1. Introduction

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Global warming is believed to be one of the most serious environmental problems for current and future generations. This shared belief led more than 180 countries to sign the Framework Convention on Climate Change in Rio de Janeiro in 1992, which declares that serious action should be taken to reduce man-made greenhouse gas emissions. To this end, the Kyoto Protocol was signed in 1997 by 38 countries which agreed to reduce their greenhouse gas emissions by an average of 5.2 per cent compared to 1990 emission levels by the target period 2008–2012. The 38 countries comprise mainly industrialized countries, including the US, all countries of the European Union and some other European countries like Norway and Switzerland, Australia, New Zealand, Canada and Japan; and a few countries in transition to a market economy such as Russia and Ukraine. Since its signature, the Protocol has been widely celebrated as a major step towards mitigating global warming. In particular, economists were in favor of the Protocol, since it constitutes the first international environmental agreement which seeks to achieve environmental targets using market-based instruments. However, four years after the signature of the Kyoto Protocol, euphoria has turned into great disappointment. Despite many negotiation rounds, the parties still could not agree on the final details of the design of the Kyoto Protocol, and hence it has not been ratified by any of those countries which committed themselves to binding abatement targets and it is therefore not yet in force. Even worse, most countries' emissions have increased over the last few years and after taking office, President Bush declared that the US would withdraw from the Protocol.

Not surprisingly, this ecologically important and highly debated political issue has also initiated a great amount of research on the problem of 'Controlling Global Warming'. In this book, three perspectives of economic research on this topic are presented: game theory (Chapter 2), cost-effectiveness analysis (Chapter 3) and public choice (Chapters 4, 5 and 6).

GAME THEORY

Global emissions exhibit a negative externality not only in the country of origin but also in other countries. Hence, there is a high interdependence between countries, and strategic considerations are important. Game theory analyzes the interaction between agents, formulates hypotheses about their behavior and predicts the final outcome of the interaction. Therefore, this method has been widely used to analyze global environmental problems. Important questions which have been analyzed with game theory are for instance: Under which conditions will an agreement be signed and ratified? On which reduction targets will the signatories agree? How many and which countries will participate in an agreement? Will the treaty be stable? Which measures are suitable for stabilizing an agreement?

The game theoretical literature has provided many insights into these questions in recent years. Many results have been obtained which help to explain the difficulties of establishing effective and efficient cooperation. However, game-theoretical approaches have also been criticized for ignoring too many practical problems and for being based on very specific assumptions. It has been argued that important aspects of international pollution problems have been neglected and that results were not general and were therefore ill-suited for policy analyses and recommendations. Chapter 2 tries to qualify this critique by laying out fundamental assumptions and important results and by pointing out those aspects which have to be considered in future research. It proceeds in four steps: (1) The fundamental assumptions underlying the analysis of global pollution problems are laid out. The need for cooperation and the problems of cooperation are defined (Section 2). (2) Two frameworks which have been used frequently to analyze global environmental problems, are described (Section 3). (3) Important findings, which help to explain the difficulties of cooperation, and measures to establish cooperation are discussed. Section 4 looks at measures for avoiding asymmetric welfare distributions and for enforcing an international environmental agreement (IEA). Section 5 discusses the properties of different policy instruments and their implications for the success of an environmental treaty, and Section 6 summarizes the results on the formation of coalitions. (4) The model frameworks outlined in Section 3 and the results and conclusions of Sections 4, 5 and 6 are critically reviewed. On the one hand, open theoretical questions are described. On the other hand, practical problems which are not captured by theory are mentioned and evaluated as to

their effect on influencing policy recommendations. The theoretical results and the derived conclusions of Sections 4 to 6 are applied to the analysis of the Kyoto Protocol (Section 7). It is shown that the theoretical results are helpful in explaining and evaluating this IEA. Section 8 briefly describes open issues for future research.

COST-EFFECTIVENESS-ANALYSIS

Successful climate protection policies require a reconciliation of two fundamental issues: efficiency in terms of overall abatement costs, and equity in terms of the distribution of these costs across countries. Though these issues are also relevant in other fields of international environmental policy, given the magnitude of abatement costs at stake, their importance in the context of greenhouse gases is unique. Considering that the benefits of mitigating global warming are uncertain and will accrue only in the long run, abatement policies aiming at achieving climate protection will be more acceptable to current society the cheaper, i.e., the more cost-efficient, they are. A high participation in an environmental agreement with ambitious abatement targets is only possible if the parties perceive the burden sharing rule to be fair. Whereas economics has little to say on equity *per se*, the description of economic effects across different agents due to policy interference is a prerequisite for any equity debate.

For rational policy making, both issues – the magnitude as well as the distribution of costs – require quantitative assessment. The main challenge of economic modeling is to capture the key factors and their impact on the agents involved. Since modeling of larger socio-economic systems is a very complex undertaking, simplifying assumptions on system boundaries and system relationships are needed. However, these assumptions crucially determine the sign and magnitude of quantitative results and therefore drive policy conclusions to a large extent. Therefore, it is not surprising that when studying the large amount of empirical literature on the economic impacts of various greenhouse abatement strategies, one may get the impression that results and conclusions are not very reliable. In particular, due to the high complexity of most empirical models and the limited amount of space in scientific journals, the underlying assumptions of different models are sometimes not very transparent to the reader and are difficult to evaluate. In fact, some critiques argue that basically any policy recommendations can be derived if the assumptions are chosen accordingly.

This contribution tries to qualify this critique by laying out the fundamental factors and the crucial assumptions of empirical models and by conducting various sensitivity analyses. It is shown that empirical models can be a very powerful tool for policy recommendations if assumptions and results are carefully related to each other. The chapter proceeds in four steps: (1) After a short introduction to the topic, Section 2 describes methodological issues in the modeling of climate change policies. Important results of the literature are critically reviewed and evaluated as to their impact on the results. The objective is to create an understanding of key determinants which drive results. Topics which are covered include baseline scenarios (projections and market imperfections), system boundaries (bottom-up versus top-down approaches, international spillovers), technological change and burden sharing rules. (2) In Section 3 a generic computable general equilibrium model is outlined. All components of this model are described, comprising production, households, foreign trade, carbon emissions and market clearing conditions as well as the data and calibration procedure. (3) Based on the model and calibration of Section 3, an assessment of greenhouse gases abatement is conducted in Section 4. For the abatement targets of the Kyoto Protocol, several policy scenarios and sensitivity analyses are computed and evaluated. Policy scenarios include (a) no trading of emission permits, (b) only trading among Annex B countries of the Protocol, (c) globally unrestricted trading and (d) no trading assuming that the US follows a business-as-usual emission path. The last scenario takes into account the decision of President Bush (March 2001) to withdraw from the Kyoto Protocol. Sensitivity analyses include the impact of (a) transaction costs from trading, (b) higher baseline emissions resulting from higher economic growth, (c) different substitution elasticities between imports and exports, (d) different supply elasticities for oil supply and (e) different ways of revenue recycling of the receipts from implementing environmental policies. (4) Results are summarized and a final evaluation and interpretation is presented.

PUBLIC CHOICE

The bulk of the politico-economic literature of environmental policy has mainly focused on national environmental problems, though some of the most recent literature has also made an attempt to analyze global environmental problems. In contrast to classical environmental economics, which assumes that politicians (should) pursue the goal of increasing the welfare of its

citizens, the politico-economic literature assumes that politicians strive to enhance their prestige, increasing their chance of being re-elected and maximizing their available budget. Thus, public choice approaches are particularly useful in explaining the divergence between policy recommendations and their implementation (*ex-post*), and anticipating the political acceptability of policy recommendations (*ex-ante*). Important questions which have been addressed by the public choice literature are for instance: Why is the level of environmental protections frequently lower than would be advisable from a cost-benefit perspective? Why are command and control instruments the predominant instrument in environmental policy though economists favor market-based instruments on efficiency grounds?

Whereas Chapter 4 determines the level of global emission reductions in a politico-economic framework, Chapters 5 and 6 derive the equilibrium choice of the policy instrument.

Chapter 4 proceeds in three steps: (1) It starts out with a theoretical analysis. It compares the cooperative and non-cooperative equilibrium if governments behave as welfare maximizers in climate negotiations – which is the underlying assumption of the game-theoretical analysis – with the political equilibrium in a median voter model. It is shown that the commonly-held conjecture is wrong that capturing the political dimension of global environmental policy would lead to more positive predictions with respect to the prospects of a cooperative abatement policy compared to the standard game-theoretical analysis. In fact, whether the level of environmental protection will be higher or lower in a public choice setting than in a game-theoretical setting depends on the ‘green preferences’ of the pivotal voter. (2) Subsequently, studies estimating the public demand for mitigating greenhouse gases emissions are discussed. A distinction is made between contingent valuation studies and public opinion polls. Both approaches are evaluated with respect to their conceptual properties. It is argued that results very much depend on the design of the study and that current studies allow only for cautious conclusions since they suffer from many shortcomings. Given this qualification, there seems to be evidence that there is a gap between people’s concern that action should be taken to combat global warming and their willingness to pay. The more the questions are specifically related to actual payment and sacrifices of economic wealth by people in order to reduce greenhouse gases, the lower is their stated willingness to pay for ambitious abatement policies. People are much in favor of their governments taking serious action to control global warming, but their average willingness to pay

for this is very low. (3) Results of empirical studies are used to interpret the position of different countries in negotiations on various international environmental agreements and the outcome of these negotiations. It is shown that the empirical results are helpful in explaining the different stakes and roles of various countries within the negotiations of the Montreal Protocol, the Framework Convention of Climate Change and the Kyoto Protocol. However, it is also argued that much more empirical research is needed to draw sound policy conclusions.

Chapter 5 discusses the choice of environmental policy instruments on the basis of an interest group approach. It surveys a large amount of literature on this topic, which also serves as a basis for Chapter 6, where the public choice approach is used to analyze the design of a permit regime under the Kyoto Protocol. Chapter 5 proceeds in five steps: (1) After a short introduction to the problem, different policy instruments are systematically described in Section 2. (2) In Section 3 the main actors in the political arena are identified, including politicians, the environmental bureaucracy, industry (owners, managers, labor unions), environmental organizations and consumers. (3) For these actors, different hypotheses about possible arguments in their objective functions are presented in Section 4. It appears that there are many and very different hypotheses around what guides the behavior of agents. (4) In Section 5, preferences of different interest groups are derived for different policy instruments based on the hypotheses of Section 4. Moreover, empirical evidence is presented to test the theoretical conclusions. It is shown that a public choice approach helps to explain why the recommendations of economists to use market-based instead of command and control instruments in environmental policy have not fallen on very fertile ground. (5) A final assessment of assumptions and conclusions is provided in Section 6.

Chapter 6 analyzes the controversy among the signatories of the Kyoto Protocol about how a permit trading system should be designed. For three different permit trading schemes, a welfare economic as well as a politico-economic evaluation is conducted. The aim of this chapter is to predict what kind of permit trading system will finally emerge within the political system (given that permit trading systems are implemented and that the Kyoto Protocol is ratified) and whether this differs from the best choice from an economist's point of view. The first scheme considered only allows for the trade of permits between governments. Governments must implement some national policy in order to match their country's emissions and the number of permits they hold. The second scheme allows permit trading among private

entities at the national and international level. The third scheme differs only slightly from the second in that not permits but credits are traded. Thus, private entities are not regulated via permits but via other instruments. Emissions reduction must be certified by some agency and can then be sold to other domestic and foreign private entities. Thus, under the first and the third scheme, governments have some leeway for choosing some instrument at the national level. Consequently, the permit trading schemes may be seen as a two-level game at the national and an international level. For the national level, instrumental preferences of different interest groups as derived in Chapter 5 are used.

The chapter proceeds in four steps: (1) After a short description of the problem, the three trading schemes are laid out in Section 2. This section provides a first judgment on the three schemes according to economic and political criteria. Specific points related to the politico-economic analysis are treated in Section 3. (2) In Section 4, the preferences of various interest groups are derived from a theoretical perspective, considering the national and international level of implementation. It turns out from the theoretical analysis that most interest groups prefer a combination of credit trading and government trading and some form of direct regulation of the command and control type at the national level, though for very different reasons. In contrast, from a welfare economic perspective, the trading scheme among private entities would be first choice. (3) In Section 5, interest group preferences are investigated empirically based on a survey of press releases on the Internet. Given the lack of empirical data, this procedure must be judged as an important first step in order to test the theoretical conclusions of Section 4. The survey covers a large number of different organizations across different countries and basically confirms the theoretical conclusion.

SUMMARY AND CONCLUDING REMARKS

In the last chapter of this book, the most important results of the previous chapters are summarized. Each method is evaluated with respect to its weaknesses and strengths. Particular emphasis is given to outlining a research agenda for the future on how the three methods can be combined, in order to have a powerful tool for the analysis of global pollution problems.

AIM AND SCOPE OF THE BOOK

This book provides the newest insights into the economic research on global warming from three perspectives: game theory, cost-effectiveness analysis and public choice. The aim is to provide the reader with an overview of each method, demonstrating the advantages and disadvantages of each method in a rigorous though easily accessible manner. The chapters survey a large amount of literature and provide many applications.

All chapters stress very much the thinking behind all arguments and results, though Chapters 2, 3 and 4 use some mathematics. However, this should pose no problem for those readers who are less technically oriented. In Chapter 2 on game theory and its application, all important findings and conclusions are compactly summarized in each section and therefore the line of arguments can easily be followed by skipping over the technical details. In Chapter 3 on cost-effectiveness analysis, only Section 3 uses some mathematics when laying out the technical details of the general computable equilibrium model used in the subsequent sections for the simulations. Again, the technically less interested reader may either just skip Section 3 and proceed directly to subsequent sections or just follow the arguments in Section 3 and ignore the formulae. In Chapter 4 on the politico-economic analysis of the level of abatement in global pollution control, only in Section 2, in which the political equilibrium is compared to the welfare economic equilibrium, is some mathematics used, though the basic line of argument can easily be followed by ignoring the mathematics. In any case, subsequent sections in Chapter 4 are more or less self-contained and can also be understood without Section 2.

Overall, this book should be accessible and interesting to anybody working and studying in the field of global environmental problems with an economics or political science background, ranging from undergraduate and graduate students to scholars working in international organizations, the public sector or academia. For anybody interested in a compact and up-to-date survey on the economic, game-theoretical and politico-economic analysis of global warming, this is the book.