
What are the limits of applying cost benefit analysis to the impacts and mitigation of climate change at different scales?

Kieran Keohane

Climate change is a complex issue which inevitably unveils many complex problems. Policy makers and scientists have generally attempted to focus on the need to mitigate greenhouse gas (GHG) emissions in order to avoid, or more realistically reduce the impacts of increased GHG concentrations in the atmosphere at different temporal, regional and spatial scales (*Baer et al., 2007*). . Cost benefit analysis (CBA) weighs up the relative benefits and costs of a particular investment in order to discern the net gains or losses (*Turner et al., 1994*). CBA is used in economic investment appraisal and in recent times it has become an important policy tool for governments in assessing the case for public intervention in markets (*Adger, 2005*). CBA has been applied on a variety of occasions notably in the Stern Review to assess the case for global intervention to mitigate greenhouse gas emissions by conducting estimations of GHG control costs weighed against the benefits of avoiding damages at a global scale (*Spash, 2007*). Neo-Classical economists would argue from the results of CBA that optimal emissions reduction occurs where the marginal benefits from avoiding climate change impacts¹ are equal to the marginal abatement cost² of emissions reduction (*Adger, 2010*) (*figure 1*). However, many have argued that the application of CBA to the impacts and mitigation of climate change is severely limited and categorically unacceptable. Concerns over the use of discounting, methods of non-market valuation, incommensurability, high uncertainty and subjectivity to name a few have been raised (*Spash, 2007*). The focus of this essay will be to describe these concerns which arguably limit the application of cost benefit analysis to the impacts and mitigation of climate change at different scales.

Economic theory defines costs and benefits according to preferences which are the determinants of utility or economic welfare (*Turner et al., 1994*). In macroeconomic CBA, individual preferences have to be summated in order to derive a social decision rule. By analysing individual's willingness to pay (WTP) for an increase in utility and willingness to accept (WTA) a decline in utility, economists have deduced a method to measure the strength of individual's preferences (*Turner et al., 1994*). The outcomes of most

¹ The marginal benefit from avoiding climate change impacts can be defined as the incremental benefit from an additional unit of emissions reduction.

² The marginal abatement cost is the incremental cost from an additional unit of emissions reduction.

policy decisions lead to some experiencing a decline in utility whilst some experience an increase in utility. Simplistically, the principles behind CBA would suggest that in moving to outcome A, if the summated WTP of the winners outweighs the summated WTA of the losers then the move is socially desirable (*Turner et al., 1994*). If compensation is distributed from the winners to losers this would be known as an actual Pareto improvement, if only hypothetically paid – a potential Pareto improvement (*Turner et al., 1994*). This utilitarian (*Adger et al., 2011*) notion is the main principle behind CBA as it technically leads to an improvement in the distribution of resources in an economy as appropriate compensation ensures that potential losers are no worse off. In the appraisal of decisions on the behalf of society there tend to be non-economic costs and benefits. Extended cost-benefit analysis takes these factors into account in an economic framework (*Adger, 2000*). Adger outlines the general steps in this analysis which are as follows:

- Step 1: definition of proposed reallocation or change in resource utilisation
- Step 2: Delineation of the relevant costs and benefits.
- Step 3: Quantification of the environmental and physical impacts of the proposed or observed change.
- Step 4: valuation of the relevant effects.
- Step 5: discounting of the temporal costs and benefit flows.
- Step 6: deciding on the desirability of the proposed change and policy recommendations.
- Step 7: sensitivity analysis and scaling activities. (*Adger, 2000*)

Steps 1-5 can be shown as a set of calculations usually in the form of net present value. A project is desirable if the present value of the benefits outweigh the costs (*Adger, 2000*) :

$$NPV = \sum_{t=0}^n \frac{(\text{Benefits} - \text{Costs})_t}{(1 + r)^t}$$

where:

r = discount rate

t = year

n = analytic horizon (in years)

(Source: *Zohrabyan,*

last cached 2010)

Discounting is common practise in conventional CBA. It incorporates individual time preferences in

relation to costs and benefits incurred over a dynamic scale. A typical formula for the discount rate is:

$$S = p + u.c$$

S is the rate of discount for society, p is the pure time preference rate displaying an individual's inclination to attach less weight to a future benefit or cost as opposed to the present, u being the measure of the elasticity of the marginal utility of consumption³ and c being the growth rate of per capita consumption (*Turner et al., 1994*). Assuming that both p and c are positive, the model for discounting implies that benefits and costs incurred by future generations are given lesser weight than if they were incurred in the present. Such a notion creates significant implicative problems (*Stern et al., 2005*) notably when applied to evaluating the costs and benefits incurred by climate change impacts and mitigation. In this context, the benefits and costs accrued are uncertain in terms of time, scale and magnitude. In applying a discount rate to climate change effects some of which may occur in the distant future, we are likely to encounter what is sometimes known as the tyranny of discounting (*Turner et al., 1994*). The benefits of avoiding irreversible climatic damages such as the large scale melting of the polar ice caps will be considerably lowered if discounted according to a standard social discount rate (*Turner et al., 1994*).

Stern displays that in the context of climate change and the varying amounts of potential mitigation there is a likelihood of divergent, non-marginal growth paths and outcomes (*figure 2*) (*Stern et al., 2005*). It is discerned that the discounting technique is relevant for marginal perturbations around a given growth path not comparing across paths (*Stern et al., 2005*). The Stern review thus implies that using an average discount rate to evaluate the non marginal climate impacts and mitigation is irrelevant and thus unsuitable.

Caney, in the context of fundamental human rights, discerns that it is immoral to apply a positive pure time preference discount rate to current and future generations. It is argued that the equity issues surrounding climate change should imply that all generations have the fundamental right “not to suffer from dangerous climate change” (*Caney, 2008*). According to Caney, this right should have an equal weighting throughout time: the protection of rights should have a zero discount rate. Empirical evidence suggesting that in fundamental humanistic cases people tend not to discriminate against future generations (*Frederick, 2003*) supports such a claim. Caney suggests that the link between people's inter-

³ The elasticity of the marginal utility of consumption measures the responsiveness of marginal utility to a change in consumption levels. The standard theory in economics is that the marginal utility from increased consumption declines when the consumption level increases.

temporal preferences and discounting is a complex one. Although Caney defends a zero discount rate for human rights, the possibility for discount rates to be applied to other values still remains.

Stern also suggests that different discount rates should be applied to distinct inter-temporal outcomes (*Stern et al., 2005*). It is certainly arguable that deriving an average discount rate from individual predicted discount rates fails to capture the wide disparities in uncertain inter-temporal events. The very basis for predictions around particular variables fundamental to discounting must also be questioned. Even the most distinguished macroeconomists find it very difficult to predict economic indicators in the short term (*Dornbusch et al., 2008*) therefore, it is very hard to have just confidence in predictions for factors such as consumption levels in the long term, which have a considerable effect on the prevailing discount rate. Economic justification for a pure time preference rate of discount is observed by behaviour in the market place (*Caney, 2008*). However, it is certainly monistic to simply apply such observations to a long run complex ethical issue such as climate change.

In the application of CBA to climate change there are considerable costs and benefits accrued which are not directly observed in a typical market form. These include ecological costs such as irreversible loss of ecosystem support functions, a decline in biodiversity and deforestation (*Adger, 2000*). There are also non-economic human costs such as increased risk to human health (*Kovats et al., 2005*) and the loss of culture and identity (*Adger et al., 2005*). According to economic theory these non-marketed values need to be incorporated into the function discerning economic values, in order to accurately calculate the true costs and benefit values of particular mitigation and impact based policies (*Turner et al., 1994*). However, many environmental and social changes are not directly amenable to economic evaluation which thus represents a constraint to applying cost benefit analysis to climate change on a global scale (*Adger, 2000*). On a theoretical level, there are a variety of valuation methods for non-economic factors. Applied to an environmental level, economists attempt to aggregate the total economic value from the value held by individuals of a particular non market resource in question (*Turner et al., 1994*). These values are disaggregated as user values and non user values. User values are derived from direct use such as timber revenues, Indirect values such as recreation and option use values which discern the desire for future personal recreation. Non user values represent the value of existence such as the preservation of biodiversity and the bequest value which represents the value of the resource to future generations (*Turner et al., 1994*). It is arguable that the total economic valuation method may fail to accurately capture total value when applied to climate change as the cause and effect relationships between climate and other variables are uncertain and asymmetric (*Tol, 2002*).

There are various studies of this kind which incorporate non market and market costs (*figure 3*). However, a considerable ethical problem arises when we place a monetary value on outcomes such as human deaths or a significant loss of biodiversity. Such a problem is compounded by the likelihood that more people are likely to die in lesser developed countries resulting from climate change impacts (*Tol, 2002*). Standard economic valuation tools infer that lives are valued higher in developed countries (*Adger 2010*), which rather detracts from the moral worth of a life. In aggregating such values we assume that recreational benefits are commensurable for catastrophic and ecological costs, as Spash ironically alludes “more golfing in the USA compensates for deaths in China or India” (*Spash, 2007*). Stern illustrates related concerns arguing that such incommensurable costs should be displayed alongside standard economic CBA to better express the human cost. Nonetheless, they are converted into a monetary form in order to make comparisons (*Stern et al., 2005*). CBA thus indirectly assumes that there is an optimal level of acceptance for an increased risk of death and suffering which can be instrumentally converted into X% amount of GDP (*Spash, 2007*). Monetary costs arguably ethically detract from the truly human and ecological costs of climate change (*Baer, 2007*), whilst some marketed benefits of mitigation such as the increase in GDP from resources used to abate greenhouse gas emissions are disaggregated from true economic welfare (*Spash, 2007*).

Global integrated assessment models have accurately assessed the market costs of climate change, and have unsatisfactorily assessed the non market costs. However, there has been limited research into the wider socially contingent, interrelated effects such as migration and irreversible loss of one’s culture and identity (*figure 4*) (*Stern et al, 2005*). These costs become more apparent when applied to finer local scales. Settlements of indigenous people such as the Pacific atolls and the Arctic are likely to face significant irreversible climatic change effects. It is argued that common decision making climate change policy tools underemphasise “the symbolic and psychological aspects of settlements, places and risks to them” such as these regions (*Adger et al., 2011*). Places of unique ecological significance are inherent to the cultures of the indigenous people. These people will incur significant psychological and cultural costs if forced to migrate to more hospitable areas. CBA assumes there is an optimal level of risk on a marginal scale. However, dramatic climatic events which could destroy these people’s homes are irreversible by nature meaning that there is no optimal level of risk. The problem is compounded by the fact that such people are distant from the standard global political, cultural and economic scheme (*Adger et al., 2011*). Neo-classical economics assumes that localised irreversible loss can be subject to a cost valuation.

However, the true humanistic price of place and meaning to the non-materialistic inhabitants of the pacific atoll and arctic regions is priceless. Therefore, the models are rather simplified in assuming that losses and gains are homogenous on both a regional scale and an inter-generational scale. This severely limits the main principles of CBA where the winners compensate the losers who will be no worse off as a result.

Aggregation of the values derived from regional changes resulting from climate change - common place in climate change CBA, arguably ignores the wide disparities on a regional scale (*Tol, 2002*). Hanemann argues that temperature increases derived from emissions scenarios (*figure 5*) fail to capture the ensuing uneven distribution of the increase across the globe, as well as, seasonal variations (*Hanemann, 2010*). For example, under the B1 emissions scenario (*Nakicenovic et al., 2000*) much of the western United States is predicted to experience a 3.3 degree Celsius increase in average annual temperature, whilst in California average winter temperature is set to rise 2.3 degree Celsius and an average summer temperature increase of 4.6 degrees Celsius. On an even finer scale, temperature increases vary spatially in comparing coastal and inland areas: the central valley is predicted to incur an increase in summer temperatures of 5 degrees Celsius. Such disparities are significant considering that the damage functions “which express physical or environmental outcomes as a function of changes in climate variables” are non-linear and asymmetric (*Hanemann, 2010*). Such variations are likely to have significant impacts on agriculture, health, energy and water yet are not accounted for in damage estimates which project moderate climate change impacts. Hanemann concludes that such assessments underestimate true climate change impacts as they fail to take into account the localised effects of climate change (*Hanemann, 2010*).

CBA tends to work well when the costs and benefits of an investment are well defined and certain. However, in the context of climate change there are considerable uncertainties surrounding the relationships between climate and other variables (*Stern et al., 2005*). In addition, there is a problem in extrapolating relationships such as weather and health into the long term (*Kovats et al., 2005*), as extreme climatic events may cause such relationships to break down. Economic theory of decision making under uncertainty when applied to climate change incorporates the probabilities of particular outcomes multiplied by the costs and benefits (*Baer et al., 2008*) accrued when these outcomes take place into a probability density function (*Stern et al., 2005*). The theory assumes that individuals act ‘rationally’ in

response to ensuing states of the world according to a set of conditions, however, it is questionable whether in reality the assumption that human behaviour can be modelled to a simple set of conditions is correct (*Baer et al., 2008*). In the application to climate change, the theory is limited even further when the potential future states of the world ensuing are considerable in number (*Baer et al., 2008*) (*figure 5*) making it problematic to make accurate predictions of expected values of impacts.

The large uncertainties surrounding climate change have led to the requirement for the use of subjectivity in order to draw conclusions. This is problematic for a variety of reasons. Firstly, when the probabilities of particular impacts are unknown as well as the size of the impact, a judgement on both the likelihood and size of an event, is required in order to incorporate such events into the analysis. This approach constrains the precision of predictions. Secondly, as the benefits from mitigation are non-marginal (*Stern et al., 2005*) coinciding with considerable uncertainty in the relationship between the level of GHG stabilisation and eventual temperature change (*figure 6*), the optimal GHG stabilisation level for a given time period cannot be determined by the MB=MAC condition as suggested in *figure 1* but by a subjective judgement. This arguably detracts from the objective economic principles behind CBA.

Despite its theoretical strengths, CBA, when applied to such a complex issue has considerable limits. Although the orthodoxy of CBA and economics in general, are undoubtedly part of the solution to the problem, there has been a divergent weighting on economic warrants (*Baer et al., 2008*) over the morality of climate change (*Baer, 2007*). It is simply monistic to compartmentalise all the issues surrounding climate change to existing investment appraisal theory (*Spash, 2007*). Optimal strategy in response to a changing climate needs to be decided through an evolutionary social process (*Baer, 2007*) not an orthodox economic one, acting in the interest of promoting a sustainable and fair planetary system.

2,959 words.

Tables and Figures

Figure 1: Economic costs of greenhouse gas abatement (Taken from Adger, N. 2010: Economic approaches to climate change: Mitigation, Week 1, Lecture 2, last accessed 23/11/10)

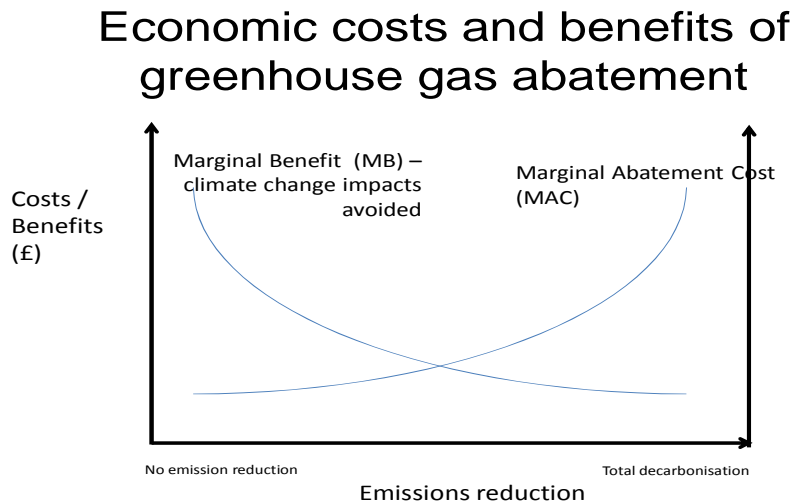


Figure 2: Conceptual approach to comparing divergent growth paths over the long term (taken from Stern, N. The Economics of Climate change, pg 35, last accessed 23/11/10)

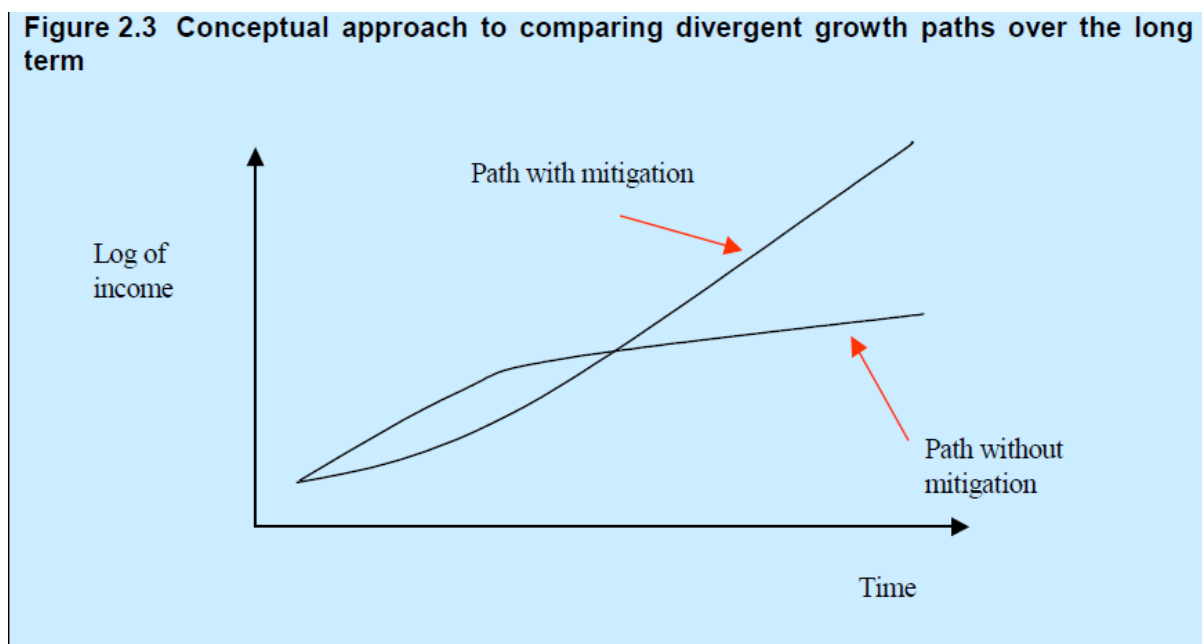


Figure 3: Estimates of Annual Damages to the U.S economy from global Climate Change (billions of 1990 dollars) (Taken from Adger, N. 2010: Economic analysis of the impacts of Climate change: Week 2 Lecture 1. Last accessed 23/11/10)

Table 2. Estimates of Annual Damages to the U.S. Economy from Global Climate Change (billions of 1990 dollars)

Type of Damage	Short-term warming based on doubling CO ₂ levels (+2.5 degrees C)	Very long-term warming (+10 degrees C)
Agriculture	17.5	95.0
Forest loss	3.3	7.0
Species extinctions	$4.0 + X_1$	$16.0 + Y_1$
Sea-level rise		35.0
Building dikes, levees	1.2	
Wetlands loss	4.1	
Drylands loss	1.7	
Electricity requirements	11.2	64.1
Non-electric heating	-1.3	-4.0
Human amenity	X_2	Y_2
Human life loss	5.8	33.0
Human morbidity	X_3	Y_3
Migration	0.5	2.8
Increased hurricanes	0.8	6.4
Construction costs	$\pm X_4$	$\pm Y_4$
Loss of leisure activities	1.7	4.0
Water supply costs	7.0	56.0
Urban infrastructure costs	0.1	0.6
Air pollution		
Tropospheric ozone	3.5	19.8
Other air pollution	X_5	Y_5
Total	$61.1 + X_1 + X_2 + X_3 \pm X_4 + X_5$	$335.7 + Y_1 + Y_2 + Y_3 \pm Y_4 + Y_5$

Source: Cline 1992.

Figure 4 : Coverage of existing Integrated assessment studies (Taken from Stern, N. The Economics of climate change, pg 150, Last accessed 23/11/10)

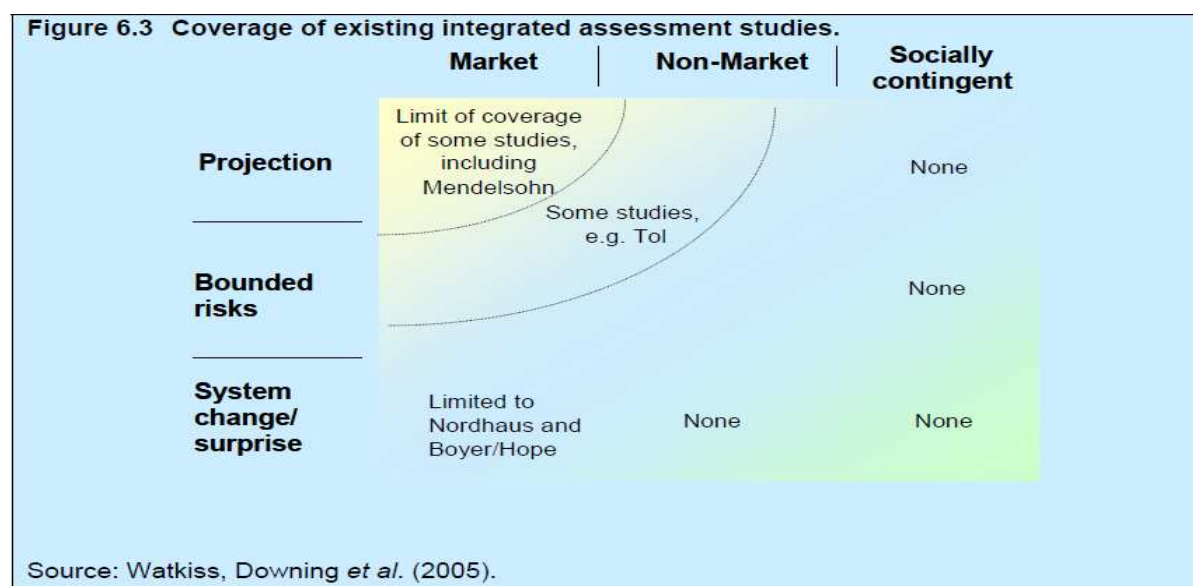
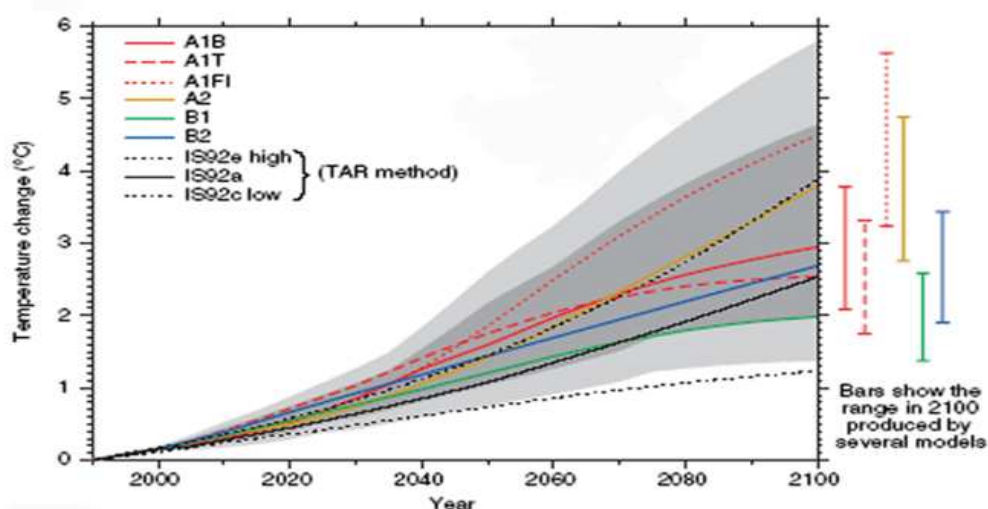


Figure 5: Global Temperatures trends Project 2100 (Taken from Adger, N. 2010: Economic analysis of the impacts of Climate change: Week 2 Lecture 1. last accessed 23/11/10)

Figure 5. Global Temperature Trends Projected to 2100

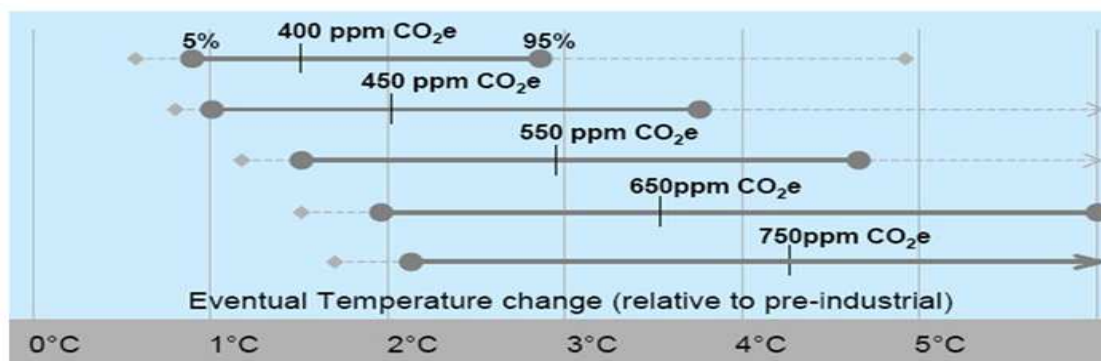


Source: IPCC, 2001: IPCC 2007 projections are substantially similar, but have a slightly greater range, from 1.1°C to 6.4°C.

Note: The IPCC used a variety of assumptions about economic growth and energy policies to construct the specific numbered projections. The gray areas represent "envelopes" showing the possible range of estimates for the various projections.

Figure 6: The Relationship between the level of Greenhouse Gas Stabilisation and eventual temperature change (Taken from Adger, N. 2010: Economic analysis of the impacts of Climate change: Week 2 Lecture 1. last accessed 23/11/10)

The Relationship between the Level of Greenhouse Gas Stabilization and Eventual Temperature Change



Source: Stern, 2007.

Bibliography

1. Adger, W. N. (1999) Environmental and ecological economics. In O’Riordan, T. (ed.) *Environmental Science for Environmental Management*. 2nd Edn. Longman: London pp. 93-118.
2. Adger, W. N. (2010) Economic approaches to climate change: Mitigation, Week 1 Lecture 2. Climate change history, Economics and Governance.
3. Adger, W. N. (2010) Economic analysis of the impacts of Climate change: Week 2 Lecture 1. Climate change history, Economics and Governance.
4. Adger, W. N., Barnett, J., Chapin F. S. and Ellemor, H. (2010 accepted) Under representation of place and meaning in climate change decision-making. *Global Environmental Politics*.
5. Baer, P. (2007). The Worth of an Ice-Sheet: A Critique of the Treatment of Catastrophic Impacts in the Stern Review. EcoEquity Discussion Paper.
6. Baer, P. & Spash, C. (2008) Cost Benefit analysis of Climate Change: Stern Revisited. Csir working paper series.
7. Caney, Simon 2008. Human rights, climate change and discounting. *Environmental Politics* 17 (4): 536-555.
8. Dornbusch, R. Fischer, S. Startz, R. (2008) Macroeconomics: Tenth Edition, Macgraw hill education, New York.
9. Frederick, S. (2010) Measuring intergenerational time preference: are future lives valued less? *Journal of Risk and Uncertainty*, 26 (1), 39-53.
10. Hanemann, M. (2010) What is the economic cost of climate change? In Schneider et al., (2010) *Climate change science and policy*. Island Press: Washington DC.
11. Kovats, R. S., Campbell-Lendrum, D. & Matthies, F. (2005) Climate Change and Human Health: Estimating Avoidable Deaths and Disease. *Risk Analysis*, 25, 1409-1418.
12. Nakiecenovic, N. (2000) Special report on emissions scenarios: A special report of working group III of the intergovernmental panel on climate change. Cambridge University Press. Cambridge.
13. Spash, C. (2007) The economics of climate change a la Stern: novel and nuanced or rhetorically restricted. *Ecological Economics* 63 no.4: 706-713.
14. Stern, N. (2007) *Economics of Climate Change: The Stern Review*. Cambridge University Press, Cambridge.
15. Tol, R.S.J. (2002) New estimates of the damage costs of climate change: benchmark estimates. *Environmental and Resource Economics*, 21 (1), 47-73.
16. Turner R K, Adger N, Doktor P, 1995, "Assessing the economic costs of sea level rise" *Environment and Planning A* 27(11) 1777 – 1796

