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# An economic approach to the analysis of country interests and positions in climate negotiations

*H. Asbjørn Aaheim*

Universitetet i Oslo

University of Oslo

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**H. Asbjørn Aaheim**

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**CICERO**
Center for International Climate and
Environmental Research – Oslo
P.O. Box 1129 Blindern
N-0317 Oslo, Norway
Phone: (+47) 22 85 87 50
Fax: (+47) 22 85 87 51
E-mail: admin@cicero.uio.no
Web: www.cicero.uio.no

# Abstract

The publication develops an approach to the appraisal of economic interests and positions in climate negotiations. The approach is based on a full-scale analysis of costs and benefits of climate treaties.

*Interest* is defined as the ‘best’ treaty a country can obtain, that is, the policy they would have chosen if they could dictate the treaty to the world. The *position* is found by a ranking of alternative proposals imposed on each country, which are different from the ’best’ treaty. The proposals are ranked according to their costs, measured in terms of consumption loss and increase in damage of climate change relative to the interest.

Some numerical illustrations for the US, EU and Japan are presented. Different from many other economic studies, the analysis indicates that the economic interests between the three countries may be substantial, and that the ranking of proposals differ. Secondly, the long-term character of climate policy leaves a considerable range of feasible solutions of the negotiations.

# Contents

# 1 Introduction

Economic studies of climate policy have mostly been concerned with issues related to effectiveness and efficiency. Studies of effectiveness aim at showing how an emission target can be achieved at the lowest possible cost. In the more demanding studies of efficiency the choice of climate policy is found by maximising the total social benefit. Insights from these studies apply directly in the designing of national climate policy. The results are useful for making a choice among alternative options to reduce emissions of greenhouse gases, whether or not to implement sink measures, and not at least for deciding how much a country is willing do in order to mitigate climate change.

On the international level, climate policy is basically a question of negotiations. Hence, how to 'design' a national climate policy is crucially dependent on whether the studies are made prior to or after an international treaty is signed. While assessments *ex-post* is mainly a question of national policy making under known conditions, the perspective of assessments *ex-ante* is to map different possible positions in up-coming negotiations. This distinction is seldom made clear, which in some cases does not matter. In examining positions prior to climate negotiations, however, the *ex-ante* perspective should be explicit. The definition of the cost of a proposal must then be related to some baseline that expresses a zero cost alternative, or "the optimal climate policy". Such a baseline can be defined as the interest of a country.

From an economic point of view it is natural to consider the position of a country in relation to the expected costs and benefits of actions to mitigate climate change. However, the interpretation of costs and benefits is not unique in this context. Many studies focus entirely on the abatement costs of achieving a given emission target.[1] Rayner et al. (1998) claim, on the other hand, that the concern for climate change world-wide was a result of an awareness that poor countries would probably have to pay the largest bill for climate change in terms of damage. Clearly, both abatement *and* damage costs matter. Analyses of costs and benefits of mitigation have been carried out by integrated models. The perspective of these studies is that of a world governor, or Leviathan, who asks what is optimal for the world.[2]

The Leviathan perspective is of course irrelevant for studies of negotiations. A couple of studies have therefore taken a game theoretic approach, such as in Carraro (1997) and Nordhaus and Yang (1997). Based on assumptions about economic performance in different countries or regions, they apply alternative game-theoretic solutions to climate negotiations. As pointed out by Underdal (1998), positions and interests can only partially be traced back to the economic factors. Other issues, sometimes of a purely political nature, often play a crucial role. For example, Gupta and van der Grijp (1998) show how important the internal controversies and institutional rigidities was to EU's performance prior to and during the Kyoto meeting in 1997. From this point of view, it may be useful to define the economic interests of a country, and further to develop the positions to certain proposals put forward in negotiations in relation to these interests, without implementing game-theoretic solutions. This may provide the economic background for a comprehensive analysis of climate negotiations.

[1] See e.g. UNEP (1994), Kram and Hill (1995), Jorgenson and Wilcoxen (1991), Manne and Richels (1991), Peck and Teisberg (1994), Oliveira-Martins et al. (1993), Dean (1993), Edmonds and Barns (1992).
[2] See e.g. Nordhaus (1993), Manne, Mendelssohn and Richels (1994), Tol (1997).

This paper develops an approach to the appraisal of economic interests and analyses positions to climate negotiations from an economic perspective. Such an analysis may be regarded as the economic explanation to the positions expressed by the parties in negotiations. It is recognised that expressed positions may deviate considerably from the economic appraisal because of the influence of non-economic factors. Nevertheless, positions cannot be analysed adequately without regard to economic factors. In section 2 of this paper I define economic interests and positions, and discuss a couple of vital assumptions required to make the appraisals coherent with observed proposals. Section 3 presents the models used to calculate interests and positions. Section 4 discusses the availability and use of data. Section 5 presents a numeric example of the model, applied to the EU, Japan and USA, and section 6 concludes the paper.

# 2 Assumptions needed to appraise interests and positions

In this paper the economic *interest* of a country refers to the best treaty a country can ever achieve, that is, the treaty that maximises welfare. The *position* is a ranking of proposals according to the cost incurred by accepting a proposal that deviates from the best treaty. The cost can be measured as the welfare loss of the proposal, that is the ‘distance’ between the proposed treaty and the interest. The interests thereby refer to some underlying preferences, and are independent of proposals suggested by other parties. The position, on the other hand, refers directly to a proposal, and is based on the assessment of a measurable variable related to the economic performance of the country.

Although these definitions are relatively straightforward and simple, an appraisal of the positions have to be based on assumptions that leave a considerable room for variability when it comes to the question of what the economic consequences of a treaty actually are. Some of them are standard for any forecast of economic growth, such as what the return on invested capital is, what the impacts of possible changes in international trade patterns are etc., but due to the long-term character of climate policy, they are more crucial than usual in economic analyses. Another kind of problems arises as a consequence of the appearance of negotiated targets: Targets are usually expressed in terms of emissions in a given year, while the perspective of planning for the future is a balanced economic growth. Below, we discuss some vital assumptions required to make negotiating targets and the economic perspective of national authorities coherent.

## 2.1 Sustainability and the choice of time horizon

Climate policy is indeed a question of long-term strategies, and therefore the interests defined above will have to reflect a long-term economic growth pattern and the associated emissions. In negotiations, such as in the Kyoto conference, the emission targets usually relate to a given point in time.[3] Whether such a target concurs with the interests can be determined if there is one and only one path that maximises welfare. This is the case if we have some conditions to apply to the terminal year of the planning period. But to rank positions, we have only one point on the emission path, and do not know what is supposed to happen before or after. In principle, therefore, a given target may represent an infinite number of emission paths.

The determination of a unique interest path calls for a discussion of what requirements to impose on the wealth of the economy and the state of the climate system at some future point in time. The question has been dealt with in the literature about sustainable development, but has received surprisingly little attention in applied analyses of climate policy. According to the World Commission for Environment and Development (1987) sustainability implies that the basic needs for the present generations are satisfied, without limiting the opportunities for future generations.

[3] The target year in the Kyoto protocol is 2010, but due to possible temporary oscillations in emissions, the emissions for 2010 are to be measured by the average over the period 2008 – 2012.

Although intuitively acceptable, sustainable development is difficult to define more precisely if the concept is to be useful for policy making. For example, Daly (1992) suggests a strong definition of the concept, which implies that any degradation of natural resources is unsustainable. As a consequence, extraction of non-renewable resources, such as fossil fuels, is incompatible with sustainability. Pearce and Atkinson (1993) have suggested a weaker interpretation, which allows natural resources, human and man-made capital to be substituted. Then the development is sustainable if degradation in one of these components is replaced by a corresponding increase of another. By requiring correspondence between reductions and increases in the stocks of different resources, however, it is necessary to attach prices to them. If we allow for this, it is also possible to apply a weak form of strong sustainability, by requiring that the wealth of a resource is to be at least as high in the terminal year as it is at present. Asheim (1994) points out that this is not the same as strong sustainability, and that the requirements to the World Commission may be violated when this interpretation is applied. Nevertheless, the weak form of the strong sustainability concept will be applied in this study.

By this interpretation of the concept of sustainability the growth path determining the interests can be fixed. To calculate positions, we also have to discuss the time horizon. One possibility is to set the time horizon equal to the time of the emission target. The weakness is then that an optimal path from present to e.g. 2010 is not equal to the sequence between present and 2010 of the optimal path from present to a terminal year beyond 2010. To put it differently, given that the shortest distance from $A$ to $B$ is a road $P$, the shortest distance from $A$ to some place $C$ between $A$ and $B$ may be different from $P$. It depends on the constraints imposed on the problem, for instance, whether the road from $A$ to $B$ goes through $C$ or you have to leave the main road $P$ at some point to get to $C$. Since the ranking of proposals is based on the aggregate of the differences between alternative paths, this bias may, however, be small.

Another possibility is to choose a longer time perspective, and include possible extensions of the proposed targets, in practice targets for 2020, 2030 etc. There is no doubt that speculations about a prolongation of e.g. the Kyoto protocol have an influence on the positions of the parties. However, the possibility of achieving the target in 2010 by alternative paths also represents an opportunity for a more flexible national policy. Hence, by choosing a distant time horizon, the cost of achieving a nearby target can be presented as a cost function that indicate what kind of targets a country may accept under alternative prolongation of the treaty. Both possibilities are worthwhile to consider.

## 2.2 Discounting

A repeatedly returning problem of long-term economic optimisation of environmental policy is how to discount future costs and benefits. Nordgaard and Howarth (1991) point at the dilemma facing the conservationist, who chooses a low rate to favour the management of slow growing trees, protection of bio-diversity, and we could add mitigation of climate change, but chooses a high rate to make projects with negative environmental consequences look uneconomic. In the case of climate change, this problem becomes crucial because of the extremely long time span between abatement and impacts of emission cuts. As a consequence, the benefits of abatement tend to ‘disappear’ after discounting. Studies based on economic optimisation models, such as those by Nordhaus (1993) and Manne, Mendelssohn and Richels (1994), therefore give little support to aggressive reductions in greenhouse gas emissions at present or in near future.

Others argue that it may be defendable to apply different discount rates to different investments.[4] This view reflects an important aspect of discounting, which is often confused, namely that the discount rate depends on many factors not necessarily equal for all investments. In the case of climate policy, a vital question is how the "shadow price of the atmosphere" evolves over time. An advantage with the approach chosen in this paper is that this shadow price is determined endogenously.

Some choices concerning the comparison of the present and the future nevertheless have to be made. When maximising the welfare over a given time horizon, we must address the question of how much future consumption should contribute to the welfare compared with present consumption. In other words, how impatient should we allow the consumers to be regarding consumption? Within the context of sustainability, one might find this question confusing, because as pointed out already by Ramsey (1928) there are no ethical reasons why present generations should be more appreciated than future generations (see also Schelling, 1994).

On the other hand, it is bothersome to completely disregard the tendency to impatience. First, it can be shown that if welfare is a concave function of aggregate consumption and the rate of impatience is zero, it might be optimal to spend the whole national product on investments and postpone consumption into infinity. Second, in order to arrive at a consumption level in reasonable accordance with the observed level in models of economic growth, one has to impose a relatively high rate of impatience. Manne (1994) shows that a 'too low' rate of impatience results in a high rate of economic growth, which compels a reduction in the present level of consumption. Estimates of the rate of impatience lie in the interval between 1 and 3 percent per year.

This is clearly unsatisfactory. A 3 percent rate of impatience implies that to compensate a consumption loss of 100 USD today, an increase in consumption of nearly 135 USD is required in 10 years. This means that the consumption of the present generation, say those being 30 years of age, contributes 35 percent more to welfare than the consumption of those being 20 years now, when they become 30. The reason why this dilemma occurs is probably that the additive welfare-function, on which most economic growth models are based disregards considerations of vital importance in intertemporal decision making. For example, the welfare at one point in time is assumed to be independent of the welfare at another point in time. Consequently, welfare is the same irrespective of whether the economy grows or declines. Another such issue is that preferences related to intertemporal equity are assumed to be the mirror of risk aversion. Therefore, we do not know whether the parameters of a welfare function revealed from observations reflect the attitude towards risk or to intergenerational equity.

It is not unusual to adapt imperfect relations to time-series data by adding a 'trend-factor'. The peculiar thing about the trend attached to intertemporal welfare-functions is that this term is given a particular interpretation, namely as a factor that reflects the preferences (i.e. impatience), rather than a correction term that takes care of some systematic unexplained bias. We will stick to the hypothesis of the imperfect welfare function, and thereby defend the use

[4] See e.g. Cline (1992), Weitzman (1995), Arrow et al. (1995) and Hasselmann et al (1997).

of a trend-factor attached to the additive welfare function also in an analysis of sustainability. Note, however, that a constant correction term applies only within a limited period of time. In the numeric examples in section 5 the time horizon is 50 years, which is relatively long in this perspective.

## 2.3 'Own' emission cuts and global reductions

The interest of a country was defined as the best treaty a country can ever obtain. The answer to this might be very simple, namely to leave all actions to mitigate climate change to other countries and do nothing in one's own country. The actions taken in a single country are in most cases negligible on the world scale. By leaving all actions to all the others one could yield all the benefits and avoid all the costs. Hence, an obvious interest of negotiating parties is to take as little responsibility for the common action as possible.

In the present analysis we aim at assessing the economic interest of a party that wants to take a 'fair share' of the responsibility. What is perceived as fair may differ from country to country, but we may assume that there is a relatively consistent view on the national responsibility in climate policy within a country. This view relates to commonly accepted principles of distribution related to some general concepts of fairness.[5] Principles of justice and fairness are widely discussed in studies of climate policy (see e.g. Rayner *et al*., 1998). A common attribute of most principles is that it relates somehow to equity. There are, however, many ways to interpret equity and to implement equity in principles of distribution. Ringius *et al.* (1998) show that the burden sharing among countries in a climate treaty varies greatly dependent on whether equity relates to emissions per capita, emission per GDP or simply to total emissions. A common interpretation of equity does not, therefore, imply a unique definition of how to share the responsibilities in a climate treaty. The perception of a fair sharing of the burden in a country is likely to be biased towards the outcome of more or less technical choices of how to measure emissions, what variables to apply in the calculation of costs, etc.

The only requirement for an assessment of interests in the approach suggested here is that it is possible to determine the global effect of own emission cuts. This means that there is a known relation between own emission cuts and global cuts. To establish this relation, we need to apply a principle for burden sharing. To make it simple, we use Rawls' concept of the 'veil of ignorance' to distribute global cuts (Rawls, 1971). That is, we assume that the emission cuts are distributed randomly across countries, such that the decision-makers do not now what the outcome of their own country will be. According to Rawls, the principle to apply for a just distribution is then the same percentage reduction for all, so-called flat rates. In practice, this means that if one country reduces emissions by 10 percent, global emissions are reduced by 10 percent.[6]

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[5] In the present analysis, the principles of fairness that applies to the distribution of commitments among countries are not necessarily compatible with those underlying the welfare- function that applies to the development of an optimal climate policy (interests).
[6] Distributing cuts instead of total emissions is not necessarily supported by Rawls' principles of justice.

# 3 Models of interests and positions

To appraise the positions relative to the economic interests, we need two models that differ with respect to the relation between national emission cuts and the global development of greenhouse gas emissions. Interests are found under the assumption that the decision-makers are free to choose how future concentrations of greenhouse gases and the resulting damages develop over time. This is basically a question of intertemporal cost-benefit analysis. When ranking proposals needed to appraise positions, the future development of concentrations and damages is fixed by the proposals. The task is then limited to maximise welfare under the constraint given by the national emission target. Below, the two models applied in this paper are presented.

## 3.1 Modelling interests

We assume that the economic interests of a country is defined by the policy that maximises welfare over a given period of time, subject to the restriction that economic growth depends on investments in real (productive) capital, but may be encumbered by damages of climate change. As in standard economic models, welfare at time $t$ ($W_t$) relates to the level of future consumption ($x_{t(0)} \ldots x_T$):

$$W_{t_0} = \int_{t_0}^{T} w(x_t) e^{-\delta t} dt \tag{1}$$

$w$ is the welfare function of instantaneous consumption with standard properties, and $\delta$ is the correction term that takes care of systematic bias. The welfare function in (1) implies that the consumption level is assumed to be the only contributor to national welfare. This means that the impacts of climate change are considered exclusively because it may affect the future aggregated consumption level. As a consequence, disadvantages of forced migration or increased morbidity and mortality are reduced to a question of what expenditures these effects cause. As Manne *et al.* (1994) points out, a major element of motivation is thereby disregarded. On the other hand, most available estimates of the benefits of climate policy refer to these expenditures, and do not take other welfare aspects explicitly into account (see Tol, 1995 or Fankhauser, 1995). We may therefore apply the available estimates of damage costs in this model, but should bear in mind that it applies a rather restricted definition of economic interests.

The national economy is described in a simple manner. Net domestic product (NDP) is generated by the stock of real capital ($k$) and may be reduced by damages caused by climate change. The damages are related to the concentration of greenhouse gases in the atmosphere ($S$). Annual NDP is allocated to consumption, and abatement costs to mitigate climate change ($y$). The remainder of NDP is net investments in real capital ($i$), which is equal to the evolution of the capital stock,

$$i = \dot{k} = f(k, S, t) - x - y\,. \tag{2}$$

$f(k,S,t)$ is the production function, net of capital depreciation. $t$ is included to account for an increase in productivity, such as technical change. It could also represent population growth, but to keep the model simple, we do not allow for substitution between capital and labour. We apply the standard assumptions about the production function, that is $\partial f/\partial k > 0$, $\partial^2 f/\partial k^2 < 0$, $\partial f/\partial S < 0$, $\partial^2 f/\partial S^2 > 0$, and $\partial f/\partial t > 0$.

The concentrations of greenhouse gases evolve according to

$$\dot{S} = \alpha S + g_1(k) - g_2(y) \tag{3}$$

$\alpha$ is the natural rate of decay for greenhouse gases. In this study we focus on $CO_2$. The assumption of a constant rate of decay is then a very rough one. Modelling concentrations of $CO_2$ is a very complex task, and requires large models. Hasselmann et al. (1997) have suggested an approximation based on a division of the concentrations into parts for which the decay rates vary. Even such an approximation is inaccurate in the long term. A constant rate of decay is therefore meant only for illustrative purposes. $g_1(k)$ represent gross emissions and $g_2(y)$ abated emissions. These functions give the contribution to concentrations of greenhouse gases world wide. Hence, $g_1(k)$ includes an exogenous element to represent total emissions from all other countries. The relation between national abated emissions and abatement world wide is based on flat rate reductions, as discussed in section 2. We assume that $\partial g_1/\partial k > 0$ and $\partial g_2/\partial y > 0$ and $\partial^2 g_2/\partial y^2 < 0$.

To appraise the interests of a country, we control $x$ and $y$ at each $t$ such as to maximise (1) subject to the constraints (2) and (3). The Hamiltonian of this system is

$$H_1 = w(x)e^{-\delta t} + q_k\left[f(k,S,t) - x - y\right] + q_S\left[\alpha S + g_1(k) - g_2(y)\right]. \tag{4}$$

$q_k$ and $q_S$ are the shadow prices of the system, that is, what the value of one unit of $k$ and $S$ is, respectively, at each $t$ along the optimal path, measured in terms of the present value of welfare. The first order conditions for instantaneous equilibrium are:

$$q_k = w'_x\, e^{-\delta t} \tag{5}$$

$$q_k = -q_S g'_2 \tag{6}$$

According to (5), the value of marginal investments, $q_k$, is equal to marginal welfare at all points in time. The second condition requires that one dollar extra ought to give the same contribution to welfare regardless of whether it is spent on consumption or to abatement. The first-order intertemporal conditions for equilibrium are

$$f'_k + \frac{q_s}{q_k} g'_2 = \delta + \mu_x \frac{\dot{x}}{x} = \rho_k \tag{7}$$

$$\alpha + \frac{q_k}{q_S} f'_S = \rho_k + \mu_y \frac{\dot{y}}{y} = \rho_S \tag{8}$$

$\mu_x$ is the intertemporal elasticity of substitution in consumption ( $\mu_x = xw''_{xx}/w'_x$) and $\mu_y$ is the elasticity of intertemporal substitution in abatement ($\mu_y = g_2''_{yy}/g_2'_y$). They characterise the curvature of the welfare function and the abatement cost function, respectively. The first condition is the so-called Ramsey rule, which requires that the marginal social return on real capital (the discount rate, denoted $\rho_k$) is equal to the welfare increment of postponing consumption. The social return on capital is the return on 'private' capital less the social cost of greenhouse gas emissions. The second condition requires that the rate of change in the value of concentrations (the discount rate of concentrations, $\rho_S$) is equal to the value of postponing abatement. The rate of change in concentrations is determined both by the gain from the natural rate of decay, and the marginal cost of damage. Note also that in general, the discount rate for concentrations differs from the discount rate of real capital.

The conditions (5) – (8) determine the relation between consumption and abatement at each point in time over the planning period. What remains in order to find the optimal policy are the start values and some restrictions at the terminal point of time for the stock variables *k* and *S*. The start values are assumed to be known and can be observed. With reference to the discussion in section 2.1 the restrictions set on *k* and *S* at the terminal point of time, *T*, are the weak form of strong sustainability. This means, firstly, that the national wealth of the capital stock is to be at least as large at $t = T$ as it is 'today' ($t = 0$). Second, the debt in the form of greenhouse gas concentrations is not larger at *T* than it is 'today'. Hence, the terminal conditions are:

$$q_{k0} k_0 = q_{k} \;\; k \tag{9}$$

$$q_{S0} S_0 = q_{S} \;\; S \tag{10}$$

## 3.2 Modelling positions

The interest, defined by the model (1) – (10), is the reference point to which the economic consequences of a proposed treaty are compared. We assume that no country is able to affect concentrations notably by one-sided actions. When adapting to a treaty, the countries therefore no longer need to relate their abatement directly to the damage costs, because the appropriate actions necessary to deal with the damages are settled implicitly by the treaty. The optimisation problem then shifts to one subject to an exogenous emission target. We use the same notation as in section 2.1. The problem is to

$$\max_{x,y} \int_0 w(x \;\;) e^{-\delta} \, dt \tag{11}$$

subject to

$$\dot{k} = f(k, S, t) - x - y \tag{12}$$

$$\dot{S} = \alpha S + h(t) \tag{13}$$

$$\varepsilon \geq g_1(k) - g_2(y) \tag{14}$$

*h(t)* represents global emissions of greenhouse gases. These are being defined by the proposed treaty, and are exogenous to the decision-maker. This means that the treaty includes emission targets for each year over the whole planning period, denoted by $\varepsilon$.

Let $p_k$ denote the shadow price of real capital (denoted $q_k$ in the former section) and $\lambda$ the shadow price of the emission target. The Hamiltonian in this case is

$$H_P = w(x)e^{-\delta t} + p_k\left[f(k,S,t) - x - y\right] - \lambda\left[g_1(k) - g_2(y) - \varepsilon\right]$$

Note that the evolution of $S$ can be considered exogenous in this case. The first order conditions for instantaneous equilibrium are

$$p_k = w'_x e^{-\delta t} \tag{15}$$

$$p_k = \lambda g'_2 \tag{16}$$

Both correspond to the conditions when modelling interests, but differ since the contribution to welfare from abatement now relates to the emission target instead of the damages of climate change. In the present case, we have

$$\lambda = 0 \;\; if \;\; \varepsilon > g_1(k) - g_2(y)$$
$$\lambda > 0 \;\; if \;\; \varepsilon = g_1(k) - g_2(y)$$

The condition for intertemporal equilibrium is

$$f'_k - \lambda g'_1 = \delta + \mu_x \frac{\dot{x}}{x} = \rho_k \tag{17}$$

Since the evolution of greenhouse gas concentration is exogenous, there is no corresponding intertemporal condition. The intertemporal condition for investments in real capital differs from the corresponding condition when modelling interests. In the present case, the welfare increment of postponing consumption is related to the return on productive capital. If the emissions are lower than the target $\varepsilon$, the return on capital is not adjusted for the social cost of the emissions. When the target is reached, the social cost of emissions is reflected by the shadow price of the emission target. The explanation for this difference is that the country could affect the level of damages when modelling interests, since they 'dictated' the treaty for all other countries. Then, the damages of climate change are within the domain of control for the country. When modelling positions, this is not the case. This difference can be regarded as similar to the cases of monopoly vs. competitive markets: The monopolist is able to affect market prices by adjusting own supply, while the competitive firm is not.

When modelling positions, only the capital stock is subject to a "sustainability condition":

$$p_{k0}k_0 = p_{kT}k_T \tag{18}$$

The terminal value of $S$ follows from the emission target.

The final question is how to measure the cost of a treaty. Most macroeconomic studies of climate policy measure the costs of emissions abatement in terms of reductions in GDP. GDP is a proper welfare measure in highly stylized growth models (Weitzmann, 1976), but fails to measure welfare in less restrictive models (Brekke, 1994, Asheim, 1994). How to measure the cost of a proposal is, therefore, not clear. Since the model maximizes welfare generated by consumption over a given time horizon, some of the costs arises because the consumption path chosen under a negotiated treaty differs from the 'first best' path developed when appraising interests. The cost of a different consumption path can be measured in terms of the present value of the consumption loss over the whole period. In the models presented above, this is $\int q_{kt}(x_t^I - x_t^P)\, dt$, where the top-scripts $I$ and $P$ refer to the solutions of the interest model and the position model, respectively. Everything else being equal, the costs are positive if the path given by the position model diverges from the optimal path. However, the position may be elaborated under a less ambitious climate policy than actually preferred by the country. Then, this term may be negative since the emission target may allow for more consumption than initially preferred. Although obvious, this effect of a non-optimal climate policy is seldom realized, something that may have contributed to exaggerate the 'pure' economic cost of climate policy.

The cost faced by a country that has to adapt to a less restrictive global climate policy than they prefer is related to the deterioration of the state of the atmosphere. This is partly captured by the experienced damage costs, which affect consumption and is thereby included in the cost component above, and partly by the value of the stock resource, atmospheric concentrations of greenhouse gases. This component can be interpreted as a loss of wealth, or increase in national debt. In terms of the models, the value of this debt can be written $q_{S,T}(S^I{}_T - S^P{}_T)$. Hence the total cost of a proposed treaty can be written as

$$C = \int_0^T q_{1t}(x_t^I - x_t^P)dt + q_{ST}(S_T^I - S_T^P) \tag{18}$$

# 4 Data availability and requirements

Some basic assumptions behind estimates of the impacts on climate policy of economic development and preferences were discussed in section 2. In addition, an appraisal of interests and positions is heavily based on estimates of the costs of mitigating climate change and the benefits in terms of lower damage costs. Ideally, there ought to be consensus about such estimates, but the fact is that estimates of abatement and damage costs exhibit large variations.

## 4.1 Abatement costs

Abatement costs are partly related to the structure and the level of development of the economy in question. The dependency of energy, the composition of energy carriers in the energy demand, and the possibilities for substitution among activities, from emission intensive to less emission intensive, are essential elements of the national abatement costs. To some degree, these factors may be taken properly into account by an extension of the macroeconomic models by sectors and commodities. In addition, a variety of options may be available if new, but known, technologies are introduced. In the models above, both categories will have to be assembled in the abatement cost function, $y = g_2^{-1}(de)$, where *de* is the abated amount of emissions

Abatement costs related to macroeconomic characteristics could be estimated by means of macroeconomic studies of emission cuts. A great number of such studies been published in later years; most of them are reviewed in Hourcade et al (1995). Reported 'observations' of cost estimates in terms of reductions in GDP for various cuts in $CO_2$ emissions in the US, Japan and various EU countries are shown in figure 1.

The figure illustrates the difficulties in achieving a uniform picture of national abatement costs. Some of the differences between the estimates may be due to assumptions made about the influence of policies in other countries, year of reference, whether or not emissions trading are assumed, etc. Other factors are less apparent. In the USA the Energy Modeling Forum aligns various studies in order to "wash out" possible differences caused by assumptions. Although the costs in US studies display a much more congruent picture than the costs in the EU and Japan, the lowest and the highest estimates for the USA nevertheless differ with a factor of 2. Although there have been some attempts to make a meta-estimate of a cost function for different countries and regions on the basis of point estimates of costs (see e.g. Tol, 1997), estimates available to me did not give appropriate results. The cost function turned out either concave or with negative marginal costs.

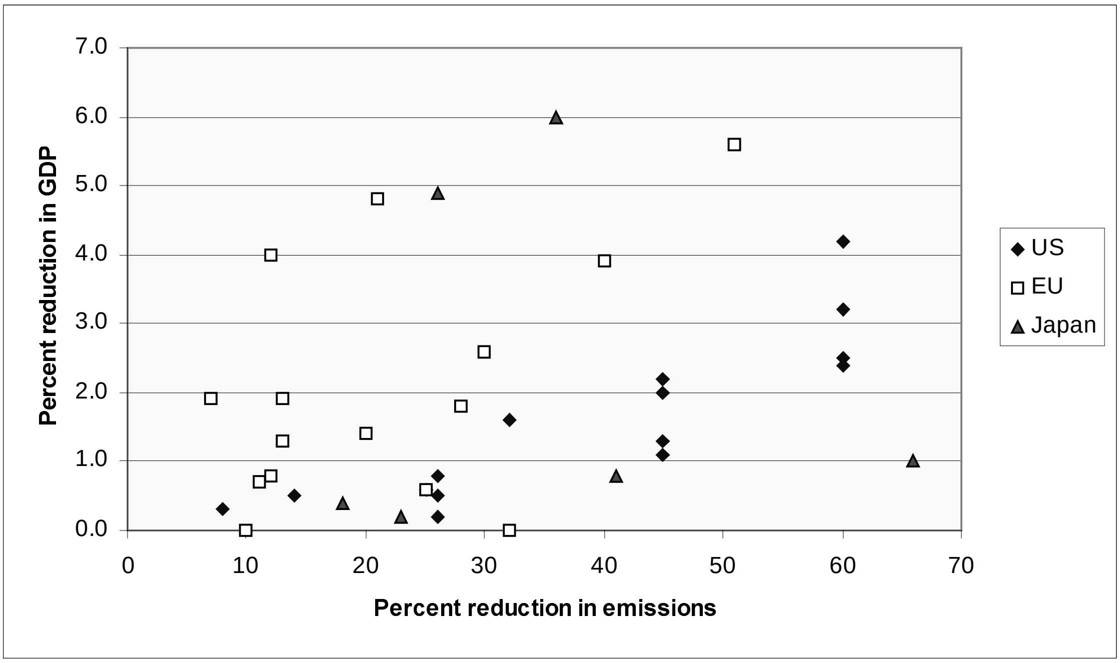


**Figure 1: Estimated reductions in emission cuts in various studies reported in IPCC (1996b).**

The options for introducing new technologies to reduce emissions have also been studied thoroughly.[7] These studies are usually based on so-called bottom-up approaches, which emphasise the description of technologies, and the effects on emissions. Again, it is difficult to get a congruent picture of the costs of abating emissions of greenhouse gases. Moreover, it is very difficult to make a clear distinction between costs included in the macroeconomic model studies and these bottom-up studies. However, bottom-up studies of technology options indicate that substantial emission cuts may be achieved at zero or even negative costs.

The results of most bottom-up studies suggest that the costs estimated by top-down models might have been overestimated. Moreover, there are additional factors not taken into account in most studies that may contribute to a reduction in the cost estimates. Cuts in the emissions of greenhouse gases usually lead to cuts in other emissions that cause local pollution. The benefits from the associated enhanced environmental quality should have been subtracted from the abatement costs of climate measures. Alfsen et al. (1992) and Aaheim et al (1998) show that these benefits may be substantial. Moreover, to the extent that emissions are reduced by means of emission charges there is a possibility for improvements of the effectiveness of the tax system, thereby yielding a so-called double dividend. Bovenberg and van der Ploeg (1998) argue, however, that the magnitude of this effect is unclear.

To sum up, it is not an easy task to attach abatement costs to single countries. We have pointed out some factors that may indicate that estimates based on macroeconomic model studies, which vary greatly themselves, may be too high. Some factors may work in the other direction. For example, it has been argued that the possibilities for substitution among commodities and sectors are exaggerated in most macroeconomic models. This may lead to biases and substantial underestimation of costs in the long-term. The numerical analysis in

[7] see e.g. IPSEP, UNEP, Kram and Hill (1995).

this paper is meant merely as illustrations of the approach. We have therefore chosen parameters of the cost function such as to calibrate the interests through the proposed emission target prior to the Kyoto meeting for each party.

## 4.2 Damage costs

The information about abatement costs is relatively complete, compared with what we know about the damage costs. IPCC (1996) sums up the state of knowledge about possible impacts of climate change, such as sea level rise and the consequences thereof, human health, extreme weather events, bio-diversity, and direct losses to economic sectors. Common to any assessment of these effects is the wide range of uncertainties. It is difficult to say whether a particular effect will turn up at all, how strong the effects are likely to be at a certain level of temperature increase, and how the effects will be diversified among regions and countries. In addition, there is a considerable uncertainty related to estimates of the temperature increase at a given level of concentrations. The IPCC suggests a range between 1.5°C and 4.5°C, with a 'best guess' of 2.5°C at a doubling of the concentrations of $CO_2$ relative to pre-industrial level ($2\times CO_2$).

An assessment of the impacts in physical terms is, however, simpler than to attach the damage costs to them. For some impacts, such as damages imposed on economic activities, one may base cost estimates on observed market prices. For other impacts it is impossible to assign values properly by means of observed prices. An alternative is to apply 'virtual' prices. However, the methods for estimating virtual prices, such as contingent valuation, hedonic pricing, or implicit valuation, are controversial, (see e.g. Arrow et al., 1992). This adds considerably to the uncertainties of the damage cost estimates.

Despite these objections, there are a number of available studies containing estimates of damage costs.[8] These studies apply widely different estimates on single effects, but there is a better concurrence when adding all effects into an estimate of the aggregate damage cost for a whole country or region. The estimates for damages for the US at $2\times CO_2$ vary between 1.1 percent and 1.5 percent of GDP in 4 of 5 studies. In the fifth study, the damage cost was estimated to be 2.5 percent of GDP, but that is largely because the assumed temperature increase at $2\times CO_2$ was 1 - 1.5 C° higher than in the other studies. There are fewer studies on other regions of the world. Estimates of Tol (1995) and Fankhauser (1995) tend, however, to exhibit better concurrence for rich regions than for poor. Tol (1995) estimates damage costs at $2\times CO_2$ in countries outside OECD, the former 'East Bloc'-countries and China to lie between 4 and 8.7 percent of GDP dependent on region. Fankhauser's estimate is 2 percent.

These estimates are point estimates giving the 'best guess'. If the uncertainty is taken into account, the expected damage costs are significantly higher. How much higher depends, apart from the range of uncertainty, on the relationships between increasing temperature, the co-variation between various impacts and the damage costs. Tol (1995) points out that if the uncertainties are large enough, the best guess estimate may turn out lower than the lower bound of a reasonable confidence interval. With conservative assumptions about the uncertainty, he estimates the expected damage costs to be between 2.5 and 3.5 times as high as the best guesses. Although we stick to a non-stochastic analysis in this study, this

[8] See for example Nordhaus (1993), Cline (1992), Titus (1992), Fankhauser (1995), Tol (1995).

discrepancy between expected costs and costs of the expectation gives some explanation why it is difficult to relate model estimates to observed behaviour.

Another weakness is that damage costs are described as a relation between temperature increase and a single economic term. Climate change affects a variety of factors that may lead to positive or negative damage costs, such as land cover change, sea level rise, human health, etc. Generally, the relation between temperature increase and damage differs widely between these factors, and between countries. Moreover, the vulnerability with respect to the different factors may depend on the measures taken to mitigate or adapt to climate change. For example, it may be possible to adapt to a dryer climate by growing new cereals in one area, while such a reorientation of agriculture is impossible in another. A diversification of measures on different factors will also affect the uncertainty of the damage costs differently. The abatement cost and damage cost functions in this paper do not capture such differences. It is assumed that mitigation and damage of climate change imply one and only one set of measures and one and only one set of impacts.

Although a country's interests in climate negotiations cannot be appraised properly without an assessment of the expectations in terms of damages, it is extremely difficult to make such an appraisal. However, also the negotiators are faced with this difficulty. Therefore, it is not necessarily fatal for an analysis of the interests and positions not to have "true" estimates of damage costs. What is likely to be the driving force behind the climate process is the subjective perception of problems related to climate change. In such a context, estimates of damage costs actually made may be more influential than beliefs about different impacts, and how they are related to each other. At least, this is the weak excuse for using a set of available damage cost estimates in this study.

# 5 Numeric illustrations

In this section, we present some illustrative calculations of interests and position for the US, EU and Japan. Because of the limited availability of data, and because the main purpose of the calculations is to demonstrate how to interpret the results, the input to the calculations are partly chosen such as to emphasise differences, in particular with respect to damage costs and abatement costs. To set the parameters of the production function, it is assumed that the net return on real capital is equal in all three countries, 5.5 percent. The capital stock is found by interpreting net domestic product (NDP) less consumption as the return. This leads to a relatively capital intensive production in Japan, while the US and EU has approximately the same capital intensity. The differences between Japan and US/EU are probably exaggerated because of Japan's capital export, which is disregarded here. The parameters of the log-linear production function are calibrated through the 'observations'. The rate of innovation is assumed to be the same in all the countries, 2 percent per year.

The abatement cost functions are also log-linear, and the parameters of the cost functions are chosen such as to make the interests align with the emission targets for 2010 proposed by the respective countries prior to the Kyoto meeting.[9] This leads to the following costs in terms of reductions in GDP at 10 and 30 percent reductions in $CO_2$ emissions:

**Table 1: Assumptions about abatement costs. Percent of GDP.**

| Reduction in emissions | USA | EU | Japan |
|---|---|---|---|
| *10 percent* | 0.010 | 0.005 | 0.015 |
| *30 percent* | 0.20 | 0.08 | 0.25 |

Compared with the estimates displayed in figure 1, these costs are very low. In practice, they indicate that emissions can be reduced by up till 30 percent by no-regret options. A reason why the proposals are based on lower cost estimates than those shown in the top-down studies were discussed in section 4. Note, however, that for instance the number of options to abate greenhouse gas emissions at very low costs is restricted. Low costs for 30 percent reduction does not mean that 50 or 60 percent reductions can be obtained at a reasonable cost. However, the cost function applied here does not allow for such a shift in the costs at a certain level. An incorrectly specified cost function may therefore lead to a serious bias in the optimal policy if the emission cuts are large. This is partly because low costs may cause abatement to be postponed to an extreme extent in optimal growth models. With very long time horizons, emissions may then turn negative towards the end of the period.

The damage costs enter the production function by the percent reduction in GDP, with reference point $2 \times CO_2$. To calibrate the parameters of damage costs, we apply the estimates in Tol (1993) reported in table 3. In addition, we have to make an assumption about the marginal damage costs at increasing levels of concentrations. Many studies adopt the Nordhaus' (1993) assumption, a cost-function with exponent 3. In this study, we use exponent 2. For

[9] The proposals that were taken as the point of departure was US: -3 percent from 1995 – 2010 (US changed their proposal from stabilisation to –5 percent a few days before the Kyoto meeting.), EU: -15 percent from 1995 – 2010, Japan: -5 percent 1995 – 2010. Note that the actual proposals were stated with reference to 1990.

concentration levels lower than 2×$CO_2$ the damages are then higher than Nordhaus', while for levels above 2×$CO_2$ the damages are lower. The time horizon is 50 years, and the concentration level never reaches 2×$CO_2$ in this period. This means that the damages are considered to be somewhat higher in the present study than in those who apply Nordhaus' guess.

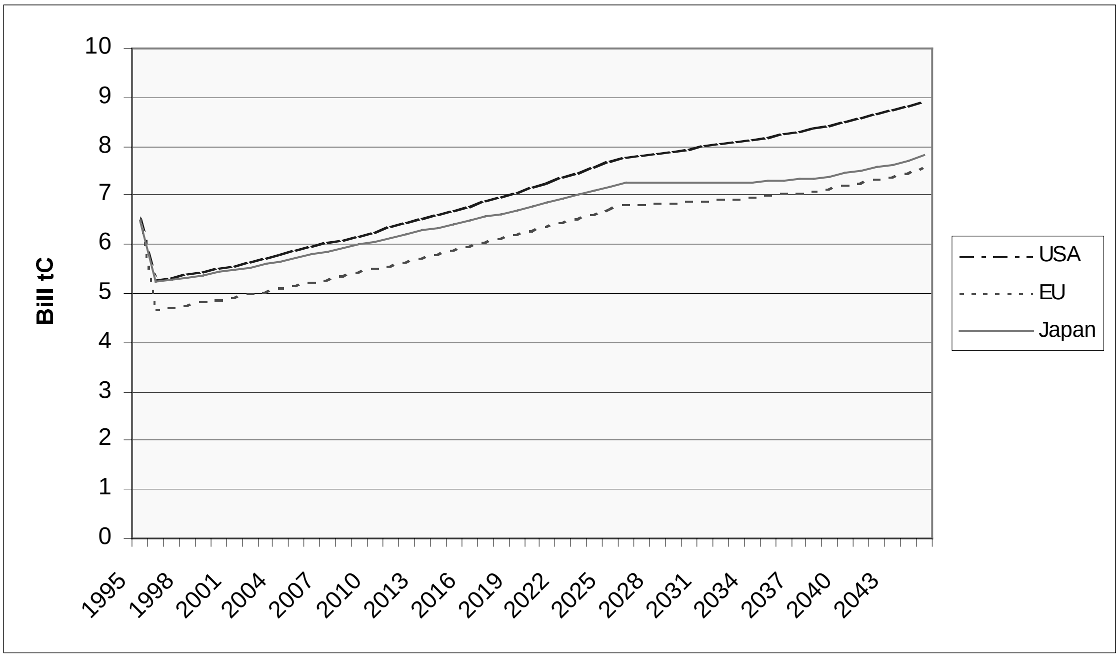


**Figure 2: Optimal world emissions according to country interests. Bill tC.**

The optimal paths for world emissions of $CO_2$ according to the interests of US, EU and Japan are shown in figure 2. The emission cuts in 2010 correspond approximately to the proposals prior to Kyoto. Japan's immediate reduction in emissions is more moderate than for the two other countries of we compare with the emission cuts over the entire period. This is due to the higher costs, both with respect to damage and abatement in Japan. Since the damages from global warming is relatively low at present, a postponement of abatement is therefore more attractive to Japan than for the two other countries. With regard to emission cuts, Japan's interests then concur with those of US in the near future, but approach EU's interests in the long run.

From figure 2, the US is the least willing to spend resources on reducing $CO_2$ emissions. One explanation is of course that US is expected to face relatively low costs of climate change and moderate abatement costs compared with EU and Japan. EU's damage costs are slightly lower than the damage costs in the US, but the abatement costs are assumed to be much lower. Another important reason for the reluctant attitude in the US is that they expect a lower economic rate of growth. Without any abatement, the emissions for the US increase by 0.6 percent per year. In Japan, the growth rate is 1.5 percent, while the growth rate for the EU is nearly 0.8 percent. The high economic growth rate in Japan is due to a high saving ratio. Present consumption thereby becomes more important relative to future consumption, and Japan therefore puts more emphasis on future abatement. The opposite is the case in the US, and partly in the EU, where future consumption plays a more important role.

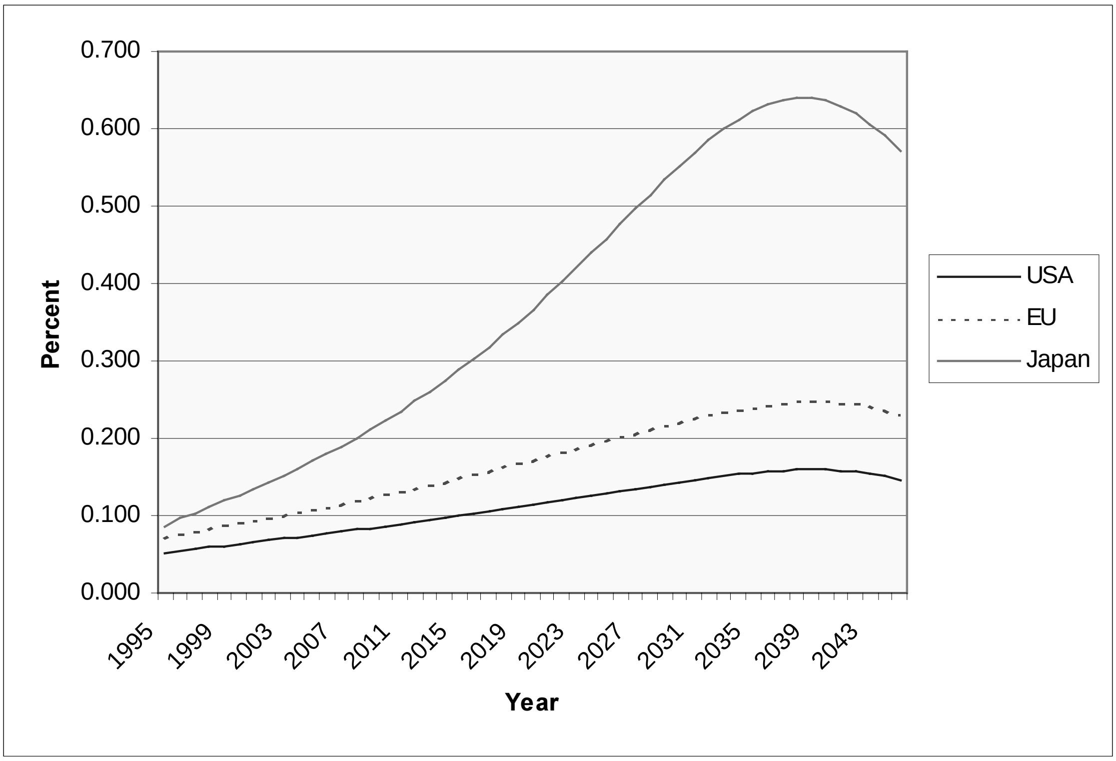


**Figure 3: Optimal abatement costs according to interests by country. Percent of GDP.**

While the US spends between 0.05 and 0.15 percent of their GDP on abatement, Japan spends up till 0.7 percent and EU spends between 0.1 and 0.25 percent of GDP. Recall that EU obtains considerably more emission reductions for each dollar spent on abatement than the other two. Nevertheless, these costs are considerably lower than other estimates of costs, but the emission cuts do not exceed 30 – 35 percent over the period. A bias due to large cuts in emissions is therefore not likely to be severe.

As stated earlier, the results are based on a highly uncertain set of data. Thus, it may be useful to study how sensitive the results are to changes in main assumptions. Figure 4 shows how the optimal path for world emissions is affected by changes in the cost function and the damage cost assumptions for the EU. The base case refers to the assumptions underlying the comparisons between US, Japan and EU above. In the high damage cost alternative, the damage costs at $2\times CO_2$ are assumed to be 3.5 percent of GDP, while the abatement costs are similar to the base case. In the high abatement cost alternative, the cost of 10 percent emission reduction is set to 0.25 percent of GDP, and the cost of 30 percent reduction is 2.5 percent of GDP. The damage is 1.3 percent of GDP at $2\times CO_2$, as in the base case.

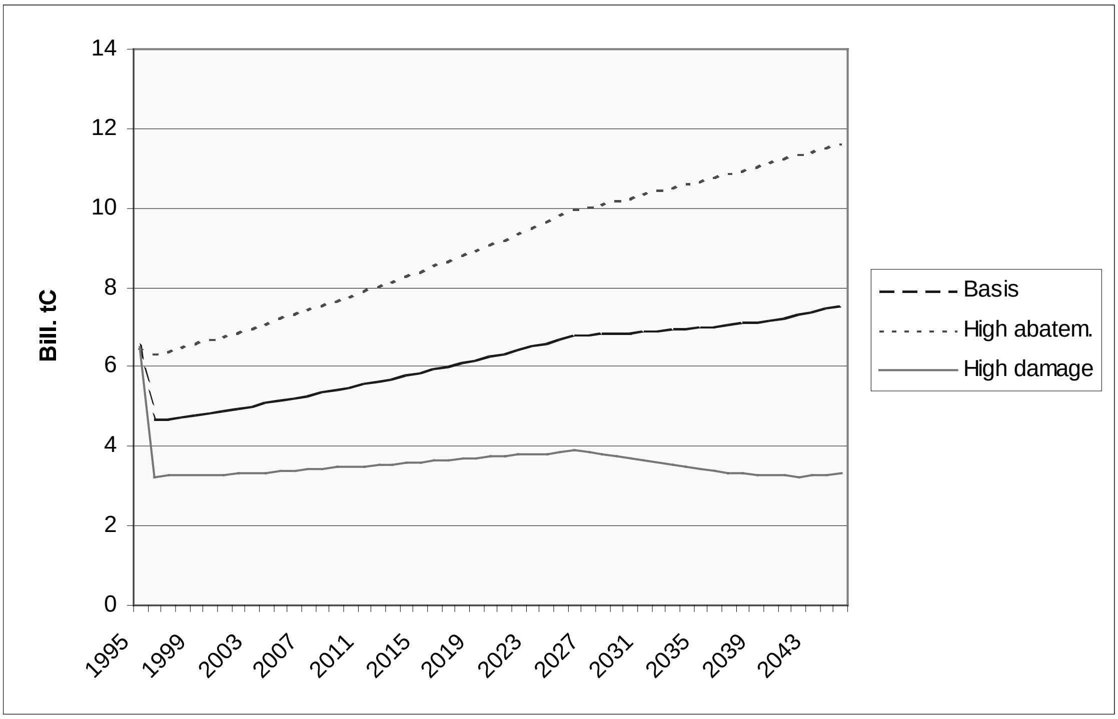


**Figure 4: Optimal emission paths for EU with alternative abatement and damage costs.**

In the high damage cost alternative, the emissions according to EU interests are more or less stabilised in a 50 years perspective at a level 45 percent lower than present emissions. The high cost alternative implies a steady increase in the emissions and very moderate abatement. According to the figure, differences in abatement costs and damage costs affect the level at which the optimal emission path should start, and the trend at which emissions should grow. The allocation of abatement over time follows the same pattern in all the three cases, that is, to start at a relatively moderate level and increase abatement costs over time.

We have calculated the positions in terms of total social costs (see equation 18) for 8 alternative proposals. Three of them are the ‘best’ treaties, calculated according to the interests of the US, Japan and EU respectively. These can be regarded as the social cost imposed on the other two countries under a Stackelberg solution. In the remaining five alternatives, we take the Kyoto meeting as the point of departure. Three alternatives include the Kyoto protocol of 6 percent reduction (i.e. we abstract from the differentiation). The three differ with respect to cuts beyond 2010. In the weak alternative, there is an increase in emissions from 2010 to 2025 to the 1995 level, and a further increase from 2025 to 2050 of 10 percent. In the medium alternative we assume an increase to the 1995 level from 2010 to 2025, and stabilisation beyond 2025. The strong Kyoto alternative implies a reduction of 15 percent in 2025 and 30 percent reduction in 2050 compared with 1995. One alternative implies stabilisation from 1995 to 2050. The last alternative implies a breakdown of the negotiations, which means that emissions follow IPCC IS92 scenario. The results are displayed in table 2.

**Table 2: Social costs from alternative proposals by country. Ranking of alternative in paranthesis.**

| Alternative | Emission targets (relative to 1995) | US | Japan | EU |
|---|---|---|---|---|
| *US' best* | 2010: -3%<br>2025: 19 %<br>2050: 38 % | 0.1<br>(1) | 22.5<br>(3) | 9.9<br>(3) |
| *Japan's best* | 2010: -6%<br>2025: 11 %<br>2050: 21 % | 4.7<br>(2) | 13.7<br>(1) | 0.9<br>(2) |
| *EU's best* | 2010: -15%<br>2025: 4 %<br>2050: 17 % | 21.7<br>(3) | 22.4<br>(2) | -2.9<br>(1) |
| *Weak Kyoto* | 2010: -6%<br>2025: 0%<br>2050: 10% | 156.1<br>(5) | 228.0<br>(7) | 134.7<br>(7) |
| *Medium Kyoto* | 2010: -6%<br>2020: -0%<br>2050: 0% | 148.1<br>(4) | 197.3<br>(5) | 115.6<br>(5) |
| *Strong Kyoto* | 2010: -6%<br>2020: -15%<br>2050: -30% | 195.4<br>(7) | 139.8<br>(4) | 73.6<br>(4) |
| *Stabilisation* | 2010: 0%<br>2020: 0%<br>2050: 0% | 157.5<br>(6) | 215.3<br>(6) | 131.5<br>(6) |
| *No agreement* | 2010: 28%<br>2020: 65%<br>2050: 95% | 280.2<br>(8) | 443.9<br>(8) | 287.1<br>(8) |

All countries give highest priority to their best treaty. However, for Japan, the cost of following an exogenous target 'dictated' by themselves is significant compared with the case where they could act as a Stackelberg leader. In fact, the costs to Japan are higher for Japan itself than for the two other parties. This is an effect of the difference between knowing that everyone else follows you and being told what to do. This effect becomes significant to Japan because of their relatively high damage costs. Note also that EU has a negative cost of its own proposal. This is probably due to numeric inaccuracies. For the other five alternatives, EU and

Japan concur with respect to the ranking. The US prefers a weaker prolongation of the Kyoto agreement than the other two. To the US, a slight increase in emissions till 2025 and then, stabilisation is better than a steady reduction in emission or a steady increase in emissions. Japan and the EU prefer a strong prolongation of the Kyoto protocol to the other. It may also be noted that no agreement is clearly the least preferred outcome to all the parties. This conclusion seems to be quite robust, and one might be tempted to use this as an explanation of why the Kyoto conference was completed with an agreement. Recall, however, that all the runs displayed in table 2 are based on the assumption that the emission target applies for all countries of the world. One should therefore be very cautious about using the results to explain the negotiations in Kyoto.

The costs displayed in table 2 consist of two terms, one related to the consumption loss from following a non-optimal path, and one to the loss in the value of concentrations. The positions of different countries may be subject to different views as to how consumption and sustainability should be emphasised. In figures 5, 6 and 7 the total costs are divided into these categories for the eight alternatives for each country.

The results show that a ranking of the alternative treaties according to the loss of consumption within the planning period, which is focused in most studies of the costs of alternative international treaties, may give a quite different picture than a ranking according to the total cost. A strong Kyoto agreement, which is preferred by Japan and EU to all alternatives except for the Stackelberg solutions, comes out as the weakest alternative among all if focusing on the consumption loss alone. Not surprisingly, the alternative with no agreement becomes much more attractive when considering the consumption path alone. But it should be noted also, that the Stackelberg alternatives are better in terms of the consumption path than no agreement for all the three parties. In other words, the damages of climate change restrict consumption if no agreement is obtained (and ratified) to such an extent that an agreement may enhance the feasible consumption possibilities within the period considered here.

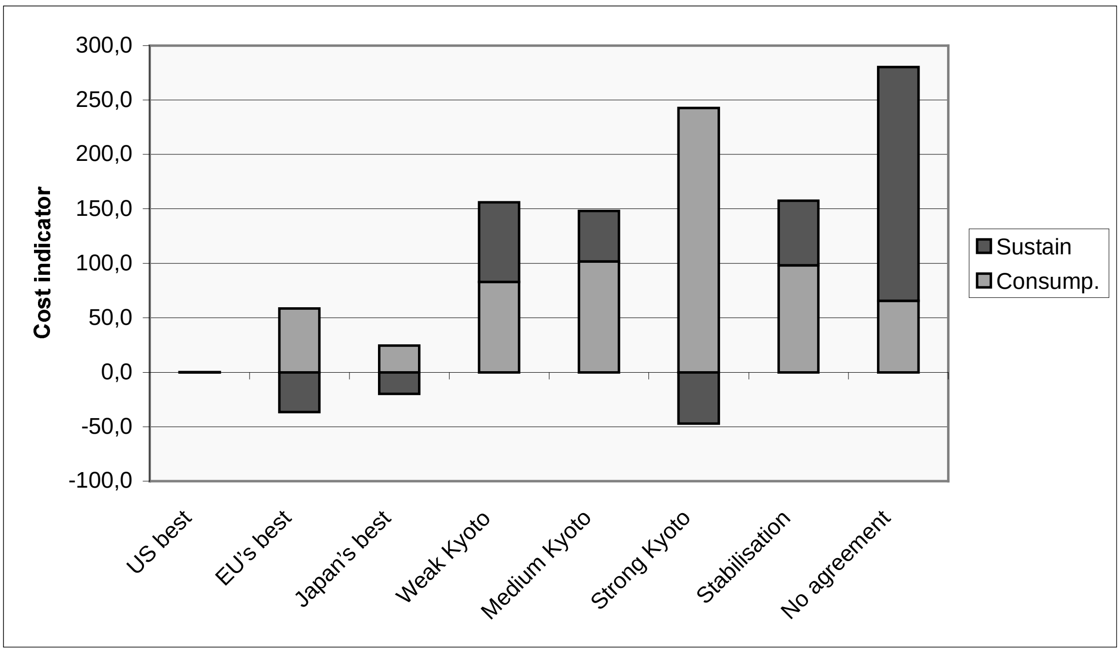


**Figure 5: Cost components of alternative treaties for the US.**

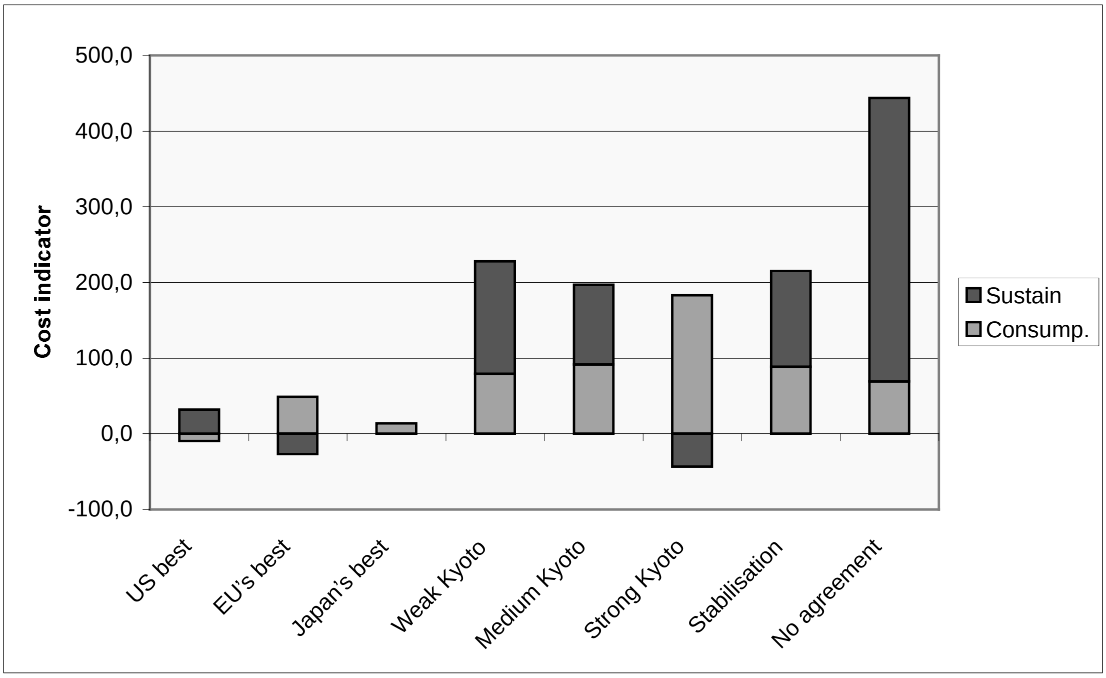


**Figure 6: Cost components of alternative treaties for Japan.**

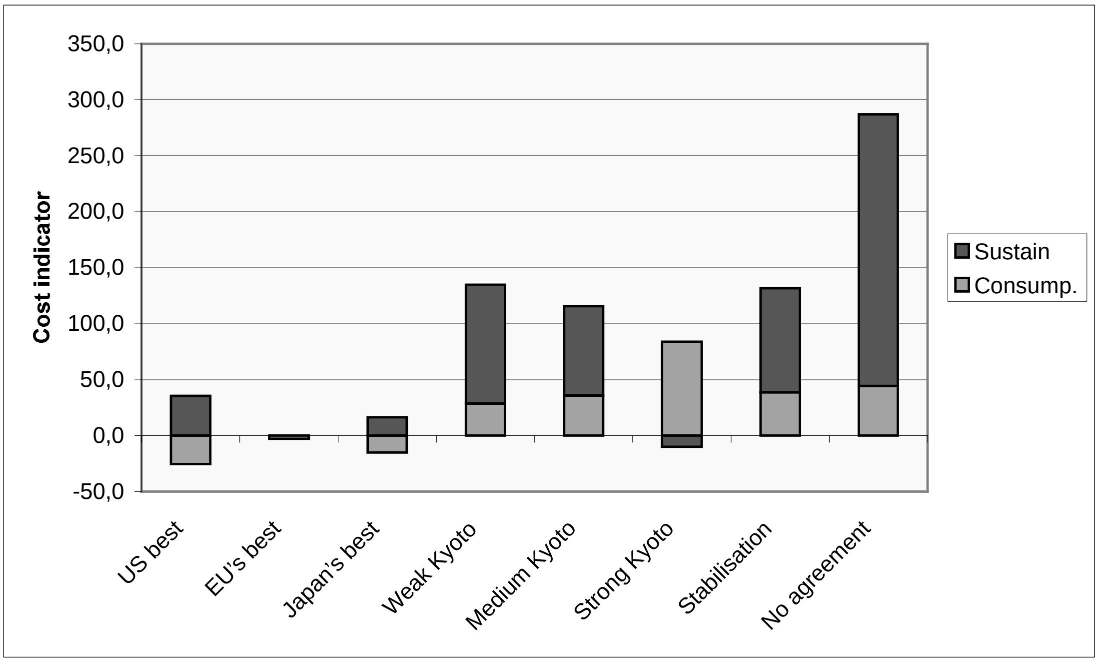


**Figure 7: Cost components of alternative treaties for EU.**

To sum up, the illustrations indicate that all the three major actors in the climate process have relatively strong motivations to succeed in obtaining long-term agreements to reduce emissions of greenhouse gases. A crucial element of each party's consideration of the agreement is how strong a sustainability criterion is regarded. Although this may be reflected by different political views, such as those between environmentalists and supporters of traditional economic growth, it must be emphasised that the sustainability criterion applied in the calculations above indirectly relates to consumption beyond the terminal year 2045. Hence, 'pure' environmental values are not considered in this study.

# 6 Concluding remarks

This paper suggests one way to establish a pay-off matrix for alternative outcomes of climate negotiations for a country. The model applied here is very aggregated, and allows only for a rudimentary representation of different countries. In principle, the model could be expanded e.g. by disaggregation to account for a wider range of differences between countries. More details might, on the other hand, make a comparison between the countries more complicated. Another weakness of the approach is that it is based on highly uncertain information about abatement and damage costs. This applies, however, to any attempt to establish a pay-off matrix of alternative climate treaties. The question may be whether damage cost estimates are of such a quality that they can say anything about damages at all. The problem is that damage costs cannot be ignored if we try to answer what the level of action in different countries ought to be. Moreover, the relation between own and global emissions is vital, but basically unknown. This would be a significant problem if we tried to predict global warming, but is less problematic when we try to predict what the negotiators believe. Finally, the model is a long-term equilibrium model with targets for an emission path, while the climate negotiations focus targets for a given year. This complicates the analysis of negotiations, since there are many pay-off matrixes valid for one target year. On the other hand, information about the alternative paths that go through a target for a given year is also useful.

Therefore, the long-term perspective also represents an advantage, since it allows interests and positions to be affected by long-term interests. Although targets for a particular year are focused in the negotiations, interests and positions in climate policy are mainly subject to long-term concerns. An example of how important this is, look again at Japan, for which the optimal emission path concurs with US in the beginning and EU in the end. Hence the 2010 target is similar that of US. However, Japan's cost of US' best path is much higher than if EU's best path is chosen. A second advantage with the approach is that it allows for an assessment of the basic economic interest of each country based on assumptions about abatement costs and damage costs. A lot of studies concentrate on the level and the distribution of abatement cost of a co-ordinated climate policy among countries. The importance abatement cost is easily exaggerated by such an approach, because damage costs are uncertain. This paper shows, however, that damage costs may be equally or more important to climate policy making than abatement costs. Third, the approach provides an explicit treatment of the sustainability criterion, which is unusual in economic analyses of climate policy. The results show that the ranking of alternative proposals may change significantly if the sustainability criterions are overlooked.

The numerical illustrations were based on rude data, and the assumption that all countries of the world participated in a climate agreement. Therefore, one has to be cautious with the conclusions. However, they show, first, that an economic evaluation of costs and benefits may give rise to relatively large differences in interests, and different ranking of alternative proposed treaties. This is somewhat surprising because other studies by intertemporal growth models indicate very low action at present of all countries (Nordhaus, 1993, Manne et al., 1994). Second, the long term nature of the climate change problem makes it difficult to make firm conclusions about interests and positions on the background of positions taken to targets for one year. The concern is rather whether the target for a year is acceptable in relation to the long-term interest of the country. Third, the evaluation of sustainability is important for the positions taken to alternative agreements.

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# This is CICERO

CICERO was established by the Norwegian government in April 1990 as a non-profit organization associated with the University of Oslo.

The research concentrates on:

- International negotiations on climate agreements. The themes of the negotiations are distribution of costs and benefits, information and institutions.

- Global climate and regional environment effects in developing and industrialized countries. Integrated assessments include sustainable energy use and production, and optimal environmental and resource management.

- Indirect effects of emissions and feedback mechanisms in the climate system as a result of chemical processes in the atmosphere.

Contact details:

CICERO
P.O. Box. 1129 Blindern
N-0317 OSLO
NORWAY

Telephone: +47 22 85 87 50
Fax: +47 22 85 87 51
Web: www.cicero.uio.no
E-mail: admin@cicero.uio.no