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COST-BENEFIT ANALYSIS OF CLIMATE CHANGE

A METHODOLOGICAL OVERVIEW OF RECENT STUDIES

This paper examines the methodological aspect of climate change, particularly the aggregation of costs and benefits induced by climate change on individuals, societies, economies and on the whole ecosystem. Assessing the total and/or marginal costs of environmental change is difficult because of wide range of factors that have to be involved. The subsequent study tries to capture the complexity of cost assessment on climate change therefore includes several critical factors such as scenarios and modeling, valuation and estimation, equity and discounting.

KEYWORDS: ECONOMICS OF CLIMATE CHANGE, METHODOLOGY, COST-BENEFIT ANALYSIS

JEL B41, C18, Q51, Q54

1. INTRODUCTION

Global warming[1] has already begun. Climate change has become a self-propelling and self-reinforcing process as a result of the externality associated with greenhouse-gas (GHG) emissions. Although it is an externality related to humankind, according to a number of unique features we should distinguish it from other externalities. Climate change is a global phenomenon in its causes and consequences. The long-term and persistent impacts of climate change will likely continue over centuries without further anthropogenic mechanism. The preindustrial (equilibrium) level of GHG concentration in the atmosphere cannot be restored since it is irreversible, but if we do not stabilize the actual level of atmospheric concentration, the situation will become much worse than it is now. Assessing the impacts of climate change requires careful considerations because of the pervasive uncertainties and risks associated with it.

Climate change threatens the most fundamental elements of life for people and makes no difference between people wherever they live from Asia to Northern America. Each individual and each economy both developed and developing are affected by the impacts of global warming. On current trends, average global temperatures could rise by 2–3 °C within the next fifty years as compared to preindustrial level average global temperatures. This phenomenon leads to a constrained

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1 In this paper 'global warming' and 'climate change' are used as interchangeable terms.

access to water, food, health and use of land and environment and this phenomenon intensifies extreme events mediated by water and wind, including droughts and floods, hurricanes, tornadoes, typhoons and blizzards. According to Stern et al. [2006] the most frequent results anticipated are the following: increase in average global temperatures, rising sea levels, melting or collapse of ice sheets, declining crop yields, melting glaciers, ocean acidification, increasing number of deaths from malnutrition and heat stress, increasing migration pressure due to extreme environmental events, extinction of species in the ecosystem and sudden shifts in regional weather patterns.

With rising temperatures, impacts in many sectors will become disproportionately more serious. Examining the relationship between the impacts of climate change and increasing global temperature, Hitz and Smith [2004] found that impacts for several climate-sensitive sectors were linear or exponential, even though they were unable to accurately determine the shape of the real functional relationship. Agricultural production, for example is depicted as an inverse parabolic function: a low level of warming may improve conditions for agricultural production in cooler regions, but further warming will have harmful effects principally in tropical (warmer) regions. All climate-sensitive sectors have their own functional form.[2]

People, through consumption and production, emit GHGs. As a consequence of emission, GHGs accumulate in the atmosphere where they trap heat and effect global warming. The related policy challenge is twofold. The first is to minimize the costs of adaptation, mitigation and that of the residual climate change damage. The second challenge is to distribute the related intertemporal and intratemporal burdens and gains in an equitable way. To carry out an economic analysis a reference point or a baseline is needed which allows us to fulfill the cost-benefit analysis of adaptation and mitigation. The reference point used in the literature on climate change is a hypothetical future no-policy scenario. Recently another term, the "cost of inaction" has become popular amongst scholars.

Total damage costs represent the sum of adaptation costs and residual damages. It is usually expressed in per cent of GDP. The marginal cost of climate change damage, sometimes referred to as the Social Costs of Carbon (SCC), is expressed in emission of metric tons of carbon dioxide (tCO_2). It is difficult to implement an appropriate assessment measure because both the total and marginal damage costs of environment change are characterized by large scale uncertainty and risks that have a hindering effect on the analysis, especially in connection with extreme events and low-probability high-impact scenarios. The physical impacts need to be assessed in monetary terms involving market and non-market goods and services, covering health, economical, environmental and social values. On one hand, it is generally accepted that some kind of equity manner is inevitable between generations as the notion of "sustainable development" suggests. On the other hand, it is also generally accepted that advanced countries are responsible for the bigger part of CO_2 emission still are less vulnerable to the effects thereof, while developing

2 See The Stern Review page 71–72 for more information on proposed functional form.

countries are less responsible for CO_2 emission but more vulnerable to the effects of them.[3] If we would like to cope with the complexity of the cost and benefit assessment of climate change, we have to take into consideration a number of crucial dimensions from market and non-market valuation, through uncertainty and risks, to equity and discounting.

In this paper we would like to provide a summary of recent studies on cost-benefit analysis of climate change. Reviewing the significant relating literature we would like to address the essential factors that have to be included in a comprehensive economic analysis and also address the neglected considerations. In the next chapter we briefly demonstrate what were and what are the typical studies and we differentiate the literature by impacts, geographical area and attempts to assess total and/or marginal damage costs. Then we turn to methodological aspects representing scenarios and modeling of climate change studies. Section 4 discusses the valuation and estimation approaches and then section 5 shows the landmarks of intertemporal and spatial aggregation. Section 6 deals with factors often ruled out of researches and section 7 concludes.

According to our interpretation, methodology and probability (probabilities and considerations for the future, scenarios, equity manners and discounting methods, aggregation over distant times and transformation into present value) are inseparable during the examination of climate change.

2. OVERVIEW OF RECENT STUDIES ON COST-BENEFIT ANALYSIS OF CLIMATE CHANGE

Prior to the 1990s, scientific research in the field of global warming was limited to natural scientist.[4] More than twenty years have passed, and the majority of research still comes from natural scientist, despite the fact that social and economic consequences become more and more important. So we can say that the number of social and economic studies is limited. After an overlook on the given literature we conclude that there are few complex and comprehensive studies in the field of the possible impacts induced by climate change. Most studies either only apply to a specific sector – e. g. agriculture – or to a limited geographical area – the United States or the European Union. Furthermore, when taking into account the possible impacts, most studies only deal with total or marginal damage costs. Tol [2005] only counted 22 new studies in the 1990s and then Tol [2008] repeated his summary and increased the numbers of new studies to 47 until 2006.

It is difficult to provide a comprehensive synthesis of this field of research. First of all a reference point should be defined but the no policy choice in itself entails

3 At the same time, the level of GHG emission by emerging or BRIC countries is growing rapidly, while in numerous advanced countries GHG emission is constrained by institutional authorities (e.g. in the case of the European Union (EU)).

4 The first international negotiations related to climate change took place in 1985. The Intergovernmental Panel on Climate Change was established in 1988 by the World Meteorological Organization and the United Nations Environment Programme.

a contradiction because of its complexity and of the numerous different ways it can be interpreted. Our objective is to give a summary of methodological consideration by assumptions, choices and methods. Different studies and different methods used in studies make very hard to implement a summary of a very wide range of estimates.

3. METHODOLOGICAL ASPECTS – SCENARIOS AND MODELING

3.1. SCENARIOS

The International Panel on Climate Change (IPCC) makes a distinction between climate scenarios and non-climate scenarios. Kuik et al. [2008] make a short presentation of climate scenarios, addressing factors like static or dynamic modeling, spatial aggregation and weights. Climate scenarios differ from each other in that there are models that compare two equilibrium states of the climate and there are models that dynamically follow changes in climate variables. Spatial aggregation is also a crucial issue as working with a simple statistical mean for the global change in temperature may lead to a bias. In climate scenarios extreme weather events and low probability high impact events are emphasized more as they get higher weights.

Table 1. Four different storylines exerted by IPCC

Economic emphasis →

Global integration ↑ | Regional emphasis ↓

A1 storyline World: market-oriented Economy: fastest per capita growth Population: 2050 peak, then decline Governance: strong regional interactions; income convergence Technology: three scenario groups: • **A1FI**: fossil intensive • **A1T**: non-fossil energy sources • **A1B**: balanced across all sources	**A2 storyline** World: differentiated Economy: regionally oriented; lowest per capita growth Population: continuously increasing Governance: self-reliance with preservation of local identities Technology: slowest and most fragmented development
B1 storyline World: convergent Economy: service and information based; lower growth than A1 Population: same as A1 Governance: global solutions to economic, social and environmental sustainability Technology: clean and resource-efficient	**B2 storyline** World: local solutions Economy: intermediate growth Population: continuously increasing at lower rate than A2 Governance: local and regional solutions to environmental protection and social equity Technology: more rapid than A2; less rapid, more diverse than A1/B1

← Environmental emphasis

Source: IPCC [2007]

The IPCC [2007] makes a distinction between four essential socio-economical climate scenarios. A1 storyline (market-oriented) is characterized by a low population growth that peaks at 2050 then declines, and a high GDP growth. Strong regional interactions make a high degree of convergence possible between rich and poor countries. Three different scenario groups can be discriminated: fossil-intensive, non-fossil and balanced. A2 storyline (differentiated) is described by a high population growth and a modest GDP growth. Regional and local governance and self-reliance rule this scenario so the lack of equalization in terms of GDP and the continuing fragmentation of technology determine this future scenario.

B2 storyline (local solutions) disposes with intermediate population and GDP growth. The pattern of environmental protection appears while regional and local authorities still play an important role. This initial environmentalism couples with more rapid technology development (though slower than in A1/B1). B1 storyline (convergent) is characterized by a low population growth but a high GDP growth. A services and information based economy allows firm convergence between poor and rich countries and eventuates clean and resource-efficient technology. Table 1 depicts the four socio-economic scenarios.

These four socio-economic scenarios determine the quantity of emissions. Emission levels in A1 storyline depend on the choice of technology. It is not hard to see that the fossil-intensive technology emit the most CO_2. A2 is characterized by medium high, B1 by low and B2 by medium low emissions. If we take a short look at Table 1 movement from one scenario to another corresponds to no other than a choice between emphases. Environment, integration, economy or regionalism should be considered the main factors and choosing an emphasis means that we completely neglect another and we can partially include the remaining two emphases.

3.2. MODELING

Non-climate scenarios are important because they determine the vulnerability of social and economic systems to climate change over time. They are capable of determining the development of global greenhouse gas emissions by designing a range of emissions scenarios. Simple models use climate change variables (e.g., sea level rise, mean temperature etc.) at a point in time and independent variables like present population and economy to assess the estimation studies on the damage cost of carbon. More advanced studies make a distinction between studies that use exogenous scenarios and studies that employ Integrated Assessment Models (IAM) to establish scenario values. Kuik et al. [2008] argue that recent studies lack the use of dynamic IAMs therefore complex analysis of the long-term and dynamic modeling climate change are highly needed to create better estimations and valuations.

Even though fully dynamic models are scarce, a few had also been developed in the early phase of climate change research before they became popular amongst specialists, at the beginning of the 1990s. Hope and Maul [1996] compared two very different approaches, the PAGE and Intera models. Both these models treat uncertainty but from a different view. In order to calculate marginal costs for CO_2, the Intera approach takes into consideration small perturbations to the global system. The reason for calculating the costs for CO_2 discharges is twofold: first, modeling the environmental effects of discharges and second, estimating the impacts of the resulting environmental change. To address the environmental impact they use simple linear models derived from Nordhaus [1991]. Four key parameters are represented in the model:

1. the fraction of CO_2 which is rapidly removed from the atmosphere;
2. the long-term rate of removal of CO_2 from the atmosphere;
3. the rise of global mean equilibrium temperature due to a given increase in atmospheric CO_2, levels;
4. a constant rate for global mean temperature changes in response to changes in atmospheric CO_2 levels.

Assumptions on impact costs are consistent with the convention employed in the United Kingdom nuclear industry for the calculation of long-term liability. They use this approach in order to give an acceptable and plausible comparison between fossil and nuclear power. The four most important assumptions of the approach are as follows:

1. Any international cooperation required to adapt to global warming will take place, therefore major social upheavals are not considered.
2. The cost to the polluter should not vary according to where the damage occurs. In particular, the value of a statistical life (VOSL) is taken to be the same, no matter where the risk of death is incurred.
3. The discount rate employed is 2% per year.
4. No consideration is given to economic growth.

The Intera analysis takes into account both economic and non-economic impacts. Economic impacts can easily be monetized as losses are counted in GDP. At the same time non-economic impacts do not appear in GDP measures. It is very hard to monetize certain parts of the ecosystem or to give accurate estimate to a value of statistical life. Hope and Maul [1996] calculated US$24 per tC as a reference discounted cost.[5]

The "PAGE" abbreviation stands for policy analysis of the greenhouse effect. The PAGE model was developed in 1991 to provide an integrated assessment of global warming policies. It calculates the costs of implemented policies and the impacts of any global warming process. Hope et al. [1993] describe the model in detailed version and Hope and Maul [1996] briefly depict it. PAGE contains equations that cover:

1. The EU and the whole World. The PAGE model was first developed for the European Union. It was later adjusted for greenhouse effect is a global problem, even if the EU is only responsible for 13% of the emission of CO_2.
2. All major greenhouse gases. CFCs and HCFCs are also included.
3. The impacts of global warming. Ten sectors of the economy are handled as global mean temperature changes
4. The effects of uncertainty.

The PAGE model applies a wide range of inputs. 200 years horizon for calculating impacts facilitates allow long time lags in the natural and socio-economic sys-

5 For more details see Hope and Maul (1996) Tables 1 to 3.

tems, while the base year is 1990. The reference point is the business as usual emission path. The model includes economic as well as non-economic impacts. Economic aspects appear and non-economic impacts do not appear in GDP measures. The adaptation of the developed is endogenous which can reduce the impacts of global warming. The PAGE model operates with an exogenously defined 2% growth rate per year. With the 2% discount rate Hope and Maul [1996] reached a far lower result, namely US$5 per tC for the marginal impacts of CO_2 emission.

The United Nations Framework Convention on Climate Change (UNFCCC) employs a version of PAGE models called PAGE2002, described as follows: "The model calculates regional and global impacts of climate change, and social costs of different greenhouse gases. It also calculates the costs of abatement and adaptation. It is an Integrated Assessment Model starting from emission projections, and carrying uncertainties throughout the calculations" (homepage of the UNFCCC)[6].

The Dynamic Integrated model of Climate and the Economy (DICE) was developed by William Nordhaus. This model aims to "integrate in an end-to-end fashion the economics, carbon cycle, climate science, and impacts in a highly aggregated model that allows a weighing of the costs and benefits of taking steps to slow greenhouse warming" [Nordhaus and Boyer 2000: 5].

Nordhaus [1991] first developed a long-run model of the global economy that involves both the abatement costs of CO_2 emission estimates and long-term climate change impacts. Cost-benefit analyses made by applying both factors allow the determining of the optimal level of control. Then he finalized the DICE model [Nordhaus, 1992], which can be described as a fully dynamic Ramsey-type optimal growth model. From the DICE model emerged an optimal time path of emission reduction and related carbon tax system.

In the DICE model the atmospheric CO_2 concentration has a negative effect on the economic output, influencing the global average temperature. The DICE model is formed by the following factors:

1. Labor and total factor productivity grow exogenously over time.
2. The carbon dioxide intensity of production and the cost of carbon dioxide emissions decrease over time.
3. The output in each period is divided between consumption, investment and expenditure on emission reduction. In each period a fraction of output is lost because of the climate change damage function.
4. The discounted sum of all future utilities from consumption has to be maximised, and utilities are discounted at a fixed pure rate of time preference.

The DICE model, besides being a fully dynamic approach of climate change and optimal CO_2 emission estimates, deals with different sectors of the economy and integrates non-economic categories as well. The potential damages from climate change are divided into seven categories: agriculture, sea level rise, other market sectors, human health, non-market amenity impacts, human settlements and

6 PAGE2002 (Policy Analysis for the Greenhouse Effect) - http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5447.php

ecosystems, and catastrophes. Nordhaus and Yang [1996] establish a modified version of the DICE model in which all global regions are represented. This modified version (RICE - regional integrated model of climate and the economy) distinguishes between the regions therefore makes it easier to determine the possible losers and winners of climate change.

Table 2 below shows the sector-specific results with optimal calibrating of the RICE model when average global temperature elevates by 2.5°C above pre-industrial level. Catastrophes and low-probability high impacts are responsible for more than 50 percent of damages.

Table 2. Damages as a percentage of global output at 2.5°C of warming

	Output weighted	Population weighted
Agriculture	0.13	0.17
Sea level rise	0.32	0.12
Other market sectors	0.05	0.23
Health	0.10	0.56
Non-market amenities	-0.29	-0.03
Human settlements and ecosystems	0.17	0.10
Catastrophes	1.02	1.05
Total	1.50	1.88

Source: Nordhaus and Boyer [2000, pp. 91.]

4. VALUATION AND ESTIMATION APPROACHES

There is a wide range of techniques for the monetary and financial valuation of the impacts of climate change. These techniques are often divided into two main groups: some impact estimates can be directly based on market observations while other impacts cannot be directly measured on market prices. The challenge appears when one would like to find appropriate future market prices for the monetary valuation of direct and especially for that of indirect impacts.

The economic valuation is based on the principles of willingness to pay (WTP) and willingness to accept (WTA) compensation. The majority of recent studies estimate – by definition – "how much we are willing to pay to purchase a better climate for our children and our grandchildren" [Kuik et al. 2008: 23]. However, few studies rather estimate "how much our children and grandchildren are willing to accept" [Kuik et al. 2008: 23]. Current studies use a mix of the above-mentioned valuation methods. There are no studies taking alternative methods into account. Furthermore, Frankhauser et al. [1997] argue that while WTP and WTA values depend on income, they reflect the unfairness of the current income distribution therefore a question of equity emerges. Rich people expect a higher compensation or are willing to pay more for a given change in environment quality, if the substitution between income and environmental services is decreasing with increasing income.

A further problem can be mentioned when a comparison between WTP and WTA is addressed. The two values are often not equal with each other; Brown [2006] insists that the difference between WTP and WTA can be substantial. Li et al. [2005] analyze American citizens' willingness to pay and find that an average American citizen is willing to pay $15/tC.

The economic impacts of climate change can also be divided into direct and indirect impacts. Direct impacts principally deal with the effects of climate change on production and consumption. Indirect impacts handle the indirect effects of changes in production and consumption. Direct cost studies are considered more common and usually ignore indirect costs while their valuation is unsolvable. Only a limited number of studies, mainly related to impacts on agriculture, forestry and fishery have received attention so far. Moreover, the interlinkages between direct and indirect effects of climate change impacts remain unclear. Indirect cost can both enlarge and diminish the direct economic impacts of climate change.

Economy-wide estimates of climate change induced impact on a certain scope are very rare. Bosello et al. [2006] examine the effects of climate change on health through changes in labor productivity and public and private demand for health care. They point out that the impacts of climate change on human health are numerous and complex and global warming would increase heat-related health problems, which would mostly affect people. Their interesting assumption is that cold-related health problems are reduced by global warming, which diminishes direct costs. But on the other hand serious diseases, for instance malaria, in particular, are to increase because of climate change, which increases the direct costs. In another study Bosello et al. [2004] conclude that the rise of sea-level implies large-scale additional costs aggravating coastal zones and increase direct costs of climate change impacts. As a consequence they emphasize that direct costs are underestimated and needed to be adjusted by determining the true costs of impacts.

5. AGGREGATION – TEMPORAL, GEOGRAPHICAL AND THEIR RESULTS

Climate change possesses a very long time horizon. Today's emission will affect climate for decades or even centuries. As we can separate causes and effects, we can separate costs and benefits. If we try to create a commensurable value of costs and benefits at a certain point in time we need to proceed to discounting. Since climate change is a large-scale problem the discount rate has to be transformed into a social discount rate. Discounting implies that events that occur in the far future are less important than those in the near future or at present. As Kuik et el. [2008] summarize, two kinds of discounting processes are used in the literature. The first one is built up by the intertemporal allocation of resources of individuals. The other one is exponential discounting.[7]

7 Discount rate is often called pure rate of time preference

There is no agreement yet in the literature on which discount rate should be chosen. Most of the climate change studies apply different discount rates, usually between 1 to 3 percent. In the Stern Review, Stern et al. [2006] took an extremely low pure rate of time preference – that is why the costs of inaction or costs of business as usual are much higher than in other studies. Discounting is the only process to convert future values to present values, although this method also has some controversies as pointed out by Pearce et al. [2003].

Since climate change is a global problem, most of the impacts of a country's emission have an effect on other countries. Geographical or spatial aggregation is not as common as needed. For the US and EU, a large-scale of studies has been conducted, but for developing countries the same amount of studies are yet to be conducted. Equity weighting is the most common form of aggregation in the literature. Considering an aggregation without equity weighting means that a death in a rich country has greater weight than a death in a poor country. Anthoff et al. [2006] state that equity weighted estimates of the marginal damage costs of carbon dioxide emissions is significantly higher than estimates without equity-weights.

Azar [1999] applies a simple welfare optimization model and he sheds light on how the introduction of weight factors affects the aggregation of cost-benefit analysis of climate change. He concludes that on the one hand the introduction of weight factors significantly reduces rich region's and the global optimal emissions, on the other hand, in a couple of decades the introduction of weight factors will significantly affect the rich region's emission, but the global emission will not decrease. A welfare theoretic approach is used by Tol [2001] where three alternatives are presented. The first alternative is inspired by Kant and Rawls – "do not to others what you do not want them to do to you" [Tol 2001: 72]. The second alternative is based on the assumption that the sum costs of emission reduction is and the costs of climate change should be equal. In the third one a global welfare function includes distaste for inequity.

In the following we would like to provide some useful evaluates in connection with climate change induced costs and likelihoods. *Table 3* represents some essential studies assessing the impacts of climate change. This table shows six different aspects through which we can compare and evaluate recent studies. Sub-Saharan African countries are the most affected negatively by climate change but Eastern Europe, Commonwealth of Independent States and especially Russia may benefit from climate change. Stern et al. [2006] deal with a more pessimistic scenario – 20 percent decrease in the worst-off region and huge 5 percent fall in the best-off region – thus, it is better to take into consideration as an outlier.

The stabilization of CO_2 concentration in the atmosphere at 450 ppm CO_2 equivalent (CO_2e) has a 90 percent probability to cause between 1°C to 3.8°C average temperature change and 10 percent to add other value outside the range. *Figure 1* depicts the CO_2e thresholds with 90 percent probability to happen in a tighter range and 10 percent to happen in a wider range including no temperature rise.

Table 4 demonstrates the likelihood of exceeding a temperature increase at equilibrium. If we choose 550 ppm CO_2e, the likelihood of exceeding 2°C is 99 percent, 69 percent is that of 3°C and 1 percent that of 7°C.

Table 3. Estimates of the Welfare Impact of Climate Change (expressed as an equivalent income gain or loss in percent GDP)

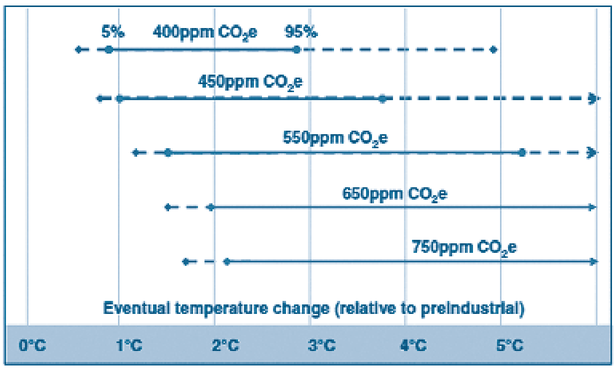
Study	Warming (°C)	Impact (% of GDP)	Worst-off region		Best-off region	
			% of GDP	Name	% of GDP	Name
Frankhauser [1995]	2.5	-1.4	-4.7	China	-0.7	Eastern Europe and CIS
Tol [1995]	2.5	-1.9	-8.7	Africa	-0.3	Eastern Europe and CIS
Nordhaus and Yang [1996]	2.5	-1.7	-2.1	Developing countries	0.9	CIS
Plambeck and Hope [1996]	2.5	2.5	-8.6	Asia (China)	0.0	Eastern Europe and CIS
Mendelsohn et al. [200]	2.5	0.0	-3.6	Africa	4.0	Eastern Europe and CIS
Nordhaus and Boyer [2000]	2.5	-1.5	-3.9	Africa	0.7	Russia
Tol [2002]	1.0	2.3	-4.1	Africa	3.7	Western Europe
Maddison [2003]	2.5	-0.1	-14.6	South-America	2.5	Western Europe
Rehdanz and Maddison [2005]	1.0	-0.4	-23.5	Sub-Saharan Africa	12.9	South Asia
Hope [2006]	2.5	0.9	-2.6	Asia (China)	0.3	Eastern Europe and CIS
Stern et al. [2006]	> 2.5	~ -8.0	-20.0	Africa	-5.0	Eastern Europe and CIS

Source: based on Tol [2009]

Table 4. Likelihood (in percentage) of Exceeding a Temperature Increase at Equilibrium

Stabilization level (in ppm CO_2e)	2°C	3°C	4°C	5°C	6°C	7°C
450	78	18	3	1	0	0
500	96	44	11	3	1	0
550	99	69	24	7	2	1
650	100	94	58	24	9	4
750	100	99	82	47	22	9

Source: Stern et al. [2006]



Source: Stern et al. [2006]

Figure 1. Stabilization and Eventual Change in Temperature

6. OFTEN MISSED FACTORS

Recent papers abound in assumptions stating that the effects on developing countries can be more serious than on developed countries. The field of game theory can present the current situation of climate change regime. For some countries it is worth staying out of global GHGs emission reduction plans because their sovereign nation-state will is more important than to participate in a comprehensive global regime.

Climate change related studies always ask the question how much it costs to prevent climate change, how much are the total or marginal damage costs of emissions. We believe that the latter questions are not the correct ones. One needs to address the question how we can save the most people, how we can prevent climate change in order not to cause human death or how we can ease the effects of climate change on individuals. The cost-oriented question is evident because of politicians' attitudes in decision-making positions, who are interested in minimizing costs but not in maximizing the number of saved people. The companies which are mostly responsible for harmful emissions have too much lobbying power to influence the mitigation and adaptation policy of a country and thus have an adverse effect on GHGs emission reduction. The political economy of climate change is often ruled out of research because it often does not rely on hard facts, but it can address some controversial questions. The political economy approach may determine some useful implications to climate change economics. The syntheses of the two approaches may give a more complex research path.

Climate change is a global problem and therefore a global solution is needed. Neither a single country nor a region alone can give an appropriate response, because one only country is capable of risking the whole ecosystem. A collective answer is needed in the framework of a stronger and more effective international institution, which can use its coercive power on each country, as the actual climate change related international regime is inappropriate to meet its duties. An international institution is needed to provide a public good, namely healthy life for present humankind and for subsequent generations in the notion of sustainability.

7. CONCLUSIONS

In this paper we briefly summarized the methodological aspects of climate change. If one aims to achieve a comprehensive and worthwhile analysis on the impacts, cost and damages induced by climate change, many factors need to be considered. Some aspects, which cannot be monetized – e.g. indirect costs, political decisions and moral questions –, make it hard to execute a damage cost assessment and to reach appropriate measures. In any case, more and more research is needed; first, to address new research paths and take into consideration a wider range of essential factors and second, to compare them and last, to give more thorough conclusions combating climate change.

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