of population for this reason. We take these two questions in turn.

On the problem of valuing life in the context of climate change, the leading contributor has been John Broome[31] (see, e.g. Broome, 2004; 2009; 2012). John Broome's analysis (Broome, 2009), of a proposition that he associates with Martin Weitzman, understandably regards the potential of extreme catastrophe, represented in particular here by extinction, as of critical importance. Unmanaged climate change might result in temperatures of 8 or 10^{o}C or more, with a small probability (see, e.g., IPCC fourth assessment report, 2007). Very high temperatures might well involve the extinction of our species, i.e. all humans, thus the wiping out of, say, 9 or 10 billion people (extinction is by definition a one-time event). If the probability is between 0.1 and 1%, Broome argues, that would be an expectation of, say, 9-90 million people killed, perhaps 100 or 200 years from now. Everybody dies sometime; what we are talking about is premature and unpleasant deaths.

What if temperature increases were 2, 3, or 4^{o}C as a result, in part, of a given set of policies on emissions? As long ago as 2000 the WHO suggested that around 150,000 deaths a year might at that time be attributed to climate change, and this as a consequence of less than a 1^{o}C increase (WHO, 2002). It is plausible that 2, 3 or 4^{o}C could entail half a million deaths a year or more; this could continue over many decades and the probabilities of such temperature increases, say over 2^{o}C, are very high under unmanaged climate change, perhaps 80 or 90%, and around 50% even with strong policy as we saw above. Thus one might argue that, cumulating these deaths over time, the expectation of the number of deaths associated with temperature increases of this magnitude is probably also in the tens of millions (in addition to the Broome/Weitzman extreme event of very high temperatures). The precise number of millions does not matter here. But it does seem reasonable to argue that (i) the subject of the treatment of deaths in the calculus of

[31] As it happens, John Broome started his graduate work and initial career like myself as a student of James Mirrlees in Oxford in the late 1960s working on the mathematical economics of public policy. He is now professor of moral philosophy at Oxford. I am very grateful for his guidance.

consequentialism is central and unavoidable and (ii) it is not dominated only by the tail-end of the distribution.

Killing or damaging human lives and causing premature death are central potential consequences of badly managed climate change. Age-specific death rates are a central determinant of population size, as are demographic structures, age-specific birth rates and fertility rates. The different elements feed into each other. Thus, arguments about causing death lead us to a discussion of population size and of the relevant ethics, particularly in the sense of how we value populations of different sizes.

The ethics of population size encounters deep difficulties. Without the idea of a "neutral level" of well-being we have little guidance, where neutral means that more people above that level is "good".[32] But if we invoke this idea we run into the difficulties illustrated by Parfit's "Repugnant Conclusion". His original formulation asked us to think of a planet where "For any possible population of at least ten billion people, all with a very high quality of life, there must be some much larger imaginable population whose existence, if other things are equal, would be better even though its members have lives that are barely worth living" (Parfit 1984, page 388). He argued that such a conclusion is 'repugnant' and unacceptable. But it is not easy to find a theory that avoids this conclusion. Many 'exit routes' from the repugnant conclusion have been explored but they run into serious problems. For example, we can try to drop 'transitivity' as a requirement for an ordering but as Broome (2004) argues, this is basic to our idea of rationality (see also Broome, 2010 and 2012, for further discussion of some of the difficulties with "neautrality intuition"). Thus the theory of the ethics of population is not in a state that gives us strong direct guidance.[33]

My own broad-brush conclusion from this chain of reasoning is that we should go beyond narrow cost-benefit analysis here, with its focus on marginal perturbations, and think also, or perhaps particularly, of questions of policy for climate change in terms of risk management where we try to describe risks and uncertainties as best we can in terms of the nature and scale of impacts and how likely they may be. Trying to understand the seriousness of possibly immense effects does not mean that we have to quantify the value of lives where they are likely to be at risk. It does mean that we try to bring the magnitude of death and physical harm into an understanding of consequences. We will find that we can get a long way in examining policy by asking how we can radically reduce the likelihood of catastrophic outcomes, without necessarily demanding explicit calculation, or specific

[32] It is a position of longstanding interest in economics (see, e.g. James Meade, 1951).
[33] For a useful summary discussion of the difficulties see the online Stanford Encyclopedia of Philosophy. http://plato.stanford.edu/archives/fall2010/entries/repugnant-conclusion

valuation, of consequences. Let me stress that this does not mean jettisoning the expected utility approach, but it does mean recognising that we are likely to do the analytics and ethics of the problem grave damage if we confine ourselves only or overwhelmingly to that approach. A narrow attempt to force the problem into a form where we can apply such a technique risks so simplifying it for tractability that we discard in our analysis the essence of the issues at stake. An attempt at more precision can end up with less rigour.

Thus far on population we have been discussing fatalities as a result of climate change. How should we think about policies that try to influence population as part of policy towards climate change? That is our second question. World population in 1900 was around 1.6 billion, in 1950 around 2.6 billion, in 2000 around 6 billion, now (2013) around 7 billion, and in 2050 is likely to be around 9 billion. There is little doubt that the challenge of holding down emissions would be easier if population were smaller: for given production and consumption patterns and levels, emissions are roughly proportional to population.

What are the ways in which population can be limited? From the accumulated work on demographic change (see e.g. Stern, Dethier and Rogers, 2005), six key variables influencing population include: education of girls and women; overall levels of income; opportunities for women in the workforce; infant mortality rates; women's rights in the household to income and assets; and women's access to reproductive and other health services. These are all dimensions where there would be powerful arguments for action, many based on women's rights, without any reference to climate change. And, in large part as a result of progress on these dimensions, fertility rates (the number of children per woman) have fallen dramatically over the last 40 years or so across the developing world. For example, in Bangladesh the fertility rate has fallen from 7 in 1970 to 3 in 2005, Iran 7 in 1970 to 2 in 2005, India 5 in 1970 to 3 in 2005, Brazil 5 in 1970 to 2 in 2005, Mexico 7 in 1970 to 2 in 2005, and Middle East and North Africa 7 in 1970 to 3 in 2005 (World Development Indicators, 2012). In India, fertility rates are likely to fall to steady-state replacement levels in the next 10 years. Population increase will be driven between now and 2050 largely by the fraction of women of child-bearing age in the population and by the fact that the fall in fertility rates in Africa is lagging behind other continents, even though they are falling there.

The scope for policy action beyond the, in my view highly desirable, continued progress along the six dimensions described, seems somewhat limited unless one goes immediately, and across the globe, for something like the one child policy in China of the last 30 years. Such policies, although that is

not my focus here, raise their own ethical issues. There is, however, an important practical point: in some countries such policies can cause such reaction that over time they might have a contrary effect. The revulsion in India, for example, to the excesses of apparently forced sterilisation and other pressures during Mrs Indira Gandhi's emergency of 1975-77 was intense (see, for example, Gwatkin, 1979, for a description of the sterilisation programme and its subsequent effects). And I have heard such reaction directly myself in the village of Palanpur (in West U.P. in India) which I have been studying (with colleagues) over the last four decades.

Thus from the point of view of ethics, development more broadly, and women's rights, the arguments for action on the six dimensions described would seem to be powerful. Thinking about climate change could reinforce them, but the arguments already seem strong.

2.4 Pareto efficiency and "the most important thing about climate change"

There are many, particularly in richer countries, who see the subject of ethics in relation to climate change as largely about intergenerational values. In developing countries discussion often stresses intra-generational issues and obligations of richer countries. But before embarking on a discussion of intergenerational or intra-temporal distributional issues and trade-offs (the subjects of Paper 2), we should remember and emphasise a basic lesson from standard welfare economics, which has already been explained above: market failures which are left uncorrected are generally associated with outcomes which are Pareto-inefficient. In the usual formal sense in economics, i.e. the production or consumption of an individual or group directly affects the production or consumption possibilities of another individual or group,[34] the emissions of greenhouse gases are an externality. If unpriced or unregulated, we have a market failure. We should therefore, from a position of uncorrected, or partially corrected, externalities, be able to identify a Pareto improvement, in this case one which improves the welfare of future generations whilst leaving the current generation no worse off.

A simple example makes the point in a fairly general way. Consider two consumers corresponding to two generations, identified with periods (N and L), which we call 'now' and 'later', with utility functions $u_N( )$ and $u_L( )$ depending only on their own consumption. Suppose there are two goods A and B, and two production sectors, one associated with each of them. Suppose further that the production of A by this generation pollutes next period's environment and damages the ability of the next generation to enjoy their consumption, but the production of B does not (or less so). And suppose that without any policy to correct the externality we have an equilibrium where the relative

[34] Standard definition, for example, in Meade (1955), Trade and Welfare.

price of A and B is one in the first period. In this equilibrium the marginal rate of substitution (MRS) in N's utility function and the marginal rate of transformation (MRT) between A and B in the production sector are both equal to one.

The following change generates a Pareto improvement: produce on the margin, in the current period, one unit less of A and one more of B (we can do this keeping overall inputs unchanged because the MRT is one), and adjust first-period consumption by corresponding amounts. The first generation is no worse off, since the MRS in preferences given by $u_N(\ )$ is one. And the next generation is better off, since the inherited pollution is less. We could, of course, adjust the example so that the first generation makes the same change in production but leaves a small amount, ε, less to the next generation in terms of bequests or grants. We could choose ε so that both generations are better off.

A second example could be constructed by, on the margin, reducing production of the damaging good in period N by applying less labour. If labour has been applied up to the point where the disutility on the margin is equal to the marginal utility of its product then generation N is no worse off and generation L is better off. However, both the examples do require more than one good in the first period (in the second example it was labour). Examples which say simply produce less, bequeath less and hold consumption the same in period N do not necessarily imply a Pareto improvement. Will the enhancement of the environment in the later period be enough to offset the reduced bequest? To show that it can be we have to say something more about the choice of consumption and production in the first period. That is how the two examples work.

Put in fairly general terms, the examples show that starting from a situation in which the climate externality is uncorrected, this generation could adjust its consumption and production in this period, and its bequests to leave both itself and future generations better off. It simply does a little less of the polluting activity and a little more of the non-polluting activity (more of B in the first example and leisure in the second) in amounts which are both feasible on the production side and on the consumption side leave the current generation no worse off. For this type of change one need not embark on agonising reflections and discussions on inter-temporal values. We shall, however, embark precisely on such discussions in the next paper because the subject goes beyond this type of Pareto improvement – for the usual reasons one cannot suppose that decision-making processes and political economy are such that all Pareto improvements are realised. And even if they were, there would still be questions of intergenerational choice.

John Broome (2010) has called this observation on Pareto improvements "the most important thing about climate change". It is surprising that it has been so under-emphasised in the economic discussion of climate change given the centrality of externalities to that subject and to its analysis. It is an argument which has been widely understood for some time – essentially when we are speaking of market failure we generally embody the idea of Pareto inefficiency. The possibility of making both current and future generations better off is emphasised and discussed explicitly in Stern (2009, p.85) and Stern (2010). Foley (October 2007) is the earliest written version, of which I am aware, applying the Pareto inefficiency idea explicitly to current and future generations; he gives the point strong emphasis.[35]

To indicate the importance in this context of the idea of market failure is not to say that if we focus there we deal with all the issues. Intergenerational distribution is fundamental to policy and climate change; so too are intragenerational issues. We return to this subject in detail in Paper 2.

2.5 Ideology and attempts to dodge the ethics

Given the above discussion of the potential severity of the consequences of emissions for the welfare of others, why is it that so many economists try so hard to shy away from the recognition that an examination of the ethics is unavoidable? What techniques or arguments are used to sustain their avoidance?

One possible reason that some may find discomfort in allowing an ethical perspective to enter the argument is that putting the externality and the ethics together provides a reason for government intervention in markets. Thus some see it as a return to the command economy of a socialist or communist era but with government officials in green hats rather than red. And they see all the problems of officialdom, intrusiveness and corruption which might be associated with such intervention. Such problems should indeed be part of any careful discussion of policy but they cannot in logic be seen as a reason for avoiding the ethical issues in economic analysis which arise from the presence of severe externalities i.e. severe damage to other people from emissions.

We saw in the 1980s and 1990s fierce examples of this ideological aversion to government intervention sometimes described, not unreasonably, as market fundamentalism (see, e.g. Stern, 2010, for a discussion). But economists should surely understand and argue that it is pro-market,

[35] See also Hans-Werner Sinn (2007) which argues that delaying fossil fuel extraction is Pareto improving.

not anti-market, to recognise market imperfections and look for policy to assist the effective functioning of markets: to fail to act on gross market failures is to grossly distort markets. The basing of policy on the recognition of market failure where it exists is surely the approach that respects and understands the ability of markets to give good results. And when we proceed in this way we encounter the ethics, particularly because the effects are so large, distributional effects so strong and the relevant imperfections so pervasive.

Of course, ethics can be dodged by denying the existence of the externality, essentially denying the science, or suggesting that it is too small or uncertain to bother with given the perceived "dangers" of government intervention. Part of the argument in suggesting the cure is worse than the disease is to suggest the disease is trivial. We have dealt with this kind of confusion and distortion of the scientific evidence in Part I of this paper.

A further way of dodging the ethical discussion is to suggest that any ethical parameters we may need can be read off from the markets, a particular version of efforts to derive ethical-economic hypotheses solely on the basis of revealed preferences. We shall show in Paper 2, Part 1, on intertemporal discounting that this argument is riddled with basic mistakes in economic analysis. This is not to make a generalised attack on the idea of revealed preferences, it does indeed carry valuable insights, but to show the plethora of important errors in many applications to the case of inter-temporal policy and ethics in relation to climate change.

The final 'cop out' is to argue that the ethics are best left to the imams, pandits, priests, rabbis, moral philosophers and politicians. This, in my view, as someone who has spent some years in the 'kitchen' of economic policy making, is to misread or be ignorant of the mechanisms and logic of policy making in practice. Those whom society has determined should have obligations to decide do not necessarily have experience in assembling or assessing empirical evidence or in its analysis. Similarly for those who may feel they must offer moral perspectives. And they would not usually know the theoretical constructs which could provide a method for organising the evidence in ways which could inform decision-making relative to the ethical perspectives they may bring. On the other hand, economists have experience and skills in working out how to specify and apply different principles, objectives or social welfare functions, and they have skills in understanding what evidence might be relevant and helpful and how to use it. That does *not* mean that analytical economists take over the ethical discussions from politicians or moral leaders, but it does, in my view, mean that they have a duty to participate in an active and constructive way.

John Stuart Mill[36] saw clearly that ethical or moral perspectives themselves adapt and change when exposed to the logic of evidence and the process of discussion and scrutiny of policies and values. That understanding is central to his emphasis on the idea of public discussion as a key element in democracy.

Thus, economists, and scientists too, are badly under-performing in relation to their potential contributions, or indeed any social obligation to be useful, if they simply try to deliver up their "positive" analysis without thinking hard about its relevance and relations to the issues, criteria, principles and political processes which might be brought to bear in taking decisions. Unless they think in this way the evidence they offer is likely to be ignored because its questions and conclusions may not be expressed in ways which a decision-maker can see as useful. Or the conclusions and analyses may be misused or distorted. To be effective, some economists and scientists may have to become directly involved in the processes. It is, of course, a challenge to do this and retain some objectivity but the alternatives may be irrelevance or gross misuse of the work.

2.6 Putting the science and ethics together: framing the economic analysis

How, then, should the scientific and philosophical analysis of the first two parts of this paper influence the framing of the economic analysis? In particular, how can it appropriately reflect the scientific risks involved and the relevant ethical frameworks, and thus be most helpful to coherent public discussion and to those who must take the decisions?

From the science we have seen, in Section 1.1 above, that unmanaged climate change could yield immense risks. To summarise briefly: there are major risks of temperatures the world has not seen for tens of millions of years, far outside the experience of homo sapiens, and possibly rewriting where big fractions of the world could live, possibly resulting in the migration of hundreds of millions, or billions, possibly risking major conflict and possibly the death of tens or hundreds of millions. How should we set about or frame an economic analysis of policy towards that sort of risk? How far do we think of investment in the reduction of emissions as an investment project to be evaluated in a familiar manner using standard cost-benefit analysis? How far can we use simple aggregate growth models, containing a few regions of the world, which are possibly perturbed somewhat by unmanaged climate change? I think the scientific evidence and discussion of the relevant ethical perspectives should tell us "not very far".

[36] See e.g. Stern, et al. 2005, p 261 for a discussion.

Standard cost-benefit techniques rely strongly on marginal methods: a project is represented as a perturbation to the world as a whole and the standard approach compares the world with and without the project using the assumption that most or all of the changes are only marginal. Often it is assumed that nearly all markets are perfect but the better applications of cost-benefit do not; a review of the theory of cost-benefit analysis in an imperfect economy is presented in Drèze and Stern (1987).[37] It is untenable to see the policy issues here as anything other than comparing policies which cover a vast range of very large possible outcomes. We have seen that unmanaged or weakly-managed climate change could stop and reverse development, dramatically lowering living standards and causing great loss of life (see also UNDP, 2007). Our standard marginal cost-benefit techniques are simply not up to a comprehensive analysis of effects which are of a scale of that magnitude.

A commonly used framework for analysis of the impacts of climate change which attempts to go beyond the narrow "project or programme approach" is the Integrated Assessment Model (IAM). Yet, these do not go very far in that they are usually formulated in terms of a simple underlying growth framework and moderate perturbations. Thus, for similar reasons, they are clearly inadequate in their most frequently used forms. The potentially devastating and complex outcomes cannot be plausibly described, as most such models do, in terms of fixed populations and aggregate consumption,[38] when potentially large-scale death and possible destruction of the relationship between humans and the planet are at issue. There is a strong, and often overwhelming, temptation in such models to assume away big changes so that damage functions (linking reductions in consumption or overall output to temperature) are usually specified to involve implausibly small damages. And they usually embody long-run drivers of growth which essentially overwhelm the damage functions. The limitations of these models in capturing the scale of the risks are described in Pindyck (2013) and Stern (2013). Overall the biggest scientific and ethical issues are all too often assumed away.

The problems of such models extend to the presentation of possible ways of reducing emissions. Technologies, costs and ways of organising economies and societies may look very different by 2100 depending on the path we choose to take. Low-carbon paths are likely to involve dynamic processes of learning. And we are likely to find that the physical (e.g. low-carbon infrastructure) and social (e.g.

[37] See also Drèze and Stern (1990) for a slightly less technical explanation.
[38] There are often regional differences but in each region the key welfare driver in the models is aggregate consumption.

community recycling) sides of life are quieter, safer, cleaner, more secure, more bio-diverse and more sustainable, in other words there are co-benefits. This dynamic story of investment, innovation and learning and of co-benefits may radically change perspectives on the benefits and role of action to reduce emissions, yet they are largely ignored in the standard modelling approaches.

My arguments should not be misunderstood. There is no suggestion that we abandon the cost-benefit analysis or an approach using IAMs. They constitute important parts of an argument which assesses the structure of the problems and the evidence. But given the great difficulty in adapting them in a tractable way to the scientific and ethical logic of the problem, we should resist the temptation embodied in their explicitness and apparent precision to give them a weight stronger than their underlying structures can carry. They constitute a possibly useful but minor part of the relevant evidence. And they are likely to be strongly biased in the direction of weak action for the reasons described. They could not be described as a simple but central case. The former may be, but not the latter. We have to use much more economics than they embody.

In my view, the arguments of Parts I and II on the science and ethics point strongly, as already mentioned, to a broad risk-management approach to the challenges of climate change. By that I mean, attempting to use the science to give a description of possible outcomes that might arise from different sets of policies, which is as broad and informative as possible, constructed in a way that can guide discussions and decisions which are framed relative to the types of ethical criteria we have been examining. That means that scientists will have to help us speculate since there is little in the way of hard past experience of the effects of changes of the magnitude that are possible. Indeed, that is the point: as humans on the planet we have not seen anything remotely like the possible consequences that could arise.

What would such a risk-management approach look like? We have to start by trying to describe, inevitably in a broad-brush way, the different kinds of consequences that could arise. Let me illustrate with Table 1 and Figure 2 from the Stern Review (2007).

Table 1: Likelihood (%) of exceeding a temperature increase at stabilisation (increase relative to the pre-industrial period).

Stabilisation level (in ppm CO2e)	2˚C	3˚C	4˚C	5˚C	6˚C	7˚C
450	78	18	3	1	0	0
500	96	44	11	3	1	0
550	99	69	24	7	2	1
650	100	94	58	24	9	4
750	100	99	82	47	22	9

Source: Stern Review (2007), Box 8.1, p.220; based on: Meinshausen 2006; Murphy et al. 2004; calculations.

Table 1 is a simple organising framework for examining the probabilities of the kinds of temperatures that could arise from different concentrations, and Figure 2 portrays possible consequences of such temperatures. As time goes by estimates of probability become revised but those expressed in Table 1 and Figure 2, used in the Stern Review, still give a reasonable picture of the issues at stake.[39] We have to link the approach represented by the Figures and Table to possible emissions paths and their possible associated concentrations and temperatures – see Figure 1 (from Bowen and Ranger, 2009) in Part 1 above.

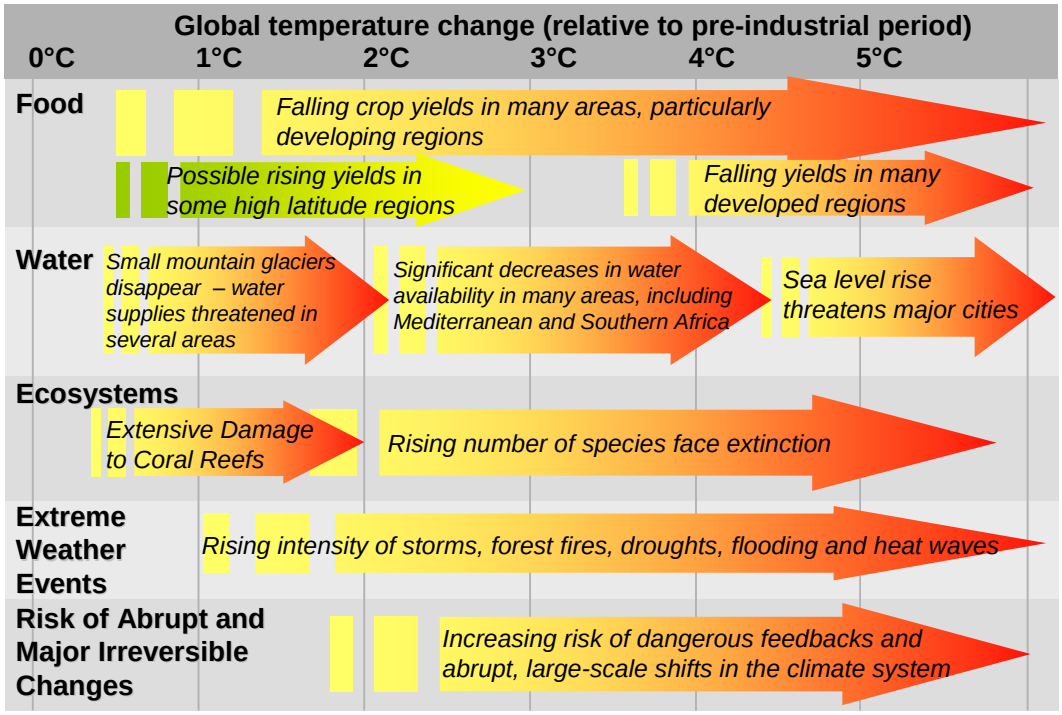
We look to the scientists to describe the possible outcomes and probabilities, as best they can, which might arise from different paths. We ask them to be as clear and explicit as possible about the consequences of major possible phenomena they find difficult to model formally, such as the possible thawing of the permafrost or collapse of the Amazon forest. And where they cannot get to grips with assigning probabilities we must ask them to be explicit about the difficulties.

As economists/social scientists we then try to organise these descriptions of possible consequences in ways which display the differential consequences from different courses of action, including potential loss of life, migration and its associated disruption, and so on. We try to attach probabilities as best we can. Various possible strategies for adaptation to climate change of different kinds will be part of the process of assessing consequences.

[39] Table 1 is reproduced for convenience from the Stern Review. It is based on work at the time from the UK Hadley Centre. Other models give somewhat different probabilities and the Hadley models give larger probabilities of higher temperatures than some others, but the basic point on the scale of risk is standard across models. See Stern (2013) for a discussion.

Again, economists should try to look at the investments and policies which could lead to different potential outcomes. These may have costs in terms of foregone consumption for certain groups at certain times and will influence or put pressure on a range of resources and lifestyles. There will likely be innovation, discovery and learning, as in previous waves of technological change. So too, co-benefits of action from reducing emissions for health, environment, biodiversity and so on. In this sense we try to give a reasonable description of the costs of different types of action, bearing in mind the potential co-benefits beyond the reduction in climate risks. We have to do all this in the context of the different types of criteria and perspectives that ethics might bring to bear.

Figure 2: Possible impacts of climate change



Note: impacts imply increasing dislocation and migration arising from higher temperatures.

Source: Based on Stern Review (2007), Chapter 3, p. 66-67.

We are then in a position to compare in a systematic way the pros and cons of different courses of action. This will not be a full and unambiguous calculus: the possible consequences of actions are hard to predict and quantify and there is a range of ethical perspectives to be considered. But this approach will provide a framework for structural choices in the context of the science, economics and ethics at issue. And we shall see that notwithstanding the uncertainties and the range of relevant ethical approaches, it can point to strong and specific conclusions.

The approach described is not unlike that which we might adopt for decisions such as strategies or policies which might influence the probabilities or impacts of catastrophe or war. It is mostly a consequentialist approach which examines the scale and nature of risk and what can be done. But it involves issues on a far bigger scale than we are used to in the economic evaluation of projects and programmes and requires broader and deeper thought.

The scientists are better placed than non-scientists to help describe the possible outcomes and risks; the economists are more experienced at setting out and analysing possible consequences in ways which can inform policy and decision-making; and those with some expertise in thinking about ethics, including some moral and political philosophers, can provide guidance on how to bring the ethics to the problem. Each of the disciplines has to be keenly aware, and make use of, the insights of the others if they are to interact constructively on a problem of such immense importance. They have to involve themselves, and occasionally collaborate, in the analyses of the others if they are to get to grips with the issues and work together effectively. We in economics have to make sure that we make judicious use of the tools of our profession. That means avoiding trying to shoe-horn the problem into an excessively narrow, fairly standard framework, which is not fit for the purpose of analysing the task at hand. On the other hand, we can be very constructive if we use the tools of our trade. These include in this context, the economics of: public policy in imperfect economies; risk and uncertainty; game theory; international relations; growth and development; environment; finance; technological change and so on. And we shall need to examine too economic history and political economy. We have much to offer if we use our subject well and go beyond the narrow and potentially misleading stereotypes. We shall have to use all the tools at our disposal and fashion some more.

We can now set out the major strategic choices. They follow in large measure from Table 1 and Figures 1 and 2 and the surrounding discussions. This is not the place to provide a full strategic discussion – see Stern, 2009 and 2012 for greater detail – and the argument is sketched only briefly. Our focus here is on one basic and fundamental conclusion: the strategic analysis, notwithstanding scientific uncertainties and a range of philosophical perspectives, points to a powerful case for strong and urgent action to create a path for emissions which can radically reduce the probability of average surface temperature increases of 4^0C and above. Recall that we have not seen 3^oC on the planet for around 3 million years and 4^oC for perhaps 10-30 million years. They are way outside human experience and they appear to carry major risk of movement of people so large as to create severe and extended conflict. Such conflict would unlikely be of a temporary nature since the cause

of the movement of people would likely continue and intensify. Given that inaction or weak action could result in the creation of immense risks in the lifetime of those alive today, I would suggest that most of the ethical positions would point to the basic conclusion proposed.

Exposing children alive today to such risks could not easily be described as "virtuous" or "good" from an Aristotelian perspective. From the point of view of rights and liberties, it would appear a gross violation of their right to a peaceful and unmolested existence and thus an infringement on their liberty and unjust. And a consequentialist analysis of such severe impacts would likely lead to the conclusion that the costs of weak action or inaction are much higher that the costs of action.

The above arguments would be weakened if there was very little we could to do reduce the risks: in fact we can do a great deal. Further, the alternative path of a transition to a low-carbon economy looks not only feasible at reasonable cost, but also attractive. Whilst there is inevitably substantial uncertainty in such estimates, given the importance of intrinsic uncertainty in the processes and the long period involved, the necessary investments might be 1-3% of GDP over 2 or 3 decades (e.g. Stern, 2007, 2009, 2012 and IEA, 2011) and would yield returns in terms of discovery of new methods, energy security, energy efficiency, safety, clean air, biodiversity and so on way beyond the fundamental reduction in the grave risks of climate change. The radical change necessary is on a scale which would essentially involve an energy-industrial revolution, or major wave of technological change, and experience of previous such changes suggest they are associated with 2 or 3 decades, or more, of investment, innovation and growth.

The particular path of reductions we should choose is not fully determined by the above argument but an examination of Table 1, and consideration of the potential scale of damage and conflict from high temperatures, points to holding long-run concentration levels to around 450ppm CO_2e or below. And the studies cited above indicate that with strong policies and investment that could be possible, although it will be difficult and require strong action starting now.

The later we leave action the more difficult and costly it will be with necessary investment much higher than if we take strong action now. We are already at or above concentrations of 445ppm CO_2e (and 400ppm CO_2) and are almost certain to overshoot 450ppm CO_2e. Thus to establish it as a long-run stabilisation would require sustained action over this century. Delayed action ratchets concentrations up still further, CO_2 is very long lasting in the atmosphere, and delay locks in high carbon capital, equipment and infrastructure. Essentially we have to follow a path such as described

in Figure 1. It would require cutting emissions by a factor of 2-3 in 40 years and, emissions per unit of output by a factor of 7 or 8 – radical transformation which should surely be described as an energy-industrial revolution.

We have seen then that the ethics, economics and science if combined as we have described do point in a strong and clear direction, notwithstanding the uncertainties about outcomes and pluralities of perspectives. Whether the necessary decisions will be taken is far from clear. That will depend on international collaboration, leadership, political economy and the creativity of scientists, technologists and investors.

Finally, in this part of the paper I should note the relation between the formulation presented here and that of the Stern Review. That Review is sometimes summarised as saying that the cost of action is much less than the cost of inaction, and that for a 1% annual cost of action in terms of GDP, there would be a return to saved damages of 5-20% of GDP per annum, averaged over space, time and possible outcomes. That, however, is a somewhat simplistic rendering of a study which in its published form (Cambridge University Press, 2007) is 27 chapters, several appendices and 692 pages. The numbers quoted came from just one chapter (chapter 6 of 30 pages). That chapter represents one approach to aggregative modelling, although that modelling is emphatically not designed as an adding up of the effects discussed in the Review.

The message that the costs of action are much lower than the costs of inaction is fundamental, but the modelling (largely using a version of an IAM) is just one way of giving a numerical expression, in a narrow model, to this statement. It is a useful and insightful way, but in the final two sentences of chapter 6 we stated, "We therefore urge the reader to avoid an over-literal interpretation of these results. Nevertheless, we think that they illustrate a very important point: the risks involved in a 'business-as-usual' approach to climate change are very large." That is indeed the key point. In the light of the still stronger scientific evidence on the great scale of the risks, I would urge still more strongly now the importance of avoiding an 'over-literal' interpretation.

Most of the Review is about understanding the risks and analysing policy in response to those risks. I think on the whole that the Review stands up well to *ex-post* scrutiny seven years after publication. There have been differences over issues such as discounting, which I deal with, I trust, clearly and strongly in companion Paper 2, but no important errors have been found. With hindsight and the ever-strengthening scientific evidence, I would now stress the importance of seeing and analysing

the big picture of risk, rather than focusing on the 'small' picture embodied in the IAMs; small in the sense of narrowness in scope of issues embodied, small in the sense of its portrayal of the magnitude of the effects which are embodied, and small in its treatment of the ethical issues involved. From this perspective, and the still accumulating scientific evidence, I think the Review understated the risks of climate change and the statement that the costs of action are much less than the costs of inaction can be made still more strongly.

Part 3 : CONCLUDING REMARKS

Conclusion 1. Start with the science, the nature of the processes and the scale of the risks: this is a problem of risk-management on an immense scale.

The economics and ethics of climate change must start with the science describing the nature of the problem, because as soon as that is set out we see the issues in terms of the management of immense risks, with unmanaged climate change likely to produce movement of people, destruction, conflict and loss of life across the planet over the next century or so on great scale. Those are not minor perturbations around some basic underlying growth story and have profound implications for both the relevant ethics and the formulation of the economics.

Conclusion 2. The nature of the potential impacts require us, when considering social objectives, to look beyond the (mathematical expectation of the) simple sum over time of social welfare or social utility evaluated at each point of time, where that social utility is simply a function of an aggregated consumption good at that time.

We have to consider directly issues of evaluation structured around an understanding of lives and living standards which goes beyond consumption, in particular to include the consideration of the possibility of large-scale destruction and loss of life, and the crucial role of environmental services in both consumption and production. Whilst some of these might, in principle, be incorporated in a formal social welfare function, it is very difficult to do this in a convincing or plausible way, and adopting mechanical or naïve ways risks placing heavy constraints on conclusions. There are direct ways of incorporating a damaged environment into production and utility functions – for some discussion see Stern (2013). However, we are thinking of something deeper than arguments included in utility functions. This subject concerns the ability to survive, and potentially immense changes in the capabilities, locations and livelihoods of people: these are not effects that a model with a simple social welfare function and a fixed population can easily capture.

Conclusion 3. When we consider broader ethical approaches to, or perspectives on, the ethics than those standard in the usual economic approach to consequences, we find that some, particularly those focusing on virtues and rights, provide key insights for understanding and for policy.
Whilst the consequentialist approach familiar to economists has much to recommend it, it should not, in this context, be confined to the simplistic Bergson-Samuelson formulation of social welfare functions and modest incremental changes: the issues at stake are too large and their nature too fundamental. Both the Aristotelian approach of virtue ethics, and perspectives which are based on rights, liberty, freedom and justice provide, in my view, important insights. Through interaction, discussion, reflection, analysis and evidence, shared understanding of what is responsible or virtuous (or their opposites) can emerge. Examples concern changing attitudes to littering, smoking, and alcohol and driving. Similarly, limitations on rights to pursue whatever economic or other activities one might choose can be examined in terms of implications for the rights of others. Some aspects of sustainability can be understood this way.

However, social contractarian approaches suffer from lack of clarity about the potential role of future generations in implicit contracts, including whether individuals or groups will be dead or alive or possibly inexistent under different possible paths for individual and collective action.[40] Similar problems arise for a Kantian approach. Further, the focus of such approaches on internal motivations makes them, in my view, difficult to apply usefully in this context.[41]

Whilst the paper has focussed mainly on European traditions, some of the philosophical traditions from other continents, many of them of longer standing than the "Occidental", show similarities in perspectives and values in terms of their recognition and use of ideas such as virtues, rights, duties and responsibilities for the consequences of actions.

Conclusion 4. Different philosophical approaches bring different perspectives on understanding and policy and may differ in their attractions to different people, yet they generally point in a similar direction, i.e. the case for strong action to manage climate change.
It is not necessary, or indeed wise, to insist that one in particular of the approaches must be the primary reason for action and that everything stands or falls on its validity. A pluralism, in the manner of Isaiah Berlin, in philosophical approach can and should guide particular policies; for

[40] Although if one puts these difficulties to one side and nevertheless applies Kantian or contractarian methods, the conclusions seem to point clearly towards strong action on climate change.
[41] This criticism of Kantian approaches is also a popular objection to some versions of virtue ethics.

example there may be both economic incentive issues and human rights issues around regulation or tax policies, and both might be judged to be relevant. Pluralism may also help muster broad agreement in complex polities where different groups emphasise different perspectives. The case for action is both strong and robust if different ethical perspectives guide us in broadly similar directions. The ambiguities which might, in principle, occur from applying a pluralist approach do not seem to be a problem here.

The term "moral uncertainty" is used to describe the problem of how to act when there is a plurality of moral views. Some have suggested we might try to act in a way that "aggregates" across such views in the manner of Harsanyi. John Broome raises such issues toward the end of his book "Climate Matters" (Broome, 2012). Since we are arguing that most moral perspectives point clearly in the direction of strong action, such aggregation would also point in the same direction.[42]

Conclusion 5. That greenhouse gases are an externality tells us that there are policies to tackle them which can make all generations better off.

Some have argued that this is the most important economic-cum-philosophical insight in the context of climate change. The Pareto inefficiency associated with market failure means that we could emit less now and be no worse off whilst those living in future periods could be better off. This implies, at least in principle, that a case for action can be established without necessarily embarking on intense debates on intertemporal valuations. However, it is unlikely to avoid important intergenerational issues in practice.

Conclusion 6. Growing populations accentuate the pressures of climate change. However the developmental and ethical arguments for policies which influence populations, particularly birth rates, such as those related to women's rights and education, income, infant mortality rates, and access to reproductive health care are very powerful even in the absence of attention to issues of the effects of population on climate change.

Thus the acute presence of the problem of climate change intensifies previous arguments for actions that reduce birth rates. However, those arguments by themselves are already strong; indeed strong enough, in my view, to suggest that action on the dimensions specified could and should be strengthened.[43]

[42] Some have argued that, in a democracy, analysts could present the implications of all perspectives to the public and let the public resolve/decide by political choice (see Ross, 2006); although such choices would, one hopes, embody consideration of rights of future generations.

[43] Compulsion is altogether a different matter. It can create a backlash and raises its own difficult ethical issues.

These conclusions tell us that a combination of the basics of the science and a clear articulation of the ethics can take us a long way in identifying how to frame questions and analyses of equity and ethics in climate change, and indicate broad directions for policy. In the second of this pair of papers we see how combining ethics with economics and politics, on the foundations of the insights of this paper, can take us a long way in identifying responses to some more specific issues of equity in national and international policy making.

References

Allen, Myles R., David J. Frame and Chris Huntingford, et al. (2009). "Warming caused by cumulative carbon emissions towards the trillionth tonne." Nature 458, 1163-1166.

Arrow, Kenneth J., Partha Dasgupta, Lawrence H. Goulder, Kevin J. Mumford, Kirsten Oleson (2012). "Sustainability and the measurement of wealth." *Environment and Development Economics* 17(3): 317-353.

Asheim, Geir B. (2010). "Intergenerational Equity." Annual review of Economics 2, 197-222.

Asheim, Geir (2007). "Justifying, Characterizing and Indicating Sustainability." Chapter 1. Springer.

Basu, Kaushik and Tapan Mitra (2003). "Aggregating infinite utility streams with intergenerational equity: the impossibility of being Paretian." Econometrica 32, 1557-1563.

Becker, Gary (1968). "Crime and Punishment: An Economic Approach." Journal of Political Economy 76 (2), 169-217.

Berlin, Isaiah (1990). "The Crooked Timber of Humanity." Princeton University Press.

Bowen, Alex and Nicola Ranger (2009). "Mitigating Climate Change Through Reductions in Greenhouse Gas Emissions: The Science and Economics of Future Paths for Global Annual Emissions." Policy Brief, December, Centre for Climate Change Economics and Policy, and Grantham Research Institute on Climate Change and the Environment.

Broome, John (2012). "Climate Matters: Ethics in a Warming World." Norton.

Broome, John (2010). "The most important thing about climate change." in Public Policy: Why Ethics Matters, edited by Jonathan Boston, Andrew Bradstock and David Eng, ANU E Press, pp. 101–116.

Broome, John (2009). "The Ethics of Climate Change." Inaugural Roseman Lecture in Practical Ethics, University of Toronto, October 23.

Broome, John (2004). “Weighing Lives.” Oxford University Press.

Buchholz, W. (1997). “Intergenerational equity.” in *Ecological Economics, a Volume in the Series A Sustainable Baltic Region* (T. Zylicz, Ed.), Uppsala Univ. Press, Uppsala.

Callicott, J. Baird and Roger T. Ames (1989). eds. “Nature in Asian Traditions of Thought: Essays in Environmental Philosophy.” Albany, NY: State University of New York Press.

Carr-Hill, Roy and Nicholas Stern (1979). “Crime, The Police and Criminal Statistics.” Academic Press, May.

Carr-Hill, Roy and Nicholas Stern (1976). "Theory and Estimation in Models of Crime and its Social Control and their Relations to Concepts of Social Output.” Presented to the International Economic Association Conference on The Economics of the Public Services, in Turin, April 1974 and published (Chapter 6) by MacMillan for the IEA, Feldstein and Inman (eds.), 1976.

Caney, Simon (2005). “Cosmopolitan Justice, Responsibility, and Global Climate Change.” Leiden Journal of International Law 18, 747-775.

Charlesworth, Max (1992). “Introduction in Religion in Aboriginal Australia - An Anthology.” 2nd Edition. (eds.) M. Charlesworth, D. Bell, H. Morphy & K. Maddock, University of Queensland Press, St Lucia, pp. 1 - 20

Climate Analysis Indicators Tool (CAIT) version 2.0. (Washington, DC: World Resources Institute, 2013). Available at http://www.wri.org/project/cait

Conger, George (1952). “Did India Influence Early Greek Philosophies?” Philosophy East and West 2 (2), 102-128.

Dahlsgaard, Katherine; Peterson, Christopher; Seligman, Martin E. P. (2005). “Shared Virtue: The Convergence of Valued Human Strengths Across Culture and History.” Review of General Psychology, Vol. 9 (3), 203-213.

Dasgupta, Swapan and Tapan Mitra (1983). “Intergenerational equity and efficient allocation of exhaustible Resources” International Economic Review 24, 133-153.

Dessler, Andrew (2010). “A Determination of the Cloud Feedback from Climate Variations over the Past Decade.” Science Volume 330 (6010) pp. 1523-1527.

Drèze, Jean, and Nicholas Stern (1990). “Policy Reform, Shadow Prices and Market Prices.” *Journal of Public Economics*, 42, 1–45.

Drèze, Jean and Nicholas Stern (1987). “The Theory of Cost-Benefit Analysis.” Handbook of Public Economics, Vol. 2, edited by A.J. Auerbach and M. Feldstein, Elsevier Science Publishers B. V. (North-Holland).

Ecofys, (2013). “World GHG Emissions Flow Chart, 2010.” with ASN Bank. http://www.ecofys.com/en/news/updated-information-on-the-worlds-greenhouse-gas-emissions/

Foley, Duncan (2007). “The Economic Fundamentals of Global Warming.” Working paper 07-12-044. Santa Fe, New Mexico: Santa Fe Institute. www.santafe.edu/media/workingpapers/07-12-044.pdf.

Gardiner, Stephen (2011a). “Rawls and climate change: does Rawlsian political philosophy pass the global test?” Critical Review of International Social and Political Philosophy, 14 (2), 125-151.

Gardiner, Stephen (2011b). “A Perfect Moral Storm: The Ethical Tragedy of Climate Change.” Oxford University Press.

Gardiner, Stephen, Simon Caney, Dale Jamieson and Henry Shue (2010). Eds. “Climate Ethics: Essential Readings.” Oxford University Press.

Gemenne, Francois (2011). “Climate-induced Displacements in 4°C+ world.” Philosophical Transactions of the Royal Society A 369(1934): 182-195.

Gilmore, Elisabeth, Halvard Buhaug, Katherine Calvin, Harvard Hegre, John Steinbruner, and Stephanie Waldhoff (2013). “Forecasting Civil Conflict under Different Climate Change Scenarios.”

Paper presented at Impacts World 2013 International Conference on Climate Change Effects, Potsdam. http://www.climate-impacts-2013.org/files/wism_gilmore.pdf.

Greaker, Mads, Per Espen Stoknes, Knut H. Alfsen and Torgeir Ericson (2013). “A Kantian approach to sustainable development indicators for climate change.” Ecological Economics 91, 10-18.

Gwatkin, Davidson (1979). “Political Will and Family Planning: The Implications of India's Emergency Experience.” Population & Development Review Vol. 5 Issue 1, 29-59.

Gosseries, Alex and Lukas H. Meyer (2009). “Intergenerational justice.” Oxford University Press.

Hebbar, Neria H. (2009). “Influence of Upanishads in the West.” http://www.boloji.com/index.cfm?md=Content&sd=Articles&ArticleID=717

Hsiang, Solomon M., Marshall Burke and Edward Miguel (2013). "Quantifying the Influence of Climate on Human Conflict." http://www.sciencemag.org/content/early/recent / 1 August 2013 / Page 1/ 10.1126/science.1235367

Intergovernmental Panel on Climate Change (2007). “Climate Change 2007, the Fourth Assessment Report (AR4).” United Nations.

International Energy Agency (2013). “World Energy Outlook 2013 Special Report: Redrawing the Energy-Climate Map.” IEA/OECD Paris.

International Energy Agency (2012). “World Energy Outlook 2012”, IEA/OECD Paris.

International Energy Agency (2011). “World Energy Outlook 2011”, IEA/OECD Paris.

Jamieson, Dale (2010). “When Utilitarians Should be Virtue Theorists.” In: Gardiner, Stephen, Simon Caney, Dale Jamieson and Henry Shue (Eds.), *Climate Ethics: Essential Readings*, Oxford University Press.

Licker, Rachel, and Michael Oppenheimer (2013). “Climate-induced human migration: a review of impacts on receiving regions.” Paper presented at Impacts World 2013 International Conference on Climate Change Effects, Potsdam. http://www.climate-impacts-2013.org/files/wism_licker.pdf.

Lomperis, Timothy, (1984). “Hindu Influence on Greek Philosophy, The Odyssey of the Soul from the Upanishads to Plato.” Ideaindia.com

McCright, Aaron and Riley E. Dunlap (2011). “The Politicization of Climate Change and Polarization in the American Public’s Views on Global Warming 2001-2010.” The Sociological Quarterly Vol. 52, 155-194.

Meade, James (1951, 1955). “The Theory of International Economic Policy. Volume I: The Balance of Payments (1951). Volume II: Trade and Welfare (1955).” London: Oxford University Press for the Royal Institute of International Affairs.

Michaels, David (2008). “Doubt is Their Product: How Industry's Assault on Science Threatens Your Health.” Oxford University Press.

The National Academy of Sciences (2010). “Advancing the Science of Climate Change: America's Climate Choices: Panel on Advancing the Science of Climate Change.” National Research Council. http://www.nap.edu/catalog.php?record_id=12782

Oppenheimer, Michael (2013). “Climate change impacts: accounting for the human response.” Climate Change 117(3): 439-449.

Oreskes, Naomi and Erik M. Conway (2010). “Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming.” Bloomsbury Press.

Parfit, Derek (1984). “Reasons and Persons.” Oxford: Clarendon Press.

Peterson, Richard (2004). “Central African voices on the human -environment relationship.” In: Gottlieb, Roger S. (eds) This Sacred Earth: Religion, Nature, Environment. London: Routledge, pp.168-174.

Pezzey, John C.V., and Michael A. Toman (2002). The Economics of Sustainability: A Review of Journal Articles. Resources for the Future.

Pindyck, Robert (2013). "Climate Change Policy: What do the models tell us?" Journal of Economic Literature, *forthcoming in September 2013 edition*.

Rawls, John (1971). "A Theory of Justice." Cambridge, Massachusetts: Belknap Press.

Reekie, Tristan and Will Howard (2012). "Geoengineering." Occasional paper series, Office of the Chief Scientist, Australian Government, Issue 1.

Righelato, Renton and Dominick Spracklen (2007). "Carbon Mitigation by Biofuels or by Saving and Restoring Forests?" Science 317, page 902.

Rohde, Robert, Richard Muller, Robert Jacobsen, et al. (2013). "A New Estimate of the Average Earth Surface Land Temperature Spanning 1753 to 2011." Geoinformatics and Geostatistics: An Overview 1, (1).

Rogelj, Joeri, Malte Meinhausen, and Reto Knutti (2012). "Global warming under old and new scenarios using IPCC climate sensitivity range estimates." Nature Climate Change 2: 248-253.

Rolston, Holmes III (1987). "Can the East Help the West to Value Nature?" Philosophy of East and West 37, 172-90.

Ross, Jacob (2006). "Rejecting ethical deflationism." Ethics 16, 742-768.

Royal Society (2011). "Four degrees and beyond: the potential for a global temperature increase of four degrees and its implications." Philosophical Transactions of the Royal Society, Volume 369 (1934), pp. 1-241.

Royal Society. (2009). "Geoengineering the Climate: Science, Governance and Uncertainty." September.

Sandel, Michael (2012). "It's immoral to buy the right to pollute." (eds) Robert Stavins, Economics of the Environment: Selected Readings, W.W. Norton & Company New York, London.

Scharfstein, Ben-Ami (1998). “A Comparative History of World Philosophy: From the Upanishads to Kant.” State University of New York Press.

Selin, Helaine (ed.) (2003). “Nature Across Cultures: Views of Nature and the Environment in Non-Western Cultures.” Kluwer academic publishers.

Sen, Amartya (2009). “The idea of justice.” Allen Lane, Penguin Books.

Sen, Amartya (1999). “Development as Freedom.” Random House, New York.

Sen, Amartya (1998). “Human Rights and the Westernizing Illusion.” Harvard International Review, Summer, Vol. 20 Issue 3.

Sen, Amartya (1997). “Human Rights and Asian Values: What Lee Kuan Yew and Le Peng don't understand about Asia.” The New Republic, Vol. 217, No. 2-3.

Sen, Amartya and Bernard Williams (1982). “Utilitarianism and beyond.” Cambridge University Press.

Shue, Henry (1996). “Basic Rights.” Princeton University Press, Second Edition.

Singer, Peter (2010). “The Life You Can Save.” Random House.

Sinn, Hans-Werner, "Pareto Optimality in the Extraction of Fossil Fuels and the Greenhouse Effect: A Note", *CESifo Working Paper No. 2083*, August 2007

Smith, Leonard. A. and Nicholas Stern (2011). “Uncertainty in science and its role in climate policy.” Philosophical Transactions of the Royal Society A, 369, 1-24.

Steinbruner, John, Paul Stern and Jo Husbands (eds) (2012). “Climate and Social Stress: Implications for Security Analysis.” National Research Council of the National Academies.

Stern, Nicholas (2013). “The structure of economic modelling of the potential impacts of climate change: grafting gross underestimation of risk onto already narrow science models.” Journal of Economic Literature 51 (3), 1-22.

Stern, Nicholas (2012). “Lionel Robbins Memorial Lectures.” CEP, London School of Economics and Political Science. See: http://cep.lse.ac.uk/_new/events/event.asp?id=142

Stern, Nicholas (2011). “Raising Consumption, Maintaining Growth and Reducing Emissions: The objectives and challenges of China’s radical change in strategy and its implications for the world economy.” World Economics 12 (4), pp. 1-22.

Stern, Nicholas (2010). “Presidential Address: Imperfections in the Economics of Public Policy, Imperfections in Markets, and Climate Change.” Journal of the European Economic Association 8 (2-3), pp. 253–288.

Stern, Nicholas (2009). “A Blueprint for a Safer Planet: How to Manage Climate Change and Create a New Era of Progress and prosperity.” Bodley Head.

Stern, Nicholas (2007). “The Economics of Climate Change: The Stern Review.” Cambridge University Press.

Stern, Nicholas, Jean-Jacques Dethier and F. Halsey Rogers (2005). “Growth and Empowerment: Making Development Happen.” The MIT Press.

Stewart, John R., and Chris B. Stringer (2012). “Human Evolution Out of Africa: The Role of Refugia and Climate Change.” Science 335(6074): 1317-1321.

Taber, John (1998). “Duty and virtue, Indian conceptions of.” In E. Craig (Ed.), *Routledge Encyclopedia of Philosophy*. London: Routledge. Retrieved August 9, 2013, from http://www.rep.routledge.com/article/F067

Toman, Michael A. (1994). Economics and “Sustainability”: Balancing Trade-offs and Imperatives. *Land Economics* 70 (4): 399–413.

United Nations (1998). “Kyoto Protocol To The United Nations Framework Convention On Climate Change.” (http://unfccc.int/resource/docs/convkp/kpeng.pdf).

United Nations (1992). “United Nations Framework Convention On Climate Change.” (http://unfccc.int/resource/docs/convkp/conveng.pdf).

United Nations Development Programme (2007). “Human Development Report 2007/2008. Fighting Climate Change: Human Solidarity in a Divided World.” United Nations.

Watling, Tony (2009). “Ecological imaginations in the world religions.” Continuum.

WHO (2002). “World Health Report: Reducing risks, promoting healthy life.” Geneva: World Health Organization.

Wiggins, David (2006). “Ethics: Twelve Lectures on the Philosophy of Morality.” Cambridge University Press.

Wong, David (2011). “Comparative Philosophy: Chinese and Western.” The Stanford Encyclopedia of Philosophy (Fall 2011 Edition), Edward N. Zalta (ed.) http://plato.stanford.edu/archives/fall2011/entries/comparphil-chiwes/

World Bank (2012). “World Development Indicators.” http://data.worldbank.org/indicator/SP.DYN.TFRT.IN

Zachos, James C., Gerald R. Dickens and Richard E. Zeebe (2008). “An early Cenozoic perspective on greenhouse warming and carbon-cycle dynamics.” Nature 451, 279-283.