The Social Costs of Climate Change – A Critical Examination

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Contents

1 Introduction

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Ongoing the first section of this paper provides a brief overview of the main results relating to the costs of reducing CO_2 emission.

Afterwards the main interest is focused to the benefits of emission abatement, defined as the benefits from avoided damages.

A synthesis of both costs and benefits is to find an economically efficient way for the optimum amongst emission abatement and not avoided damages otherwise. Guided by the mainly applied Cost-Benefit-Analysis (CBA), there are several examinations to evaluate the social costs of greenhouse gas emissions.

Finally some criticism related to the here presented and often applied Cost-Benefit-Approach as well as an outlook will follow.

2 The Costs of Reducing CO_2 Emissions

In recent years there have been numerous studies dealing with the reduction of CO_2 emissions (see a synopsis in IPCC 1996, MICHAELIS 1997). To identify the costs related with any reductions of CO_2 emissions, economists principally apply two different approaches, known as „top-down"-models and „bottom-up"-models.

„Top-down"-models analyze aggregated behaviours based on economic indices of prices and elasticities. Furthermore, a „top-down"-model tries to capture the overall economic impact of a climate policy, for example the introduction of quantitative restrictions or carbon taxes.

„Bottom-up"-models on the other hand are based on a detailed analysis of technical potential. From an economic point of view, „bottom-up"-models have the disadvantage, that they only add partial assessed potentials of mitigation, whereas potentials of mitigation in a national economy often depend on each other (for more details see NORDHAUS 1991b or JOHANSSON & SWISHER 1994).

Following a look at the results of the so-called „top-down"-models will be provided, because these models take into account economic considerations like changes of prices, demands and reaction of adaption over time (for example see MANNE & RICHELS 1990).

1 Introduction

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Following a look at the results of the so-called „top-down"-models will be provided, because these models take into account economic considerations like changes of prices, demands and reaction of adaption over time (for example see MANNE & RICHELS 1990).

By applying a „top-down“-estimate, first a „business as usual“-scenario is calculated which depicts the future development of the Gross National Product (GNP) and the CO_2 emissions without measures of climate protection.

Second, certain measures – for instance carbon taxes – are introduced and the resulting new calculations are compared with the previous (see PEARCE 1991 for some theoretical considerations due to carbon taxes, for an empirical survey see CANSIER & KRUMM 1997). Assessed distinctions in the GNP finally can be interpreted as the economic costs of the mitigation of CO_2 emissions.

Table 3.1 ongoing reviews the results of some global studies related to the costs of reducing CO_2 emissions.

Furthermore there are studies only for to the United States, other OECD countries, the transitional economies of eastern europe just as the former Soviet Union and developing countries.

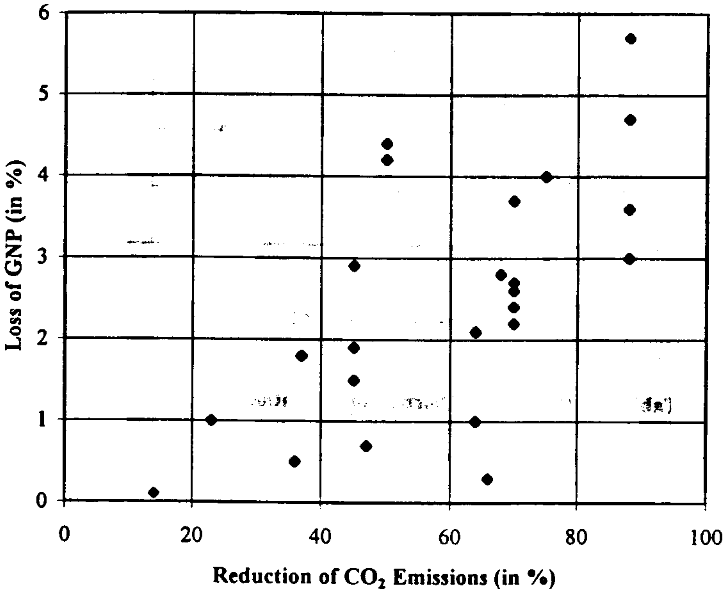


Table 3.1: Costs of reducing CO_2 emissions.

Source: after FANKHAUSER (1995), IPCC (1996), MICHAELIS (1997).

Unfortenately the depicted studies provide a wide range of distinctions. An essential first step in discussing the results is to determine why the estimates differ so widely.

There are many explanations for the disagreements: choice of methodologies, underlying assumptions, emission scenarios, policy instruments and reporting year. For example, mitigation costs will be affected by a wide range of factors, including population growth, consumption patterns, resource and technology availability, land use and trade.

But as shown in table 3.2 – at this point presented with the current time horizon of the different studies – rates of abatement in a magnitude of 20-50% are attainable to costs lower than 3% losses in the GNP – moreover in a medium range until the year 2050. Further reductions are usually related with higher losses in GNP.

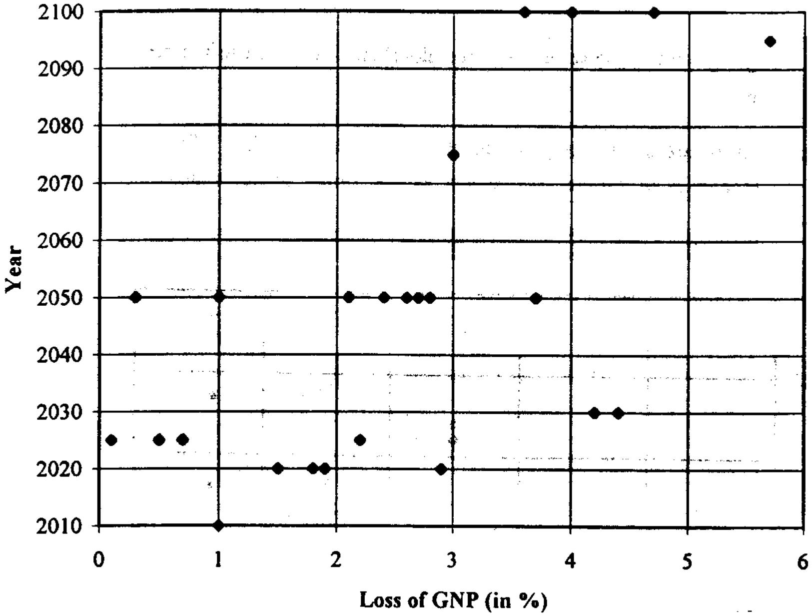


Table 3.2: Related time horizon of mitigation costs.

Source: see text.

An exact assessment of the costs of mitigating CO_2 emissions is very unreliable and provides too many results with too many assumptions as explained above.

The results of studies only for the United States or certain other OECD countries also provide a wide range of estimates as well as studies for transitional economies or developing countries (see IPCC 1996).

3 The Benefits of Emission Abatement

In a most generally way the benefits of GHG emission abatement can be derived from the benefits of avoided damages. To quantify certain damage costs, first it is necessary to identify harmful impacts and second to monetize them.

Whereas the estimation of mitigation costs – as outlined in the section above – is very difficult and provides a wide range of results, an exact assessment of future damages related to the global warming respectively the climate change seems to be nearly impossible.

Global warming can cause a variety of possible effects, as shown in the figure 3.1 below.

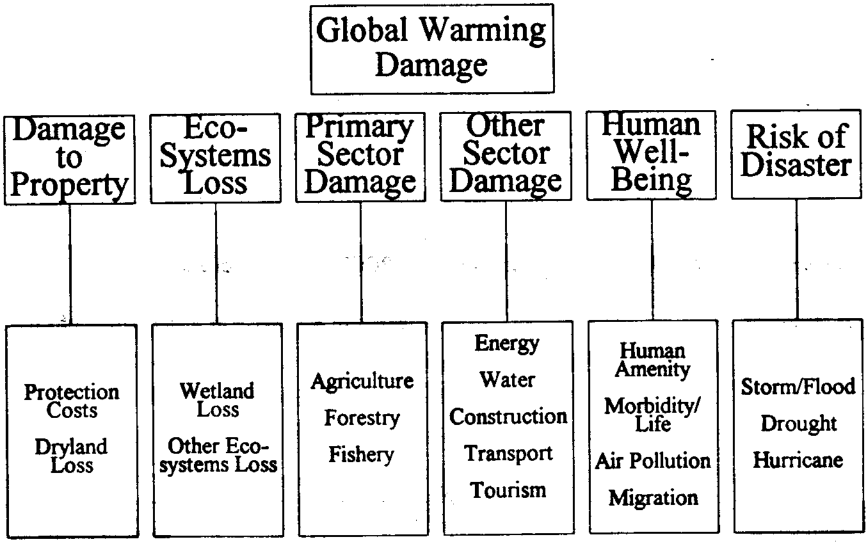


Figure 3.1: Overview on global warming impacts.

Source: FANKHAUSER (1995).

As empasized, for each of these „sectors“ in figure 3.1 the physical effects have to be identified and furthermore to be monetized. In particular the problems of a monetary valuation have to be considered in this context.

Generally a monetary valuation bases on market prices and actual monetary transactions. This method for example can be used to value protective measures for the rise in sea level or to value the impact on agriculture.

But what about the case of determining a value for non-market goods like species loss? In this case the economic theory has developed several procedures, one of the most important is the contingent valuation method. This method uses survey-techniques to estimate a willingness to pay which reflects how much individuals might be willing to pay for an environmental resource as – for example – the biodiversity. By the way, recent studies provide convergent estimates for several environmental resources (see an overview in Carson et al. 1996 or Geisendorf et al. 1996). A fact that could be helpful in economic decision making.

Most available damage studies are concerned with the impact of an equilibrium climate change associated with a doubling of the pre-industrial carbon dioxide equivalent concentration of all greenhouse gases. Long run impacts however have gained less attention.

For this case of $2xCO_2$ several monetary damage values have been estimated, mainly for the United States. As shown in table 3.3 there are estimates for a number of sectors in the market economy and – in addition – there are estimates for some non-market damages.

Table 3.3 summarizes the existing estimates of climate change damage for the mentioned case of doubling CO_2.

In the United States the losses reach over 1% of Gross Domestic Product (GDP) in the studies of Cline (1992), Fankhauser (1995) and Tol (1995) up to 2.5% of GDP in the Titus (1992) estimates. It should be emphasized that the Titus (1992) estimates are based on average warmings of 4°C, evidently higher than the IPCC's best guess of 2.5°C.

The results by Nordhaus (1991a) are less comprehensive and arrive at a calculation of only 0.26% of GDP, primarily from the sea level rise. In view of many not assessed categories, Nordhaus (1991a) also sets a loss of 1% of GDP as a reasonable central estimate.

However, these damage figures in fact can deviate from true impacts, mainly for three reasons:

- Several effects are not quantified, for example nontropical storms, droughts or floods.
- Forms of adaptation are not fully taken into account; adaptation in this context offers a means to reduce the harmful impacts of climate change.
- Plausible the estimates are not exact, species loss valuation in particular could be far higher. In fact, some of the economic figures presented above and in table 3.3 are based on earlier climate and impact research.

Damage Category	CLINE (1992) (2.5°C)	FANKHAUSER (1995) (2.5°C)	NORDHAUS (1991a) (3°C)	TITUS (1992) (4°C)	TOL (1995) (2.5°C)
Agriculture	17.5	8.4	1.1	1.2	10.0
Forest loss	3.3	0.7	small	43.6	-
Species loss	4.0+a	8.4		-	5.0
Sea level rise	7.0	9.0	12.2	5.7	8.5
Electricity	11.2	7.9	1.1	5.6	-
Non-elec. Heating	-1.3	-		-	-
Human amenity	+b	-	not	-	12.0
Human morbidity	+c			-	-
Human life	5.8	11.4	assessed	9.4	37.4
Migration	0.5	0.6	categories	-	1.0
Hurricanes	0.8	0.2		-	0.3
Construction	±d	-	estimated	-	-
Leisure activities	1.7	-	at	-	-
Water supply					
-Availability	7.0	15.6		11.4	-
-Pollution	-	-	0.75%	32.6	-
Urban infrastructure	0.1	-	of	-	-
Air pollution					
-Trop. O_3	3.5	7.3		27.2	-
-Other	+e		GDP	-	-
Mobile air cond.	-	-		2.5	-
Total	**61.1**	**69.5**	**55.5**	**139.2**	**74.2**
% of GDP	**1.1**	**1.3**	**1.0**	**2.5**	**1.5**

a, b, c, d, e = Costs that have been identified but not estimated

Table 3.3: Monetized 2xCO_2 Damage to Present U.S. Economy (Base Year 1990; Billion $ of Annual Damage)

Source: see IPCC (1996).

Estimates for other OECD countries than the United States are mostly in the same range of 1-2% losses of GDP, as outlined in table 3.4.

Region	Fankhauser (1995)		Tol (1995)	
	bn $	% GDP	bn $	% GDP
European Union	63.6	1.4		
United States	61.0	1.3		
Other OECD	55.9	1.4		
OECD America			74.2	1.5
OECD Europe			56.5	1.3
OECD Pacific			59.0	2.8
Total OECD	*180.5*	*1.3*	*189.5*	*1.6*
Eastern Europe / Former USSR	18.2[a]	0.7[a]	-7.9	-0.3
Centrally planned Asia	16.7[b]	4.7[b]	18.0	5.2
South and Southeast Asia			53.5	8.6
Africa			30.3	8.7
Latin America			31.0	4.3
Middle East			1.3	4.1
Total non-OECD	*89.1*	*1.6*	*126.2*	*2.7*
World	**269.6**	**1.4**	**315.7**	**1.9**

[a] Former Soviet Union only; [b] China only

Table 3.4: Monetized $2xCO_2$ Damage in Different World Regions (Annual Damages)

Source: IPCC (1996).

The worldwide estimates of table 3.4 are expressed as the total sum of regional damages relative to the global sum of GDP.

Table 3.4 also shows that the damage in developing countries is more severe than in developed countries. Fankhauser (1995) and Tol (1995) report damages for the Non-OECD region about 1.6-2.7% losses of GDP.

The main causes for these high estimates are primarily health impacts and the high proportion of natural habitats and wetlands that might be destroyed. By the way, these data provide the surely true indication that climate change will have the worst impacts in the developing world. For this reason can also be argued on equity grounds that there should be greater weights placed on impacts for low income countries.

4 The Social Costs of Emission Abatement

The last sections dealt on one side with the costs of reducing CO_2 emissions, on the other side with the related benefits respectively the damages that can be avoided.

In addition to single cost respectively benefit researches, today there is a limited number of studies which moreover confront costs with benefits in the so-called cost-benefit analysis.

4.1 The Cost-Benefit Analysis

Initially the cost-benefit analysis (CBA) was developed to compare the perceived costs and the perceived benefits of an action or a project. Furthermore, the method was developed to evaluate projects that were limited in scale, geographic extent and time span.

Its basic principles are simple and well unterstood: For an action to be justified, the costs should be less than the related benefits, compared at a certain point in time. To compare the present value of a flow of costs and benefits over time, the arising values have to be discounted.

If there are certain alternatives, obviously that option whose benefits most exceed the costs has to be selected.

Despite the attention to the „doubling CO_2" case and its related *total* damages, for the appraisal of abatement projects it is more important to know the *marginal costs* of each additional unit emitted. Equally it's important to know the *marginal benefits* of each additional unit avoided.

In this context it's helpful to recognize some economic considerations related to the appraisal of projects. As often applied in infrastructural projects, the cost benefit-analysis also is the main approach to the question of the optimal global warming policy.

4.2 The Basic Concept

An economically efficient level of GHG emissions – or in other words an efficient policy for the reduction of emissions – is one that maximizes the net benefits – the benefits of reduced climate change less the costs of suitable measures.

The economic theory related to such a question indicates the „optimum" of emissions at that level where the environmental benefit of an additional unit of reduced emissions – the marginal benefit – is equal to the cost of an additional unit of emission reduction – the marginal cost.

[redacted]

Figure 5.1 illustrates this shortly mentioned concept of marginal costs and marginal benefits in a simplified model.

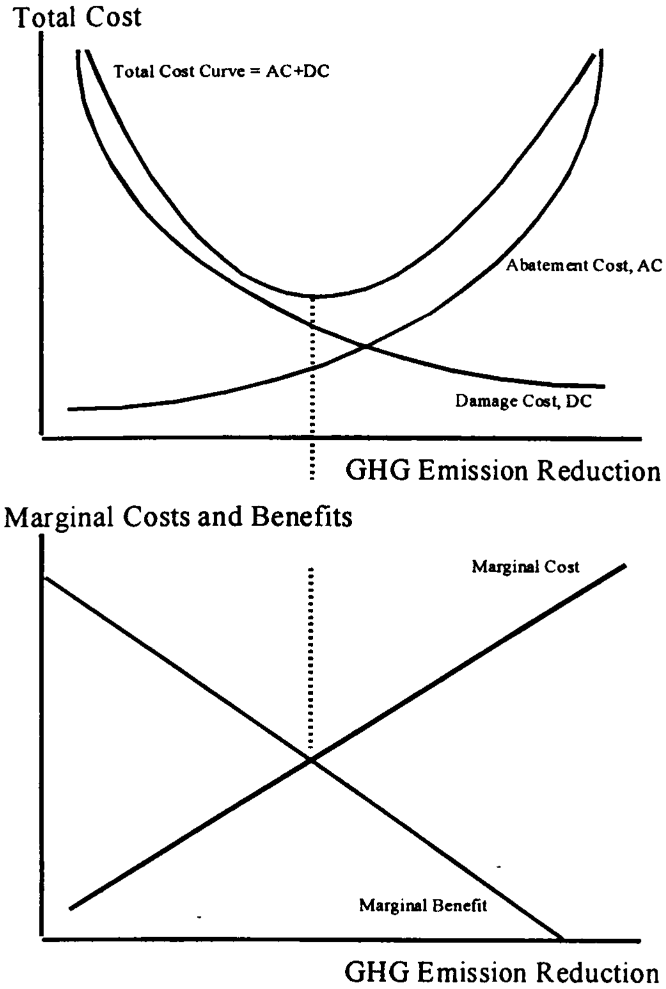


Figure 5.1: Total and marginal costs and emission reductions.

Source: after MICHAELIS (1997).

In the lower box, the marginal abatement cost at any level of emission reduction is equal to the slope of the abatement cost curve at the same level – as sketched in the upper box.

The shape of the abatement cost curve shows the idea of diminishing returns. Each additional unit of emission reduction will have a higher unit cost. Thus the abatement cost curve is upward sloping. Similarly, the damage cost curve is downward sloping, each additional unit of emission reduction will have a lower unit cost.

The consequence of the foregoing is that the total cost curve has its minimum at that point where the positive slope of the marginal (abatement) cost curve equals the negative slope of marginal benefit curve. This point of the socially optimal reduction level implies that there is an optimal combination between measures in climate change protection and remaining emissions.

4.3 A Review of Applied Social Cost Estimates

Before discussing the results of previous studies on the social costs of greenhouse gas emissions, in face of the applied models it's helpful to make a distinction between studies on the *actual marginal social costs* of greenhouse gas emissions and the concept of a *shadow price*.

In a cost-benefit framework the optimal output of GHG emissions is obtained at the intersection point of the marginal (abatement) cost curve and the marginal benefit curve as explained above. In the case of global warming or climate change the costs of additional greenhouse gas abatement have to be equal to the additional benefits of avoided damages, *and this at each point in time calculated in an intertemporal optimization framework*.

The described situation can be achieved by taxing emissions at a level equal to the marginal damage they cause. In this case the tax or – in other words – the *shadow price* of emissions is equal to the actual social costs.

It should be emphasized that this is only correct in the case if future emissions follow the path calculated in the model. But there is no guarantee, that this will occur indeed. Future emissions can deviate from the optimal path, then shadow values and actual social costs will differ. However, the discrepancy should be slight and the shadow value calculated in cost-benefit studies can be interpreted as indicator of the actual social costs of greenhouse gas emissions.

In other models the marginal benefits are calculated directly as the difference in future damage levels caused by a marginal change in baseline emissions. Thus the calculation compares the present value of the stream of damages associated with a certain emissions scenario to an alternative scenario with marginally different emissions in the base period.

Shortly summarized the social costs of greenhouse gas emission can be expressed with the shadow value of cost-benefit models as well as the calculated difference in future damage levels caused by a marginal change in baseline emissions. Both methods have been used so far, as shown in table 5.1.

[redacted]

Study	Type	1991-2000	2001-2010	2011-2020	2021-2030
NORDHAUS (1991a)	MC		7.3 (0.3-65.9)		
AYRES & WALTER (1991)	MC		30-35		
NORDHAUS (1994)	CBA	5.3	6.8	8.6	10.0
CLINE (1992, 1993)	CBA	5.8-124	7.6-154	9.8-186	11.8-221
PECK & TEISBERG (1992)	CBA	10-12	12-14	14-18	18-22
FANKHAUSER (1995)	MC	20.3 (6.2-45.2)	22.8 (7.4-52.9)	25.3 (8.3-58.4)	27.8 (9.2-64.2)
MADDISON (1994)	CBA/MC	6	8.1-8.4	11.1-11.5	14.7-15.2

MC = Marginal Social Cost study
CBA = Shadow Value in a Cost Benefit Analysis

Table 5.1: The Social Costs of CO_2 Emissions in Different Decades (in 1990 $/tC)

Source: after FANKHAUSER (1995), IPCC (1996).

The pioneering examination on the social costs of CO_2 emissions leads back to NORDHAUS (1991a). NORDHAUS (1991a) applied a dynamic optimization model and calculated social costs of 7.3 $ per tonne of carbon emitted. The values in parenthesis result by applying different rates of discount and varying assumptions on the $2xCO_2$ damages.

Furthermore these results have been strongly criticised by several authors. CLINE (1992) for example refered to the shortcomings of the model itself. The assumption of a resource steady state which implies a constant level of CO_2 emissions over time is discussed controversially in this context. The simple linear structure of the climate and damage sectors also implies that the costs will remain constant at 7.3 $/tC, although climate processes without any doubt are non-linear and the costs of CO_2 emissions will depend on future concentration and warming levels. In other words, the costs of CO_2 emissions will vary over time.

The calculations by AYRES & WALTER (1991) based on the NORDHAUS model, but the study has additional shortcomings. Highly questionable for example is the assumption of identical commodity values in all countries of the world: land prices in Europe clearly differ from those in India or Pakistan.

The shortcomings of his earlier paper were considered and corrected by NORDHAUS' (1994) second approach. He applied the well-known DICE – Dynamic Integrated Climate Economy – model which is a growth model including a climate module and a damage sector which feed climate changes back to the economy (see also Nordhaus 1993). Nevertheless the shadow values of carbon calculated by the DICE model are in a comparable order as the previous results: starting at 5.3 $/tC in the year 1995 rising to 6.8 $/tC and finally up to 10 $/tC in the year 2025.

The DICE model also was applied by Cline (1992), who suspected that a certain choice of parameter values may have led to underestimation of the true costs. The main interest here is due to the discount rate. The results of the Cline (1992) study – also reported in table 5.1 – vary widely, mainly as the consequence of different discount rates.

Peck & Teisberg (1992) as well as Maddison (1994) calculated social costs within the same order as the DICE results. Peck & Teisberg (1992) applied the CETA (Carbon Emission Trajectory Assessment) model, which take into account a climate and a damage sector as the DICE model, but is more detailed with respect to economic aspects by incorporating a energy sector. Differences between the two researches result mainly due to different assumptions about the dimension of the 2xCO_2 damage. Common to both papers is the assumption of a 3% discount rate.

In comparison Fankhauser (1995) identifies shadow prices from initially 20 $/tC up to 28 $/tC in later decades. Fankhauser (1995) uses a probabilistic approach to the range of discount rates, in which low and high discount rates are given different weights. It can be suggested that a moving from high (3%) to low (0%) discounting could increase marginal costs by a factor of 9.

5 Criticism and Outlook

The cost-benefit analysis has many advocates but also many detractors. The rather narrowly defined traditional approaches to CBA, developed to assess projects with a time horizon no longer than 25 years, without any doubt have difficulties in dealing with long time frames and high levels of uncertainty encountered in the climate change context.

Shortly summarized, there are mainly two points of criticism:

- All well founded estimates of global damage are related with „doubling CO_2“, but this is only one point of a damage function which is necessary for applying a CBA. Furthermore, the economic valuation of the costs related to this point is very difficult. As proved, even different mathematical descriptions of the damage function will provide a wide range of results. Applying his DICE model, Nordhaus (1993, 1994) used a quadratic function. However a cubic function or any function with a positive first derivation is conceivable (Michaelis 1997).

- The application of certain discount rates has extensive impacts and is – espacially in the context of global warming – discussed increasingly (for example BROOME 1992, AZAR & STERNER 1996, BAYER & CANSIER 1998). NORDHAUS (1994) as well as PECK & TEISBERG (1992) and MADDISON (1994) used a discount rate of 3% – following the rates of interest on capital markets.

To make clear the extensive impacts of different discount rates, a view on figure 6.1 may be helpful.

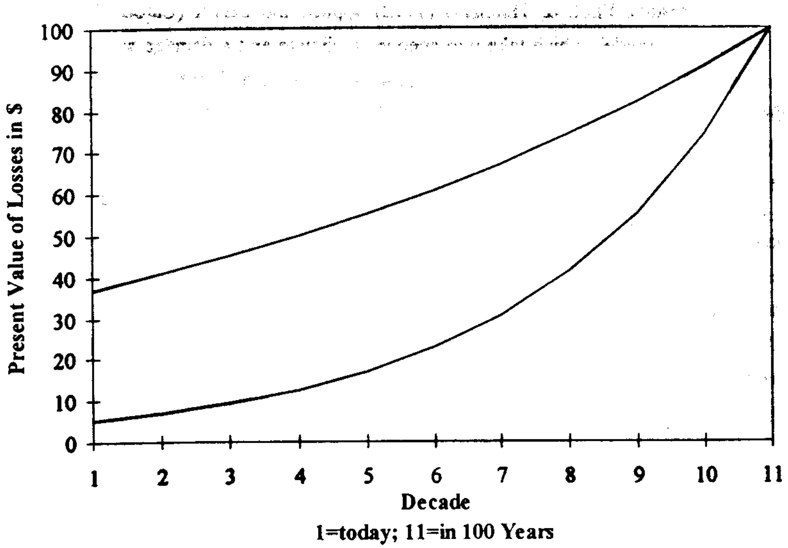


Figure 6.1: Present monetized losses in dependency of different discount rates.

Source: see text.

Figure 6.1 shows on one hand the shape of a discount rate at 1% – the upper curve, and on the other hand the shape of a discount rate at 3% – the lower curve.

It is easy to point out that a lower discount rate implies more extensive measures in GHG emission abatement, because the present values of future losses are weighted higher.

Whereas losses of – let's say 100 dollar – in 100 years today by using 3% discount rate are worth roughly 5 $, they reach an amount of 37 $ by using a 1% discount rate. In other words, by applying higher discount rates, a lower present value of future damages will result.

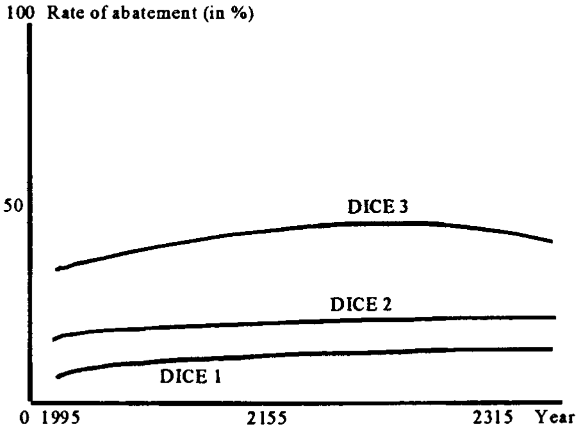
CLINE (1992) for example calculates the following rates of abatement in comparison with different discount rates, as shown in table 6.1.

Discount Rate (%)	Rate of Abatement (%)
0	80
0.5	45
1	30
2	15-20
3	15

Table 6.1: Different discount rates and related rates of abatement.

Source: see CLINE (1992).

Finally figure 6.2 shows in a simplified form the recalculations using the DICE model with variations of the discount rate and the damage function.



DICE 1: Discount Rate 3%, quadratic damage function
DICE 2: Discount Rate 1%, quadratic damage function
DICE 3: Discount Rate 1%, cubic damage function

Figure 6.2: CO_2 avoidance in dependency of different discount rates and damage functions.

Source: see MICHAELIS (1997).

Related to a sensitivity analysis of certain parameters, variated definitions lead to other „optimal" rates of GHG abatement. Using a discount rate of only 1% and cubic damage function (DICE 3), a trebled rate of abatement in comparision with the former results of NORDHAUS (1994) is obtained (MICHAELIS 1997).

Thus the application of a CBA in the context of climate change implies that using a sufficiently high discount rate nearly every damage in future can be justified. Furthermore in this context, the application of a CBA implies also that the benefits of today's generation will be compared with the costs burdened on later generations. This point leads immediately to aspects of intergenerational justice.

In the view of these problems, an alternative approach is to ignore damage considerations and exogenously impose an upper atmospheric concentration, determined on the basis of ethical, political or precautionary considerations (FANKHAUSER 1995). This approach is known as the „carbon budget approach" and is part of the concepts relying sustainability and safe minimum standards.

There are mainly two arguments leading to the endorsement of the carbon budget approach:

- The first bases on questions relating to the uncertainty and claims for carbon targets in the context of a risk minimization policy. To minimize the risk of a climate catastrophe the approach requires a target that is set at the maximun level of emissions under which a climate catastrophe can reasonably be excluded.

- The second argument relates to the monetization of global warming impacts. It questions wether the impacts of global warming can at all be expressed in monetary terms. Hence the absence of damage estimates implies that abetement targets have to be determined on different grounds, according to political, social or ethical considerations.

One of the first suggestions in this context were provided by the UNEP Advisory Group on Greenhouse Gases in 1989: The concentration of GHG have to be stabilized at such a level that the possibility *of rapid, unpredictable and non-linear responses that could lead to extensive ecosystems damage* can be excluded.

Targets in more concrete terms have been proposed in several contexts and by several bodies. For example, the Toronto target of a 20 % emission cut, the Rio target of emission stabilization at 1990 levels or the scientific targets set by the IPCC.

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