International Max Planck Research School on Earth System Modelling

Equity and Climate Change: Applications of FUND

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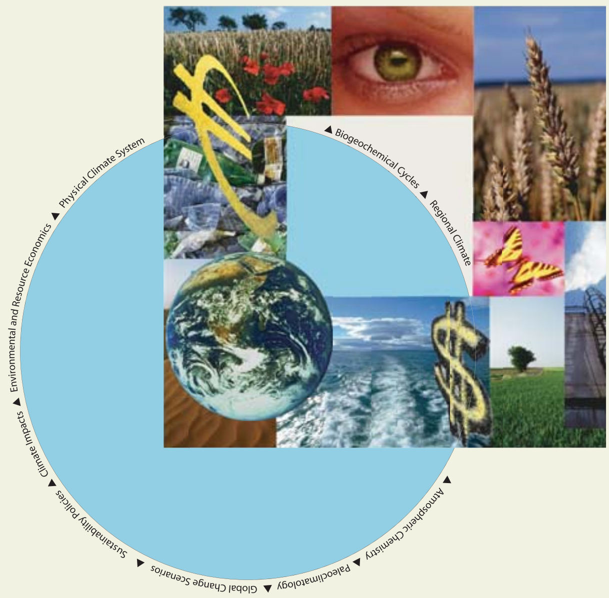

General Introduction

Climate change was for a long time the domain of natural science research. While a small group of economists was working on the issue early on as well (Nordhaus, 1991; Cline, 1992; Fankhauser, 1995; Tol, 1995; Pearce *et al.*, 1996), the focus of policy makers and the controversies surrounding climate change research focused on the basic physical science question for a long time. Through a series of reports from the Intergovernmental Panel on Climate Change (Houghton *et al.*, 1990; Houghton *et al.*, 1995; Houghton *et al.*, 2001; Solomon *et al.*, 2007), many of these controversies have been settled. The basic scientific questions of whether humans cause climate change and whether climate change will intensify in the future due to human greenhouse gas emission were answered affirmatively in those reports, and these results are widely accepted today.

Such agreement is mostly missing though on the question how a response to climate change should look like. Should one try to slow global warming by putting resources into mitigating greenhouse gas emissions? Or should one put resources into adapting to the expected impacts of climate change? Reductions of emissions are a global public good, which immediately brings up the question how it can be provided and who should provide how much of it. Climate change is characterized by an extremely slow causal connection: Emissions today will mostly affect people that are not yet alive and any costs to mitigate emission reductions today will be borne by people that will most likely not be alive anymore when the benefits of those emission reductions occur, which leads to difficult questions of how the interests of different generations are to be weighed against each other. Finally, one of the key characteristics of climate change policy is that one has to come up now with policies that are meant to solve problems whose precise magnitude is inherently uncertain, simply because they are based on predictions of what is going to happen many decades from now. How should such potentially large catastrophic, but nevertheless highly unlikely, events be considered when designing climate change policy?

All of the above are questions that are outside the traditional physical sciences whose results started the initial urge to act against climate change. The need for other disciplines, and economics in particular, to work on climate change research was recognized in expert circles for a long while, but found its most prominent public expression in the publication of the *Stern Review* in 2006 (Stern, 2007). In this thesis I try to contribute to the economic research on climate change, by both applying existing economic theory to specific issues thought to be of importance in relation to climate change, as well as in clarifying on what theoretical basis one might tackle specific questions that are posed by climate change.

In the remainder of this introduction I will give a brief outline of the chapters of this thesis and locate their role in the economic climate change research agenda.

1. Overview

A useful first starting point for a discussion of the economics of climate change is an estimate of the total damage to be expected from climate change impacts. The *Stern Review* (Stern, 2007) published one such impact estimate, but used a different metric than all other previous economic impact studies, making it difficult to compare the results from the *Stern Review* with the existing literature. The *Stern Review* expressed impacts as changes in balanced growth equivalents (BGE), whereas previous studies had used either net present total impact estimates or marginal damage cost estimates. In chapter 1 we first propose rigorous definitions of the BGE for multiple regions and under uncertainty, which was missing from the *Stern Review* itself. We show that the change in the BGE is independent of the assumed scenario of per capita income. For comparable welfare economic assumptions as the *Stern Review*, we calculate lower changes in BGE between a business as usual scenario and one without climate impacts with the model *FUND* than the *Stern Review* found with the model *PAGE*. We find that mitigation policies give even lower changes in BGE and argue that those policy choices should be the focus of the research effort rather than total damage estimates. According to our results, the current carbon tax should be below $55/tC. Sensitivity analyses show that the *Stern Review* chose parameters that imply high impact estimates. However, for regionally disaggregated welfare functions, we find changes in BGE that are significantly higher than the results from the *Stern Review*, both for total damage and for policy analysis. With regional disaggregation and high risk aversion, we observe fat tails and with that very high welfare losses.

Most studies of the total impact of climate change are based on an enumerative approach, where primary impact estimates are calculated for different sectors of the economy and then added up later to derive a total impact estimate. In chapter 2 we contribute to the estimation of one particular impact sector, namely impacts from rising sea-levels. Using the *FUND* model, we conduct an impact assessment over the 21st century for rises in sea-level of up to 2m/century and a range of national socio-economic scenarios. The model balances the costs of retreat with the costs of protection, including the effects of coastal squeeze. While the costs of sea-level rise increase due to greater damage and protection costs, the model suggests that an optimum response in a benefit-cost sense remains widespread protection of developed coastal areas. The socio-economic scenarios are also important in terms of influencing these costs. In terms of the four components of costs considered in *FUND*, protection seems to dominate, with substantial costs from wetland loss under some scenarios. The regional distribution of costs shows that a few regions experience most of the costs, especially East Asia, North America, Europe and South Asia. Importantly, this analysis suggests that protection is much more likely and rational than is widely assumed, even with a large rise in sea level. However, there are some important limitations to the analysis, which collectively suggest that protection may not be as widespread as suggested in the *FUND* analysis. Equity weighting allows the damages to be modified to reflect the wealth of those impacted by sea-level rise. Taking these distributional issues into account increases damage estimates by a factor of three, reflecting that the costs fall disproportionately on poorer developing countries.

Chapter 3 presents a systematic sensitivity analysis of the social cost of carbon with respect to two crucial parameters: the pure rate of time preference and the curvature parameter of the utility function, which plays the triple role of risk aversion, inequality aversion and elasticity of intertemporal substitution parameter in the standard preference function mostly used in climate change economics. We show that the social cost of carbon lies anywhere in between 0 and $120,000/tC. However, if we restrict these two parameters to match observed behavior, an expected social cost of carbon of $60/tC results. If we correct this estimate for income differences across the world, the social cost of carbon rises to over $200/tC.

Estimates of the marginal damage costs of carbon dioxide emissions require the aggregation of monetized impacts of climate change over people with different incomes and in different jurisdictions. Implicitly or explicitly, such estimates assume a social welfare function and hence a particular attitude towards equity and justice. In chapter 4 we show that previous approaches to equity weighing are inappropriate from a national decision maker's point of view, because domestic impacts are not valued at domestic values. We propose four alternatives (sovereignty, altruism, good neighbour, and compensation) with differing views on concern for and liability towards foreigners. The four alternatives imply radically different estimates of the social cost of carbon and hence the optimal intensity of climate policy.

A necessary condition of an efficient global climate change mitigation policy is to equate marginal abatement costs across world regions, so that the cheapest available abatement options are used. The welfare economic justification for such an approach rests on lump sum transfers between regions to compensate for any unwanted distributional consequences of such a policy. In chapter 5 I contrast this efficient solution with a second best situation in which lump sum transfers between regions are impossible. I derive that in the latter case optimal taxes are different for regions with different per capita consumption in a dynamic setting. I estimate the optimal tax rates with the integrated assessment model *FUND* and find that optimal mitigation is less stringent when equity is explicitly considered for widely used parameter choices of a utilitarian social welfare function.