Springer Climate

Karl W. Steininger · Martin König
Birgit Bednar-Friedl · Lukas Kranzl
Wolfgang Loibl · Franz Prettenthaler
Editors

Economic Evaluation of Climate Change Impacts

Development of a Cross-Sectoral Framework and Results for Austria

EXTRA MATERIALS
extras.springer.com

Springer

Springer Climate

Series editor

John Dodson, Menai, Australia

Springer Climate is an interdisciplinary book series dedicated to all climate research. This includes climatology, climate change impacts, climate change management, climate change policy, regional climate, climate monitoring and modelling, palaeoclimatology etc. The series hosts high quality research monographs and edited volumes on Climate, and is crucial reading material for researchers and students in the field, but also policy makers, and industries dealing with climatic issues. Springer Climate books are all peer-reviewed by specialists (see Editorial Advisory board). If you wish to submit a book project to this series, please contact your publisher (elodie.tronche@springer.com).

More information about this series at
http://www.springer.com/series/11741

Karl W. Steininger • Martin König •
Birgit Bednar-Friedl • Lukas Kranzl •
Wolfgang Loibl • Franz Prettenthaler
Editors

Economic Evaluation of Climate Change Impacts

Development of a Cross-Sectoral Framework and Results for Austria

Springer

Editors
Karl W. Steininger
University of Graz
Graz, Austria

Martin König
Environment Agency Austria
Vienna, Austria

Birgit Bednar-Friedl
University of Graz
Graz, Austria

Lukas Kranzl
Vienna University of Technology
Vienna, Austria

Wolfgang Loibl
Austrian Institute of Technology
Vienna, Austria

Franz Prettenthaler
Institute for Economic and Innovation Research
Graz, Austria

Additional material to this book can be downloaded from http://extras.springer.com

ISSN 2352-0698 ISSN 2352-0701 (electronic)
ISBN 978-3-319-12456-8 ISBN 978-3-319-12457-5 (eBook)
DOI 10.1007/978-3-319-12457-5
Springer Cham Heidelberg New York Dordrecht London

Library of Congress Control Number: 2014959279

The results reported in this book have been acquired in a project financially supported by the Austrian Climate and Energy Fund (COIN project, carried out within the Austrian Climate Research Programme, ACRP).

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Preface

Our current actions determine both our own well-being and that of future generations. Beyond climate change, there are very few areas where the lag between action and potential impact is that long and where the risk of delaying an appropriate response may entail impacts of such enormous magnitude. There is thus a clear need for adequate information for society on climate change and its impacts.

Climate change impacts are multifaceted, interdependent and characterised by a high degree of uncertainty. Their analysis thus necessitates collaboration across a broad set of disciplines and expertise, and entails devising appropriate scenarios.

In this volume, we show how, at the national scale, relevant societal information on climate change impacts can be generated. Here, particular emphasis is placed on the generation of information related to economic evaluation and economic implications of climate change. A tool box enabling consistent analysis across the many fields of climate impact is developed and then applied to one particular country, Austria.

Climate scenario analysis to date indicates that the expected mean values associated with climate change damage are increasing. However, as such mean values are surrounded by a considerable amount of uncertainty, it is also crucial to consider the potential range of damage that might occur (e.g. potential higher and lower damage values). Identification of such ranges is also useful in that it helps clarify that several different types of response can and will be relevant. The paths of socio-economic development taken by our societies not only determine the extent of greenhouse gas emission mitigation, but of at least equal importance, they also determine how resilient society and its individuals will be to a changing climate (and whether they will be in a position to actively implement robust countermeasures in response). For example, questions such as whether we continue to construct infrastructure in flood prone areas, whether sealing and urban sprawl continue to increase the urban heat island effect, whether institutions such as hospitals or old people's homes are equipped to deal with heat waves (particularly in the light of expected future ageing), whether energy services of all types (heating and cooling, transport, production processes) will remain affordable—all of these questions are crucial in determining a society's level of resilience in a changing climate. Given the potential impact of 'tipping elements' at various levels, and the potential damage that can be caused by extreme events, it becomes clear that adequate risk management needs to consider also substantial mitigation policies.

This exercise was undertaken by a team comprising 18 research groups and scientific institutions. With a time span of less than one and a half years between kick-off and submission to print, including three review cycles, a substantial degree of discipline and collaboration was necessary, particularly given the high level of interdependency across the modelling approaches. It was a pleasure to be part of an endeavour where each and every scientist did his or her best to ensure the achievement of a collaborative common result.

The project was fostered greatly by its Scientific Advisory Board, comprising Paul Watkiss, Roger Street and Reimund Schwarze, who reacted immediately to all our manifold requests and reviewed the full manuscripts thoroughly. Their advice was extremely helpful. In addition, via a process of continuous consultation throughout, they wisely directed the project to its successful completion. It is our wish that every project may have such a supportive advisory board.

Günther Liebel, Helmut Hojesky and Barbara Kronberger-Kießwetter of the Austrian Ministry of Agriculture, Forestry, Environment and Water Management, as well as Jose Delgado and Tobias Orischnig of the Ministry of Finance, supplied crucial feedbacks on practical applicability of results and information demands throughout the project in a very constructive and supportive way, for which the team thanks indeed.

Matthias Themessl, at the Service Centre of the Climate Change Centre Austria (CCCA), exercised much care and thought in organising and directing the international review process. We thank all 39 reviewers for their valuable contributions. These were a great help in improving the respective chapters. Two anonymous reviewers from the publisher, Springer, then reviewed the entire volume resulting in significant improvements.

Administration of the project was substantially supported by Karin Eisner at Wegener Center, the native speaker checks were carried out by a multitude of experts, but for a substantial number of chapters we would like to express particular thanks to Laurie Conway. The uniform and attractive layout of the chapters and of the supplementary materials is owed to the careful work of Michael Kriechbaum. Matthias Themessl, Angelika Wolf and Michael Kriechbaum produced further dissemination material.

Finally, it was a pleasure to work in the production process with Barbara Feß, Johannes Glaeser and their team at Springer.

We wish to express our thanks to all of them. May the impact of this volume be seen as a reward to all.

Graz, Vienna
August 2014

Karl W. Steininger
Martin König
Birgit Bednar-Friedl
Lukas Kranzl
Wolfgang Loibl
Franz Prettenthaler

Executive Summary

The infrared absorption capacity of greenhouse gases is inducing a warming of the earth's atmosphere. Already in 1979 the World Meteorological Organization found "that it is now urgently necessary for the nations of the world: [. . .] to foresee and to prevent potential man-made changes in climate that might be adverse to the well-being of humanity," and that "it is possible that some effects on a regional and global scale may be detectable before the end of this century and become significant before the middle of the next century" (WMO 1979).

In various assessment reports published since 1990, and most recently in 2013/2014, the Intergovernmental Panel on Climate Change (IPCC) has confirmed the findings presented in the scientific literature that climate change has led to a global mean temperature increase of almost 1 °C since 1880 and that it is predominantly caused by human activities (IPCC 2013, 2014). The IPCC also reports that, left unabated, future emissions will lead to a temperature increase by the end of the twenty-first century of 3.2–5.4 °C. Even the most ambitious mitigation scenarios could potentially lead to dangerous climate change; i.e. even if global average warming is limited to 2 °C relative to pre-industrial levels (the current international goal agreed, noting that this is unlikely to be met). For most regions, particularly land-locked mountainous and continental climate zones, this implies a more substantial increase, e.g. a 4.5–6.6 °C increase by 2100 is projected for the Alpine region and thus for a country such as Austria (Jacob et al. 2013).

Due to the inertia of the climate system, societies are thus confronted with the need to adapt to climate change and—in order to avoid a further increase that gets increasingly unmanageable in the future—the need to engage in attempts to agree on and implement greenhouse gas emission mitigation policies. For both types of decisions, adaptation and mitigation, well-informed decision making requires knowledge on the type and magnitude of climate change impacts expected and on the type of information available and deducible.

During the last two decades a rich body of literature has thus developed on climate change impacts, with results put into perspective most recently in IPCC (2014). In this literature two strands can be distinguished. One is employing aggregated impact functions, within so-called Integrated Assessment Models, which have been applied mainly at the global level in order to quantify the social costs of carbon (the additional damage of an extra ton of greenhouse gas (GHG) emitted). A second strand builds upon physical impact assessments, often extended by related economic valuation.

All of these studies indicate the high demand for evaluations at the national and sub-national level, as this is where climate change materialises and where administration and governance of adaptation takes place. This also lends force to the IPCC's demands for disaggregated studies and scenarios capable of allowing for more appropriate impact assessment at the national to local level. To date, however, studies at the national and sub-national level have tended to focus solely on a few selected fields of impact (i.e. on those considered the most important).

This clear gap in the literature provides the motivation for the present volume. The objective here is to cover *as broad a* field of impacts as possible at the national level within a single comprehensive cost evaluation. To create such information at the national level, the present volume presents (a) a toolbox for deriving future climate impacts and arriving at related monetary quantification at the sectoral level, (b) the means for doing so consistently across all fields of impact, (c) a framework for impact integration in terms of a consistent macroeconomic framework in order to quantify economic feedback effects, (d) an approach for dealing with non-market impacts, e.g. impacts related to human health and biodiversity and (e) appropriate methods for considering extreme events and their 'fat tail' distribution.

Methodologically speaking, the approach presented combines a scenario-based impact assessment across all fields of impact, a computable general equilibrium (CGE) analysis so as to capture cross-sectoral linkages and economy-wide effects, and a qualitative analysis to capture additional non-market effects where monetisation is not considered appropriate.

The volume first gives an overview of climate costs at the European level. Impacts are found to amount to several percentage points of GDP by the end of the century, and are characterised by large differences in the patterns of impacts across Europe. For example, due to a combination of enhanced climate signal and higher local vulnerability, there are more negative impacts in South-Eastern Europe and the Mediterranean area.

In general, available national assessments of climate change risks and adaptation planning follow one of two approaches, i.e. either the use of top-down global Integrated Assessment Models (IAMs) which are then downscaled to reflect the national or regional scale or the use of bottom-up sectoral impact assessments which are scaled up to capture the regional or national level. On comparing the national evaluations undertaken in the UK, France, Germany and Switzerland, it becomes clear that the approach presented in this volume can indeed generate complementary information. Specifically, the new approach is helpful in the following three important areas: (a) it explicitly considers uncertainties through high impact case narratives (i.e. damage-enhancing socio-economic developments and high-damage climate change scenarios), (b) it applies consistent socio-economic scenarios and shared policy assumptions across various sectors and (c) it advances the state of the art with respect to the assessment of cross-sectoral, indirect and macroeconomic effects.

The national scale evaluation approach is designed specifically to deal with the following issues:

- Provision of a consistent overall framework
- Derivation of local indicators from climate model ensembles
- Development of shared socio-economic pathways necessary to ensure consistency across sectoral evaluations
- Creation of a toolbox for economic impact evaluation ensuring consistent evaluation
- Development of the macroeconomic modelling framework
- Macroeconomic integration of sectoral impacts while taking sufficient account of feedback effects.

We consider the methodological approach as comprehensive regarding the fields of impact and the relevant aspects of climate change costs. However, we are aware that the quantification of costs has to leave many open questions and relevant impacts which could not be quantified in this work.

In order to exemplify its use, the set of tools is applied to a single country, i.e. Austria. The following results were derived:

With respect to observed welfare damage of climate- and weather-induced extreme events in Austria, insurance data reveal annual average sums of 97 million euros (M€) in the 1980s, 129 million euros in the 1990s, and 705 million euros in the last decade. However, these figures are covering large events (catastrophes of class 5 and 6) only, and are of incomplete coverage even for this subcategory pre-2002. In the past, the most significant damage at the national scale in Austria was related to riverine flooding, valued at 3.5 billion euros in 2002 and 2.3 billion euros in 2013 (which amounted to 1.4 % and 0.7 % of GDP, respectively; all monetary values given in this summary are at prices of 2010). Non-market impacts of premature heat-related deaths can be evaluated at a current annual average 150–390 million euros. Thus, the current welfare damage of climate and weather induced extreme events in Austria is an annual average of about 1 billion euros (large events only).

We find that this has the potential to rise to 4–5 billion euros by mid-century (annual average, known knowns of impact chains only, undiscounted), with an uncertainty range of 4–9 billion euros. When extreme events and the tails of their distribution are included, even for a partial analysis focused on extremes, damages are seen to rise significantly, e.g. with an estimated increase to 40 billion euros due to riverine flooding events alone by the end of the century. These highlight the need to consider the distribution of impacts, as well as the central values.

In contrast, traditional economic measurements, such as those assessing climate change impacts on GDP, provide, at best, only a partial picture. For example, GDP losses do not account for losses in stocks (e.g. buildings) due to climate change events.

For the case of Austria, the following climate impacts were identified in detail by impact field:

Agriculture Potential average yields increase at least until the middle of the century (mostly due to a lengthening of the vegetation period as a result of higher temperatures, rather stable annual precipitation sums, and the CO_2 fertilisation effect). However, several factors are at work which tend to offset (partially or fully) such an increase, e.g. disruption caused by extreme weather events or periods, higher investment costs or / and disruptions in the functioning of ecological systems (e.g. in the effectiveness of insect pollination and biological pest control). Furthermore, the agricultural sector itself is less likely to benefit from the (uncertain) potential increase in yield than are the food and retail sectors.

Forestry In mountain forests longer vegetation periods result in increased productivity, while at low elevations in the east and in the south of Austria, drought will negatively impact on forest growth. Assuming no suitable adaptation measures are taken, increases in bark beetle infestations and possibly also storms are likely to result in yield reductions. In addition, the investment needed to maintain protection functionality against gravitational hazards in spite of losses of protective forest cover is higher than that needed to compensate for productivity loss alone.

Ecosystem Services Climate plays a major role here. Researchers have only just begun to derive the specific threshold values at which ecosystem services start to decline. In economic terms, the pollutant buffer capacities of soil and vegetation, erosion protection and the provision of drinking water are all extremely significant ecosystem services. In our assessment reported here, the only agricultural services that were investigated were insect pollination and biological pest control, and the results were taken into consideration as explained earlier for agriculture.

Human Health More intensive and frequent heat waves raise the number of deaths in the growing share of the elderly (leading, under the mid-range assumptions, to an additional 1,000 annual deaths in the period 2036–2065). In more extreme years, where the group of those vulnerable is extended to include the chronically ill, health impacts may be as much as six times higher than those found under the mid-range assumptions (more than two times higher than under the high range assumptions).

Water Supply and Sanitation By mid-century, the already high level of investment required for dealing with socio-economic development will be at least 10 % higher due to climate change implications. However, as is the case for all impact fields, but of particular importance here, only a subset of impact chains was quantified.

Catastrophe Management Already today, riverine flooding is one of the economically most important weather and climate risks in Austria. There is thus a clear need for catastrophe management, especially in terms of reducing vulnerability. However, as extreme weather events are, by their very nature, outliers, the uncertainties with respect to forecasting the flood risk for the future climate remain quite high. While for the period 1981–2010 the average annual figure for flood cost damage was about 200 million euros; forecasts for the period 2036–2065 arrive at a corresponding average annual cost figure of between 400 and 1,800 million euros. Estimates for flood events with a recurrence time of 100 years show that, as a result of climate change and increases in wealth, the cost of flood damage in the period 2036–2065 is likely to be twice as high as in 1977–2006. Such flood events would result in damage of between 5 and 7 billion euros.

Transport Even today, damage to transport infrastructure, primarily resulting from landslides or from road and rail undercutting (or washouts) caused by heavy precipitation, is already considerable (amounting to 18 million euros p.a. for road infrastructure). The extent of future damage depends directly on how traffic networks develop. Network exposure depends on the nature of network extensions. Local aspects need to be considered (e.g. geological conditions determining landslide potential, slope gradients, the risk of damage through undercutting (washouts) or wind). Depending on the duration of the disruption and on the availability of alternative routes, the indirect impact of traffic disruptions (losses in production and time) may easily exceed the direct costs of repair.

Buildings and Energy With respect to the energy needs of buildings, it was found that by the middle of the century, the savings in fossil fuel energy in the winter period more than offset the additional energy demand for cooling needed in the hot season. One potentially critical aspect, however, is the growing peak load for cooling and the discrepancy between electricity production capacity (which in Austria is based to a large extent on hydroelectric generation) and the increasing demand for cooling energy in the summer period. Higher peak demand occurs at the same time as summer drought imposes limits on traditional production, with excess demand for electricity needing to be met either by increased imports or by extending plant capacity (with quite a potential for photovoltaic electricity). Increased importing of electricity (particularly from southern European countries) not only places a higher burden on the grid network, there may be also an increase in the risk of widespread power failure and blackouts.

Manufacturing and Trade The impacts of climate change in this sector are diverse and branch-specific, and range from the need for adjustments in cooling and cooling chains, on to the impact of extreme weather events on transport networks and their related essential services. A uniform assessment of the losses in labour productivity arising from more frequent heat waves was undertaken for all branches in manufacturing and trade. By the middle of the century, the annual cost of such losses, alone in manufacturing and trade, amounts to up to 140 million euros.

Urban Green Climate change will result in even more pronounced urban heat islands. The normal cooling effect caused by vegetation is lost in the presence of sealed surfaces and buildings and will be further accelerated by additional city growth. As a result, urban areas are a few degrees warmer than their surroundings. The impact of future climate change could be limited by additional investments in green and blue infrastructure to maintain their thermal comfort service.

Tourism While rising temperatures and lower precipitation benefit summer tourism, they are detrimental to winter tourism (in its present form). In the mid-range climate scenario, by the middle of the century, the loss in winter overnight stays is expected to exceed the gain in summer overnight stays by 1.5 million. This net loss alone results in average annual costs of 300 million euros. Related macroeconomic effects lead to further costs (and magnify cost by 60 % over direct sector cost), as do changes in the sector's cost structure (e.g. increased costs for artificial snow, air conditioning, water supply, etc.) and the impact of extreme weather events.

References

IPCC (2013) Climate Change 2013: The Physical Science Basis, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Oxford University Press, Oxford

IPCC (2014) Climate Change 2014: Impacts, Adaptation, and Vulnerability, Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Oxford University Press, Oxford

Jacob D et al (2013) EURO-CORDEX: new high-resolution climate change projections for European impact research. Reg Environ Change. doi:10.1007/s10113-013-0499-2

WMO (1979) Declaration of the World Climate Conference. World Meteorological Organization, Geneva

Testimonials

"This study is a landmark, setting a new standard for the assessment of the impacts of climate change. It stands out for the comprehensiveness of its coverage of potential impacts across different sectors of the economy. Beyond that, it innovates in three important ways. First, it clearly delineates the current vulnerability to climate (the current "stock" of climate and weather induced damages) before going on to identify the additional impacts expected to occur with future global warming. Second, it makes a serious effort to consider the "fat tail" of climate impacts, which is central to the debate on climate policy when this is viewed—as it should be—as an exercise in risk management. Third, unlike the recent US national climate assessment, it characterises the effects of climate change not just in physical, biological and social terms but also in terms of economic endpoints. This is a model for how a national assessment should be conducted!"

Michael Hanemann, Professor of Economics, Arizona State University and Professor of the Graduate School, University of California, Berkeley

"Climate change is a defining issue of our time. It triggers a broad set of impacts with significant interactions within the economy and broader society. Economic impact evaluation is of crucial importance to plan society's response. This volume develops a consistent, bottom-up approach for such an evaluation across the whole range of impact fields, acknowledging their macroeconomic feedbacks and budgetary implications. The applications are exemplified with data for Austria but this book provides core insights that could and should be applied to other countries to support appropriate societal decisions."

Thomas Sterner, Professor of Economics, University of Gothenburg

"This volume provides an essential methodological element for climate impact evaluation and the application and sharing of lessons learnt adds to the potential for transferability to other settings—both critical to stimulating action. It provides credible evidence and demonstrates the scale of the problem. The lasting value of this book will come from the methodology with its frameworks, consistent toolbox and comprehensive integration, as well as the lessons learnt and shared, exemplified through application in Austria. For this Alpine country unmitigated weather and climate induced net damages are shown to increase by mid-century at least four to eight-fold, with tail events raising damages even an order of magnitude higher."

Roger Street, Director of UK Climate Impacts Programme, University of Oxford

Contents

Part III Fields of Impact

Chapter 1
Introduction

Karl W. Steininger

Research on human-induced climate change has a long history. The Swedish scientist Svante Arrhenius quantified the impact of the infrared absorption capacity of the greenhouse gas CO_2 as early as 1896. He pointed out that cutting its concentration in the earth's atmosphere by half would produce an ice age, while doubling the concentration would result in a warming of 5–6 °C (Arrhenius 1896). After almost a century of further scientific analysis, the US National Academy of Sciences was asked by the US government administration to assess the scientific basis concerning the projection of possible future climate change resulting from anthropogenic carbon dioxide emissions. The respective report (Charney et al. 1979) found that a doubling of the earth's atmospheric CO_2 concentration was associated with a temperature increase of 1.5–4.5 °C, an assessment that has been repeatedly reconfirmed since. The report also concluded, that "it appears that the warming will eventually occur, and the associated regional climatic changes so important to the assessment of socioeconomic consequences may well be significant, but unfortunately the latter cannot yet be adequately projected" (Charney et al. 1979, p. 3).

In the same year, 1979, the World Climate Conference of the World Meteorological Organization found "that it is now urgently necessary for the nations of the world: [. . .] to foresee and to prevent potential man-made changes in climate that might be adverse to the well-being of humanity". It also concluded that "it is possible that some effects on a regional and global scale may be detectable before the end of this century and become significant before the middle of the next century" (both: WMO 1979).

A vast body of scientific literature, rigorously compiled by the Intergovernmental Panel on Climate Change (IPCC) in its Assessment Reports since 1990, has confirmed that climate change is taking place with global mean temperature increase of almost 1 °C since 1880, and that it is predominantly caused by human activities (IPCC 2013, 2014). The IPCC also reports that if left unabated, future emissions will lead to a temperature increase by the end of the twenty-first century of 3.2–5.4 °C. Even the most ambitious mitigation scenarios could potentially lead to dangerous climate change; i.e. even if global average warming is limited to 2 °C

K.W. Steininger (✉)
Wegener Center for Climate and Global Change, University of Graz, Graz, Austria

Institute of Economics, University of Graz, Graz, Austria
e-mail: karl.steininger@uni-graz.at

K.W. Steininger et al. (eds.), *Economic Evaluation of Climate Change Impacts*,
Springer Climate, DOI 10.1007/978-3-319-12457-5_1

relative to pre-industrial levels [the current international goal agreed (UNFCCC 2010)], noting that this is unlikely to be met). Given that surface air temperature above oceans will warm by less than the global average, many regions, particular land-bound mountainous and continental climate zones, will face more substantial increases; e.g. a 4.5–6.6 °C increase by 2100 is projected for the Alpine region and thus for a country such as Austria (Jacob et al. 2013, APCC 2014)[1]. Societies are thus confronted with the need to adapt to climate change—both to that already triggered by past emissions, as well as to that expected as a result of future emissions—and to weigh the need for adaptation against the need to avoid such risks in the first place, i.e. to agree on and implement greenhouse gas emission mitigation policies. While adaptation policy is mainly addressed at the national and regional level [see, for example, the EU white paper "Adapting to climate change: Towards a European framework for action" (EU Commission 2009)], mitigation obviously entails an additional, stronger, global harmonisation component, as has been addressed to date within the United Nations Framework Convention on Climate Change and its Conferences of Parties. For both types of decisions, adaptation and mitigation, well-informed decision making requires knowledge on the type and magnitude of climate change impacts expected, and on the type of information (potentially and actually) available.

During the last two decades a rich body of literature has thus developed on climate change impacts. Most recently, IPCC (2014) puts these results into perspective, and for the first time in its assessment reports devoted a separate sub-volume to the detailed assessment of impacts on the continental and regional-to-local scale. As the translation of such impacts into a uniform scale of monetary values is often considered helpful for decision making, attempts at evaluation of climate impact cost (or 'damage') have also gained momentum. In one strand of the literature, these have been put forward using aggregated impact functions, within so-called Integrated Assessment Models, which have been applied mainly at the global level in order to quantify the social costs of carbon (the additional damage of an extra ton of greenhouse gas emitted). This approach has recently been questioned on several grounds, including the use of highly simplified and thus somewhat arbitrary economic damage functions (Pindyck 2013).[2]

[1] This range for the Alpine region refers to the "likely" range, i.e. the 17–83 ‰. To be fully comparable with the global temperature range given by IPCC, which refers to the 5–95 ‰, the range for the Alpine region would be larger.

[2] The three most often applied Integrated Assessment Models (IAMs) to date are DICE (Dynamic Integrated Climate and Economy), PAGE (Policy Analysis of the Greenhouse Effect), and FUND (Climate Framework for Uncertainty, Negotiation, and Distribution), with model descriptions given by Nordhaus (1991, 2011) and Hope (2006)—on which the Stern review is based (Stern 2007)—and Tol 2002a, b, respectively. They are used to provide total net present values for future damage over time and to estimate the marginal social costs of carbon (the damage cost of an extra tonne of GHG emissions). Their use to this end has been questioned, most importantly for arbitrary parameter choice in social welfare functions, ill-founded climate sensitivity (the temperature increase a GHG doubling implies), arbitrary and non-empirical based climate damage functions (usually a functional relationship between temperature increase and (regional) GDP loss, for

A second strand of the literature builds upon physical impact assessments and related economic valuation. Metroeconomica (2004) for the UK is an example at the national level, as are the three large European evaluations at the continental scale: Aaheim et al. (2012), Bosello et al. (2011) and Ciscar et al. (2011, 2012). International institutions have built on this second strand in their evaluations, e.g. the World Bank (2013) for its focus at developing regions, and the EEA (2008, 2012) for Europe. An alternative, but related, third approach is to map impacts and vulnerability, but refrain from monetisation (e.g. ESPON Climate 2013).

All of these studies indicate the high demand for evaluations at the national and sub-national level, as this is where climate change materialises and where administration and governance of adaptation takes place. This also lends force to the IPCC's demands for disaggregated studies and scenarios capable of allowing for more appropriate impact assessment at the national to local level.

To date, however, studies at the national and sub-national level have tended to focus solely on a few selected fields of impact (i.e. on those considered the most important).

This clear gap in the literature provides the motivation for the present volume. The objective here is to cover *as broad a* field of impacts as possible at the national level within a single comprehensive cost evaluation. The intention here is first, to provide a toolbox such that any effort made in this direction may be applied consistently across the fields of impacts and thus to result in meaningful results at the aggregated level. Second, and by way of example, to apply the framework and methods developed to a single country, in our case to Austria. Third, to draw conclusions concerning the nature of results arrived at when undertaking such an endeavour.

Methodologically our approach draws from and combines the following:

- Scenario-Based Impact-Field-Assessment: to capture impacts at the most detailed level available
- Computable General Equilibrium (CGE) analysis: to capture cross-sectoral linkages and economy-wide effects
- Qualitative analysis: to capture additional non-market effects where monetisation is not considered appropriate or possible.

The opening section in the present volume, Part I, offers an overview of climate costs at the continental scale. In Chap. 2, Paul Watkiss gives a condensed report on the results of a regional assessment for Europe—the EU FP7 ClimateCost project, Watkiss 2011—which has combined sectoral assessments and wider economic analysis. The results show large differences in the patterns of impacts across Europe, with more negative impacts in South Eastern Europe and the Mediterranean due to a combination of the enhanced climate signal and the higher

FUND also distinguishing individual sectors), and neglect of consideration of possible catastrophic outcomes. For a detailed discussion see Pindyck (2013).

vulnerability in these regions. While this European-wide view is important, the chapter also shows there is a need for country level analysis—as is presented in the remainder of this book—in order to capture national context and insights, to allow for analysis of country specific risks, and to provide the national-level information needed to start planning for adaptation.

An overview of the available national assessments of climate change risks needed in adaptation planning is given by Reimund Schwarze in Chap. 3. This chapter covers both of the standard methodologies used for risk assessment at the aggregate national or regional level, i.e. top-down global integrated assessment models (IAMs), which are downscaled to the national or regional scale, and bottom-up sectoral impact assessments, which are up-scaled to the national or regional level. The chapter gives a comprehensive overview of approaches applied in the UK, France, Germany and Switzerland, places them in context and indicates their respective merits and shortcomings. It not only evaluates in which respects the approach presented in the present volume complements the earlier approaches, it also points out its shortcomings. The merits of the approach developed in the present volume are found to lie in the possibility of advancing cost-benefit analysis by explicitly considering uncertainties through worse case narratives; the ability to apply consistent socio-economic scenarios and shared policy assumptions across sectors; the combination of observations and projections, which can then be more easily communicated in national dialogues than in top-down models; advancing the state of the art of the assessment of cross-sectoral, indirect and macroeconomic effects; and, finally, the greater ease with which the consequences for public budget may be indicated. In terms of shortcomings, the chapter reveals that owing to important gaps in data and methods, quantitative results tend to be somewhat "conservative" and, thus need to be augmented by qualitative research.

The methodological approach needed to achieve consistent application across sectors and macroeconomic evaluation is developed in Part II. Here, in Chap. 4, Steininger et al. provide the overall framework, while Formayer et al. in Chap. 5, set forth how climate change scenarios can be used to derive local indicators from climate model ensembles. König et al. in Chap. 6, define the shared socioeconomic pathways necessary to ensure consistency across sectoral evaluations, and, finally, Bachner et al. in Chap. 7, develop the macroeconomic modelling framework and present the means by which economic impact evaluation methods may be employed consistently across sectors and what the implications are in terms of macroeconomic aggregates and feedback-effects.

Part III looks at each impact field in detail, and by way of example, explores the case of one country, Austria. Impact evaluation is provided for the following fields: Mitter et al. analyse impacts on agriculture (Chap. 8), Lexer et al. on forestry (Chap. 9), Zulka and Götzl on ecosystem services (Chap. 10), Haas et al. on human health (Chap. 11), Neunteufel et al. on water supply and sanitation (Chap. 12), Kranzl et al. on buildings, i.e. heating and cooling (Chap. 13), Kranzl et al. on electricity (Chap. 14), Bednar-Friedl et al. on transport (Chap. 15), Urban and Steininger on manufacturing and trade (Chap. 16), Loibl et al. on cities and urban green (Chap. 17), Prettenthaler et al. on riverine flooding (Chap. 18), and Köberl et al. on tourism (Chap. 19).

Aggregate evaluation is covered in Part IV of the present volume. While each of the above chapters focused on a mid-century time horizon, and only some extended the analysis even further into the future, Kettner et al. (Chap. 20) derive a more comprehensive cost assessment up to 2100 based on a Delphi-approach. These authors also identify the most relevant barriers to adaptation. Bachner et al. (Chap. 21) assess climate change impacts across all the ten sectors with quantified impacts simultaneously and draw conclusions concerning overall macroeconomic impact. Finally, Steininger et al. (Chap. 22) place the results within a broader perspective in order to give an overall evaluation of climate impacts at the national level and then consider what we may (or may not) conclude from such an endeavour.

Acknowledgements Financial support for this research by the Austrian Climate and Energy Fund for the project COIN, carried out within the Austrian Climate Research Programme (ACRP) is thankfully acknowledged.

References

APCC (Austrian Panel on Climate Change) (2014) Austrian assessment report 2014. Summary for policy makers, Österreichischer Sachstandsbericht Klimawandel. Austrian Academy of Sciences, Vienna

Aaheim A, Amundsen H, Dokken T, Wei T (2012) Impacts and adaptation to climate change in European economies. Global Environ Change 22(4):959–968

Arrhenius S (1896) On the influence of carbonic acid in the air upon the temperature of the ground. Philos Mag J Sci Ser 5(41):237–276

Bosello F, Eboli F, Parrado R, Nunes PALD, Ding H, Rosa R (2011) The economic assessment of changes in ecosystem services: an application of the CGE methodology. Economía Agraria y Recursos Naturales 11(1):161–190

Charney JG, Arakawa A, Baker DJ, Bolin B, Dickinson RE, Goody RM, Leith CE, Stommel HM, Wunsch CI (1979) Carbon dioxide and climate: a scientific assessment. Report of an ad hoc study group on carbon dioxide and climate. National Academy of Sciences, Washington, DC

Ciscar J-C, Iglesias A, Feyen L, Szabó L, Van Regemorter D, Amelung B, Nicholls R, Watkiss P, Christensen OB, Dankers R, Garrote L, Goodess CM, Hunt A, Moreno A, Richards J, Soria A (2011) Physical and economic consequences of climate change in Europe. Proc Natl Acad Sci USA 108(7):2678–2683

Ciscar J-C, Szabó L, van Regemorter D, Soria A (2012) The integration of PESETA sectoral economic impacts into the GEM-E3 Europe model: methodology and results. Clim Change 112(1):127–142

EU Commission (2009) Adapting to climate change: towards a European framework for action, White paper of the Commission of the European Communities, COM(2009) 147 final. EU Commission, Brussels

EEA (European Environment Agency) (2008) Impacts of Europe's changing climate—2008 indicator-based assessment, Joint EEA-JRC-WHO report, EEA report 4/2008. EEA, Copenhagen

EEA (European Environment Agency) (2012) Climate change, impacts and vulnerability in Europe, EEA report 12/2012. EEA, Copenhagen

ESPON Climate (2013) Climate change and territorial effects on regions and local economies, Final report, ESPON and IRPUD. TU Dortmund, Dortmund

Hope C (2006) The marginal impact of CO_2 from PAGE2002: an integrated assessment model incorporating IPCC's five reasons for concern. Integr Assess 6(1):19–56

IPCC (2013) Climate change 2013: the physical science basis. Working Group I contribution to the fifth assessment report of the intergovernmental panel on climate change. Oxford University Press, Oxford

IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability, working group II contribution to the fifth assessment report of the intergovernmental panel on climate change. Oxford University Press, Oxford

Jacob D, Peterson J, Eggert B et al (2013) EURO-CORDEX: new high-resolution climate change projections for European impact research. Reg Environ Change. doi:10.1007/s10113-013-0499-2

Metroeconomica (2004) Costing the impacts of climate change in the UK: overview of guidelines, UKCIP technical report. UKCIP, Oxford

Nordhaus WD (1991) To slow or not to slow: the economics of the greenhouse effect. Econ J 101 (407):920–937

Nordhaus WD (2011) Estimates of the social cost of carbon: background and results from the RICE-2011 model. National bureau of economic research working paper 17540

Pindyck RS (2013) Climate change policy: what do the models tell us? J Econ Lit 51(3):860–872

Stern N (2007) The economics of climate change: the Stern review. Cambridge University Press, Cambridge

Tol R (2002a) Estimates of the damage costs of climate change, Part I: Benchmark estimates. Environ Resour Econ 21(1):47–73

Tol R (2002b) Estimates of the damage costs of climate change, Part II: Dynamic estimates. Environ Resour Econ 21(2):135–160

UNFCCC (2010) The Cancun agreements, United Nations framework convention on climate change. http://unfccc.int/meetings/cancun_nov_2010/meeting/6266.php

Watkiss P (ed) (2011) The ClimateCost project. Final report. Volume 1: Europe. Stockholm Environment Institute, Sweden

WMO (1979) Declaration of the world climate conference. World Meteorological Organization, Geneva

World Bank (2013) Turn down the heat: climate extremes, regional impacts, and the case for resilience. A report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics. World Bank, Washington, DC

Part I
Cost and Opportunities of Climate Change at the European Level

Chapter 2
The Cost of Climate Change in Europe

Paul Watkiss

Abstract Climate change has the potential to lead to major impacts and economic costs in Europe. This chapter reports on a recent regional assessment—the ClimateCost project—which has combined sectoral assessments and wider economic analysis to derive such estimates.

The results reveal potentially high economic costs from climate change in Europe, though these vary with the emission scenario and time period. While many of these impacts are projected to be adverse and lead to economic costs, there are also economic benefits. The results also show large differences in the patterns of impacts across Europe, with more negative impacts in South-Eastern Europe and the Mediterranean, due to a combination of the enhanced climate signal and the higher vulnerability in these regions. The analysis of different scenarios shows that mitigation (towards a 2 °C stabilisation scenario) would reduce these costs significantly, but only in the medium-long term (after 2040). There will therefore be a need for adaptation as well as mitigation, but given the high future uncertainty, this is likely to be best advanced through a framework of adaptive management.

While this European-wide view is important, the chapter also shows there is a need for country level analysis—as presented in this book—to capture national context and insights, to allow analysis of country specific risks, and to provide national-level information to start planning for adaptation.

The research leading to the results reported in this paper received funding from the European Community's Seventh Framework Programme, as part of the ClimateCost Project (Full Costs of Climate Change, Grant Agreement 212774) www.climatecost.eu. Additional support for the paper was provided by funding from the European Union Seventh Framework Programme (FP7/2007–2013) IMPACT2C Project: Quantifying projected impacts under 2 °C warming, grant agreement no. 282746.

P. Watkiss (✉)
Paul Watkiss Associates, Oxford, UK
e-mail: paul_watkiss@btinternet.com

K.W. Steininger et al. (eds.), *Economic Evaluation of Climate Change Impacts*,
Springer Climate, DOI 10.1007/978-3-319-12457-5_2

2.1 Introduction

There are a wide range of potential impacts from climate change in Europe. These include impacts on the built and the natural environment, which affect many sectors. These impacts will lead to economic costs, which are often referred to as the 'costs of inaction' (the economic costs of climate change if no mitigation or adaptation takes place). These costs include all effects on society, i.e. both market and non-market impacts, and environmental, economic and social costs, rather than direct financial costs or losses alone. Many of these costs are projected to be adverse, though there will also be benefits.

The estimation of these costs is increasingly being used to provide policy input. By reporting future impacts in monetary terms, these assessments provide a common metric to compare impacts over time and across sectors. They also help to inform the debate on the costs and benefits of mitigation (i.e. the reduction of greenhouse gases emissions) and increasingly, the major risks and the prioritisation of adaptation. This information is potentially relevant at a number of different aggregation levels, addressing different objectives. It can provide input at the European level, where information on the economic costs of climate change can raise awareness on the scale of the challenge, and provide context and justification for European mitigation policy, as in the European Road Map for a low carbon economy (CEC 2011). It can also provide the economic case for adaptation, as in the EU Strategy on Adaptation (CEC 2013), with the analysis of the costs of inaction and economic benefits of adaptation.

These European estimates are the focus of this chapter. They provide important contextual information and insights, but similar analysis is also needed at the national level, as shown in Chap. 3 (Risk and Opportunity). This is because a national level assessment—as presented in this book—can analyse national risks in more detail. It can capture important local impacts that may be excluded in a European-wide assessment (e.g. impacts on Alpine regions). Finally, it can better align to national context and policies, and inform adaptation strategies, the development of which is primarily governed at the national level.

2.2 Methodological Approaches and Frameworks

Over the last few years, a wide range of methodologies have emerged for assessing the costs of climate change. These are well documented (e.g. UNFCCC 2009; Chambwera et al. 2014) and include 'bottom-up' assessments at local to sector level, as well as 'top-down' macro-economic or global assessments. The main methods are (Watkiss and Hunt 2010):

- Scenario-Based Impact-Assessment. This approach combines climate model outputs with sector impact models (or functional relationships) to estimate physical impacts, which are then valued to estimate welfare costs. These can be applied to market and non-market (e.g. health) sectors, at the European scale (e.g. Ciscar et al. 2011a, Watkiss 2012) or country level (e.g. UK CCRA 2012). However, these assessments are not able to capture cross-sectoral, economy-wide effects. There are a number of variations, including risk assessment, which focuses on extreme (probabilistic) events such as flood (using historical analogues or damage-loss relationships), and econometric based assessments, which use historical relationships between economic production and climate and then apply these to future climate scenarios.

- Computable General Equilibrium models (CGE). These provide multi-sectoral and macro-economic analysis of the economic costs of climate change. Examples include European analysis (e.g. Ciscar et al. 2011a) and national level analysis (e.g. SCCV 2007). These have the advantage of capturing cross-sectoral linkages and economy wide effects (and metrics), and they can also look at price and trade effects. However, they use aggregated representations of impacts and omit non-market impacts.
- Global economic integrated assessment models. These assess the economic costs of climate change using an integrated framework. They can be used to provide total net present values for future damages over time and to estimate the marginal social costs (the damage cost of an extra tonne of GHG emissions). These models provide valuable headline estimates, but they use highly aggregated functions, see Watkiss (2011).

These three approaches use different metrics, modelling approaches and assumptions. No one method is right or wrong—their use depends on objectives. More recently, some studies combine all approaches in a single framework, to produce complementary information. An example of such an analysis is presented in this chapter, summarising results on the economic costs of Europe from the European Commission FP7 Funded ClimateCost Project.

The study started with scenario-based sectoral impact assessment modelling. The results of this analysis were then fed into a number of CGE models to assess wider economic effects. Complementing this, the study ran a number of IAMs, assessing the effects on Europe as part of a global integrated assessment. The overall approach follows the stylised Fig. 2.1.

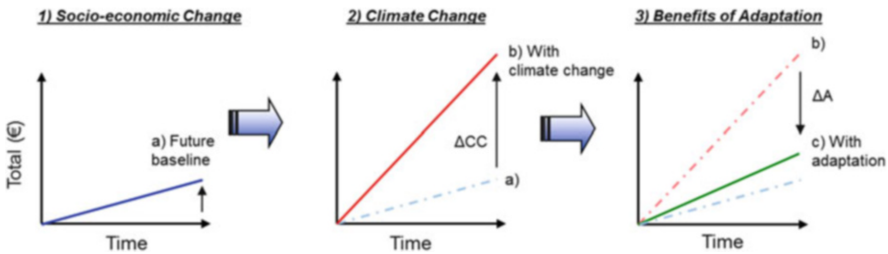

Fig. 2.1 Outline and steps of a stylised framework. *Source*: UNFCCC (2009)

1. The economic costs are first estimated for the future baseline, shown in (a). This is needed because future impacts are strongly influenced by socio-economic change, e.g. population growth, increased wealth, and these will occur even in the absence of climate change. Previous studies show that socio-economic change can be as important as climate change in determining economic costs.
2. The additional impact of climate change is added (ΔCC) to give the total effects of socio-economic change and climate change together, shown in (b). Strictly speaking, only the marginal (or net) increase above the baseline in (1) is due to climate change. Note that in some cases, socio-economic and/or climate change may lead to economic benefits, as well as costs.
3. Adaptation reduces the impacts downwards, shown in (c) as the residual costs. The reduction (ΔA) provides the economic benefits of adaptation and this can be compared against the costs of adaptation and the residual impacts after adaptation.

The aim is to express the impacts in terms of the effects on social welfare, as measured by individuals' preferences using a monetary metric. The basic approach to the costing analysis in such a framework is to multiply relevant unit values (market prices or non-market prices) by the physical impacts identified. While most studies primarily used market and non-market estimates of Willingness to Pay (WTP), in some cases cost-based estimates have been used as a proxy.

It is highlighted that the analysis below presents the results of one study only. There is a growing literature on European, regional, country and sector assessments, as reported in IPCC AR5 Europe Chapter (Kovats et al. 2014), though costing remains primarily focused on flood defences, water, energy, and agriculture sectors.

2.3 The Costs of Climate Change in Europe: Results for a European Assessment

2.3.1 Climate Model Projections

Analysis of the future impacts of climate change requires climate models. These require inputs of future GHGs based on modelled global socio-economic scenarios, in order to make projections of future changes in temperature, precipitation and other variables. The ClimateCost project considered two emissions scenarios: a medium-high baseline scenario (A1B SRES, Nakicenovic et al. 2000) and a mitigation scenario (E1, from the ENSEMBLES project, Van der Linden and Mitchell 2009), which stabilises global temperature change at about 2 °C above pre-industrial levels, using multi-model ensemble data from the ENSEMBLES project. Under a medium-high emission baseline (A1B), with no mitigation, the climate models projected that global average temperatures could rise by between 1.6 and 2.3 °C by 2041–2070, and 2.4 and 3.4 °C by 2071–2100, relative to the

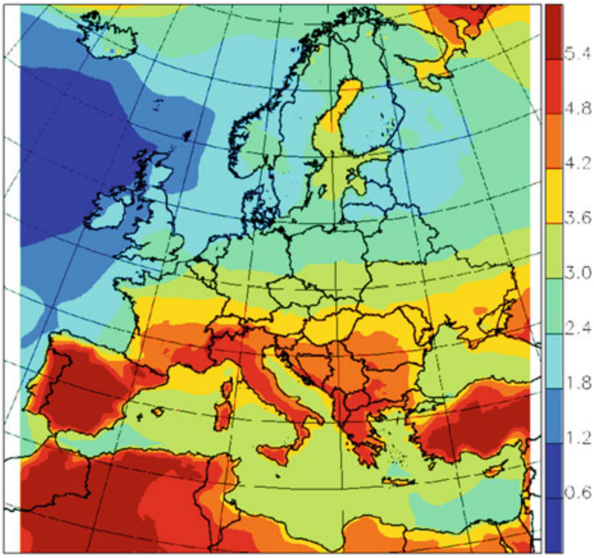

Fig. 2.2 Summer temperature change for Europe from a Regional Climate Model (1960–1999 to 2070–2099, A1B), showing the higher warming in Southern Europe. *Source*: Christensen et al. (2011)

modelled baseline period of 1961–1990. However, the models project larger temperature increases for Europe in summer. They also show a highly differentiated pattern, as shown in Fig. 2.2. Southern Europe and the Iberian Peninsula are projected to experience much higher levels of warming than the global average, with a mean increase for the latter up to 5 °C by 2071–2100. This differentiated signal is important in impacts across Europe. Under the E1 stabilisation (mitigation) scenario, future warming is significantly reduced, though only after 2040.

The projections of future precipitation change show much greater differences across scenarios, models and regions of Europe. These can be seen in Fig. 2.3. This shows the change in summer precipitation across different time periods (top), different scenarios (middle) and different climate models (bottom). There are some robust patterns of change, e.g. wetter winters are projected for Western and Northern areas but drier conditions projected all year for the South. However, in other areas (notably a band from the UK in the west across to Eastern Europe) the changes are uncertain, and the driest (left, bottom) and wettest (right, bottom) results even differ in sign (i.e. decreases vs. increases). The consideration of this uncertainty is important in analysing and reporting on future impacts, and in the subsequent analysis of adaptation.

2.3.2 Sector Results

The climate projections were input into sector impact assessment models. The results are summarised below, with economic costs in future periods reported in current prices to facilitate direct comparison over time.