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ECONOMIC EFFECTS OF CLIMATE CHANGE: AN ESTIMATE FOR FINLAND

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ABSTRACT: This study surveys the cost-benefit analyses concerning climate change. The previous analyses differ greatly both in conceptual framework and in results. Based on the previous papers, an estimate is made for the economic effects of the climate change in Finland. Due to uncertainty inherent in the global warming, the results are presented in three different estimates: pessimistic, central and optimistic. According to the central estimate, which is thought to be the most probable one, Finland would benefit from the global warming during 2030-2050 by an amount corresponding to as much as 0.9 per cent of the 1990 GDP. However, the indirect consequencies of the climate change can be strongly negative. Furthermore, Finland may have to support other countries, e.g. as a future member of the EC or by increasing its development aid.

The emphasis of this study is on the 50-year time span. This may not be long enough when the benefits of the greenhouse warming abatement are considered. Only 25 per cent of the foreseen global warming will be avoidable during the next 50 years. However, the warming can be stabilized on a longer perspective at a level, which corresponds to the business-as-usual scenario in the coming 50 years. This equilibrium state is compared to the prognosed development if no preventive steps are taken during the next 200 years. The benefits of the global warming abatement for Finland are estimated to be FIM 100-450 per reduction of a tonne of CO_2 emission, calculated with a 1-0 per cent discount rate. When discounted at a higher rate the benefits are more or less negligible.

KEY WORDS: climate change, greenhouse effect, cost-benefit analysis

KINNUNEN, Jouko, **ILMASTONMUUTOKSEN TALOUDELLISET VAIKUTUKSET: ARVIO SUOMELLE**. Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 1993. 35 s.

TIIVISTELMÄ: Tutkimuksessa luodaan katsaus ilmastonmuutoksen taloudellisten vaikutusten arvioihin. Ne eroavat toisistaan perusteiltaan ja tuloksiltaan huomattavasti. Tutkimuksessa rakennetaan kokonaiskuva ilmastonmuutoksen taloudellisista vaikutuksista Suomessa ensi vuosisadan puoliväliin mennessä. Ilmastonmuutokseen liittyvän epävarmuuden vuoksi tulokset esitetään pessimistisenä, keskimmäisenä ja optimistisena arviona. Todennäköisimpänä pidetyn keskimmäisen arvion mukaan ilmastonmuutoksesta aiheutuisi hyötyä Suomessa vuosina 2030-2050, jonka suuruus on noin 0,9 % vuoden 1990 BKT:sta. Ilmastonmuutoksen välilliset vaikutukset voivat kuitenkin olla voimakkaan negatiiviset. Suomi saattaa mm. joutua avustamaan muita maita esim. EY-jäsenyyden vuoksi tai kehitysavun muodosssa.

Tutkimuksen pääpaino on noin 50 vuoden aikavälillä. Tämä aikaväli ei kuitenkaan ole riittävä tarkasteltaessa kasvihuonekaasujen päästöjen rajoittamisesta saatavia hyötyjä, koska tulevasta ilmastonmuutoksesta vain noin neljännes on vältettävissä seuraavien 50 vuoden aikana. Pidemmällä aikavälillä ilmasto voidaan tasapainottaa tilaan, joka vastaa nykyisen kehityksen mukaista tilaa 50 vuoden kuluttua. Vertaamalla tätä tasapainotilaa tilanteeseen, joka syntyisi 200 vuoden kuluttua ilman rajoittavia toimenpiteitä, saadaan arvio päästöjen rajoittamisen hyödyistä pitkällä aikavälillä. Täksi arvioksi saadaan Suomen osalta 100-450 mk 1-0 % diskonttokorolla laskettuna. Suuremmilla diskonttokoroilla ilmastonmuutoksen taloudelliset vaikutukset jäävät mitättömän pieniksi.

AVAINSANAT: ilmastonmuutos, kasvihuoneilmiö, kustannus-hyötyanalyysi

TIIVISTELMÄ

Tässä tutkimuksessa on käsitelty ilmastonmuutoksen taloudellisia vaikutuksia erityisesti Suomen kannalta ensi vuosisadan puoliväliin mennessä. Suomi näyttää sangen hyväosaiselta kansainväliseen kehitykseen verrattuna. Pohjois-Atlantin ja Skandinavian ilmaston muuttumista on kuitenkin muita hankalampi ennustaa, koska lämpötilan muutoksille alttiit merivirrat vaikuttavat voimakkaasti ilmastoomme. Suomen Ilmakehänmuutosten Tutkimusohjelman SILMUn "paras arvaus" on, että Suomen keskilämpötila kohoaa 0,4 °C vuosikymmenessä vuoteen 2100 asti.

Tärkeimmät haitat ja hyödyt aiheutuvat analyysin perusteella maa-ja metsätaloudessa. Metsämme eivät nykytietojen mukaan kuitenkaan näytä juuri kärsivän ilmastonmuutoksesta, jos muutos onnistutaan pysäyttämään tai oleellisesti hidastamaan ensi vuosisadan puoliväliin mennessä. Itse asiassa maamme metsätalous ja välillisesti myös metsäteollisuus voivat hyötyä nopeutuneesta metsänkasvusta sekä uusista täällä menestyvistä puulajikkeista. Samalla kasvitautien ja tuholaisten uhka kasvaa, mihin on varauduttava metsänhoidossa.

Maamme maataloussektori saattaa myös hyötyä ilmastonmuutoksesta lisääntyneenä tuottavuutena. Maatalouden sopeutumismahdollisuudet ovat metsätaloutta paremmat lyhyemmän kasvukauden ansiosta. Viljelylajikkeiden vaihto ei tuottane ongelmia, koska niitä on jalostettu runsaasti erilaisiin ilmasto-oloihin.

Jos tarkastellaan asiaa noin 50 seuraavan vuoden aikana Suomen näkökulmasta, ilmastonmuutoksen taloudelliset vaikutukset ovat tämän analyysin mukaan noin -0,5 - +1,9 % vuoden 1990 BKT:sta. Keskimmäisen arvion mukaan Suomi hyötyisi noin 0,9 prosentin verran.

Mahdollisten positiivisten muutosten vastapainoksi Suomi joutunee osallistumaan muiden maiden kustannusten rahoittamiseen.EY:n jäsenenä Suomi ei voine välttyä kantamasta osuuttaan esim. mahdollisesti lisääntyvistä ympäristöpakolaisuuden kustannuksista.

Pitkällä aikavälillä haitat lienevät hyötyjä suuremmat. 200 vuoden aikavälillä kustannusten arvioiminen on äärimmäisen hankalaa. Ilmastonmuutoksen luonteen vuoksi näinkin pitkän aikavälin kustannusarviot ovat tarpeen, koska ilmastonmuutoksen estäminen on mahdotonta 50 vuoden aikävälillä. On arvioitu, että pitkällä aikavälillä on mahdollista pysäyttää ilmastonmuutos hiilidioksidin pitoisuuden esiteolliseen aikaan verrattuna kaksinkertaistumista vastaavalle tasolle. Vertaamalla tämänsuuruisen ilmastonmuutoksen kustannuksia "jatketaan entiseen tyyliin" -skenaarion mukaisen ilmastonmuutoksen kustannuksiin saadaan arvio kasvihuonekaasujen rajoittamisen hyödyistä Clinen (1991b) esimerkin mukaisesti. Alustavana arviona saatiin tulokseksi, että 200 vuoden aikavälillä kasvihuonekaasujen rajoittamisen rajahyöty olisi 100-450 markkaa hiilidioksiditonnilta 1-0 prosentin diskonttokorolla laskettuna. Korkeammilla diskonttokoroilla rajahyöty on mitättömän pieni.

FOREWORD

The global climate is foreseen to change during the next century. The Intergovernmental Panel on Climate Change, IPCC, has among others generated considerable amount of information about the climate change from a natural science perspective. Also the Finnish Research Programme on Climate Change, SILMU, has provided interesting results that concern our country.

It is also important to make economic assessments using natural science-based results in order to determine a reasonable course of action in the face of the climate change. This is a demanding task, because the effects are felt in many areas of the economy in possibly unpredictable ways. Furthermore, a very long time span is indispensable for this kind of analysis, which makes a reasonable assessment even harder to make.

The present paper is an abridged version of the study Kinnunen (1992), published in Finnish. The aim of this study is to give an overall picture of the connections between the climate change and economy. Furthermore, an estimate for the economic effects in Finland is made. Special emphasis is put on the areas of agriculture and forestry, in which the major impacts are felt. As the objective of this study is very complicated and the economic measurement of climate change is still under development, the results should be seen as tentative attempts to monetarize these effects.

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1. INTRODUCTION

Scientific estimates of the changing climate have leapt forward during the 1980's and become sharper and more reliable. However, the integration of this approach into economic analyses is needed in order to translate the results of the natural scientists into political language. Economic evaluations are bound to run into difficulties because of the long time span and uncertainty inherent in the climate change. This study aims to shed a little light on the economic consequences of the climate change especially on the Finnish economy.

The present paper is an abridged version of the study Kinnunen (1992), published in Finnish. The study is divided into five sections after the introduction. Section two provides a brief overview on the natural scientific estimates of climate change in Finland. Section three reviews the earlier cost-benefit studies on this matter. In section four economic estimates for different impacts are made. Section five summarizes and interprets the effects presented in the previous section. Section six concludes the study. A Finnish summary is provided in section seven.

2. CLIMATE CHANGE IN FINLAND

The intensifying greenhouse effect will have large and subtle consequences for the global ecosystem and the human beings living in it. The warming is caused by buildup of greenhouse gases in the atmosphere[1]. As the composition of the atmosphere changes, so does its reflective characteristics, too. The short-wave radiation from the sun will penetrate the atmosphere as before, but the longer-wave radiation from the earth will be captured and reflected back to the earth on a larger scale. The most important human-induced greenhouse gases are carbon dioxide (CO_2), methane (CH_4), chlorofluorohydrocarbons (CFCs) and nitrous oxides (NO_x).

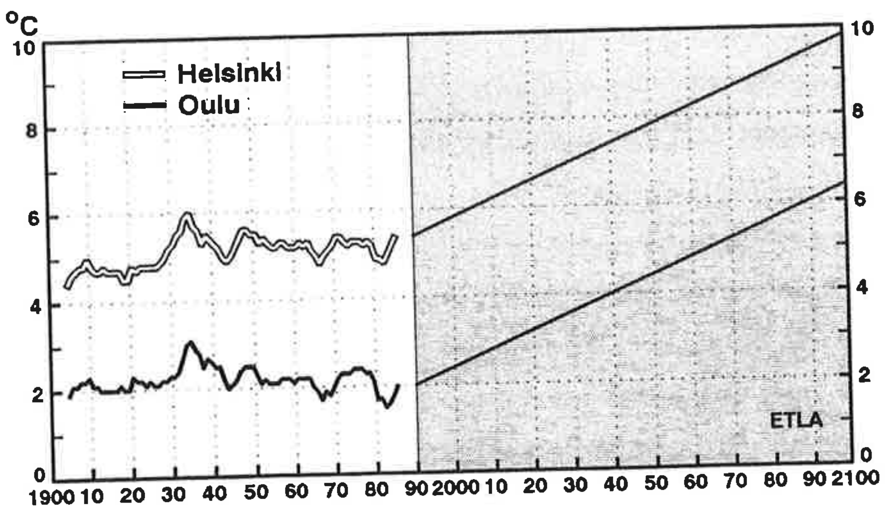
On the basis of the climate models and climate history, scientists of the

[1] The greenhouse effect is useful for the earth as such: without it the mean temperature would be -18 C instead of the present +15 C.

Intergovernmental Panel on Climate Change (IPCC) expect a global warming of 1.5 -4.5 °C by the end of the next century. However, this warming is unevenly distributed over the different climate regions. The strongest effect will be felt near the polar regions and the temperature rise will be smallest near the equator.

Presently, because of the warming impact of the Gulf stream medium temperatures in Southern and Northern Finland are about 6 °C and 11 °C higher than otherwise in these latitudes, respectively. The Gulf stream is a result of the temperature difference between the tropical Caribbean sea and the higher latitudes. The difference in temperature is foreseen to narrow, which may weaken the impact of the Gulf stream (Wahlström et al., 1992). The weakening Gulf stream might offset the warming otherwise caused by the greenhouse effect on the Northern Atlantic and in Scandinavia. This makes climate prognoses more unreliable for Northern Europe than for other areas (Jantunen - Nevanlinna, 1990).

Figure 1. Average annual temperatures and forecasts



The data are 10-year moving averages (centred plottings).
Temperature forecasts are made in accordance with that of the SILMU project.

Sources: The Finnish Meteorological Institute. Kanninen, 1992.

The Finnish Research Programme on Climate Change SILMU claims, however, that the best guess for the medium temperature increase is 0.4 °C per decade. This would increase the medium temperature by 4.4 °C by 2100. Figure 1 shows how drastic this prognosis is compared to recent climatic history in Finland.

There are also many uncertainties about how the precipitation will change, but the greatest unanimity prevails about the increase of the wintertime precipitation. During the summer evaporation may grow more than precipitation, which would intensify summer droughts.

The warming climate reduces the annual duration and thickness of snow coverage. This affects living possibilities of pests, timing of spring overflows, traffic conditions and recreation possibilities.

SILMU scenario of the climate change

The atmospheric concentration of CO_2 was about 350 ppm in 1990. In the year 2020 it is estimated to be 540 ppm and by 2100 it will be about 820 ppm. These assumptions correspond the "business as usual" scenario of the IPCC.

The temperature will rise 0.4 °C per decade and thus by 2020, 2050 and 2100 it will rise in Finland by 1.2 °C, 2.4 °C and 4.4 C, respectively. The temperature rises simultaneously in the whole country and it is evenly distributed between seasons.

The precipitation will increase about 3 % per decade from the present level, i.e. by the years 2020, 2050 and 2100, the increase will be 9, 18 and 33 %, respectively.

Source: Kanninen, 1992.

3. REVIEW OF COST-BENEFIT STUDIES ON CLIMATE CHANGE

This section reviews foreign cost-benefit analyses on the climate change, namely those made by Nordhaus, Cline and Ayres & Walter. Table 1 below shows the coverage of these studies.

Table 1. Comparison of the analyses

Effects	Nordhaus (1991b)	Cline (1991a)	Ayres & Walter (1991)
Agriculture, production	+ -	-	
Agriculture, consumption		-	
Forestry	+ -	-	
Fishery and other prim.	+ -		
Construction	+	+ -	
Water transportation	+ -		
Demand of electricity	-	-	
Demand of heating (other than electricity)	+	+	
Water resources	-	-	
Infrastructure	-	-	
Sea level rise			
- loss of land	-	-	
- protection of land	-	-	-
Housing & leisure	+ -	-	-
Biodiversity		-	
Storm damages		-	
Amenity values	+	-	-
Air pollution		-	-
Health and mortality		-	-
Migration		-	-

The table tells which impacts are included in the analysis and of what sign they are (+ means a gain in welfare, like resource saving, +- that there is no quantitative economic estimate on the matter, nor an estimate on the direction of change, and - denotes a welfare loss).

It can be seen from the table that the analyses differ markedly from each other both in coverage and in results. Cline has the widest range of effects included. His work will serve as a basis for the following analysis as to the number of effects on which a quantitative assessment on the consequences of climate change will be made.

3.1 Results of Nordhaus' analysis

In his analysis Nordhaus divided the US economy into three groups of sectors according to their vulnerability to the climate change. He called them severely impacted, moderately impacted sectors and sectors with negligible effects. Sectors with potentially severe impacts accounted to 3 per cent of the US economy. Moderate impacts could be expected in about 10 per cent of the economy. Nordhaus estimated the rest of the economy to be rather insensitive to climate changes.

The table below presents the results of Nordhaus' (1991b) analysis on the cost of greenhouse warming in the United States.

Table 2. Impact estimates, annual gains (+) and losses (-) in different sectors, as a reaction to a doubling of CO_2.

Sectors	billions (1981 USD)
Severely impacted sectors	
Farms, impact of greenhouse warming	
and CO_2 fertilisation	-10.6 or +9.7
Forestry, fisheries, other	small + or -
Moderately impacted sectors	
Construction	+
Water transport	+ or -
Energy (electric, gas, oil)	
Electricity demand	-1.65
Non-electric space heating	+1.16
Water and sanitary	- ?
Damage from sea level rise	
Land-rent component	?
Loss of land	-1.55
Protection of sheltered areas	-0.90
Protection of open coasts	-2.84
Hotels, lodging, recreation	?
Total	
Central estimate	-6.23
Percentage of national income	-0.25 %

Source: Nordhaus, 1991b.

Converted into 1990 dollars the estimate by Nordhaus would amount to USD 8.8 billion. If the costs of greenhouse warming are converted by using the same share in GNP as it was in 1981 the estimate would be USD 14.0 billion. All these cost estimates describe the loss that would accrue yearly from doubling CO_2 concentration in the atmosphere.

Nordhaus emphasized that his calculations gave only a rough estimate of the costs and it had many deficiencies. A wide variety of non-marketed goods and services are not included, such as human health, biodiversity, amenity values of everyday life and environmental quality. Inclusion of these effects would raise the costs to about one, or at most to two per cent of GNP.

Nordhaus has also analyzed the costs of reduction of GHG emissions. He used a dynamic economic model, in which environmental costs were compared to changes in the consumption level. According to his calculations he proposed that 11 per cent of GHG emissions would be abated. 9 per cent would come from CFC gas reduction and the rest, 2 per cent, from carbon dioxide abatement. We shall return to Nordhaus' model later.

3.2 Critique of Nordhaus' calculations

A lot of criticism has been raised against Nordhaus' calculations. Mors (1991), among others has commented upon them as follows:

1. It can be questioned whether at present there is sufficient scientific knowledge available to quantify the damages.

2. Costs of transition from one equilibrium to another are not considered.

3. Costs of increased probability of hurricanes and droughts are not taken into account. If this probability rises, it will cause costs also on other sectors than forestry and agriculture.

4. The side benefits of GHG abatement are ignored. These benefits are important especially in case of abatement of SO_2 and CFC emissions.

5. A longer time horizon is arguable, because CO_2 doubling is not a climatic equilibrium state and because costs may rise more than linearly in the future.

6. Energy saving seemingly offers possibilities to cut emissions with negative costs, i.e. energy saving would be profitable in purely economic terms.

Also Morgenstern (1991) has criticised Nordhaus' work. First, monetary estimates may be too low. Secondly, the effects of the sea level rise are calculated erroneously. Taking this into account doubles the costs of the sea level rise to USD 10.6 billion. Furthermore, if the high-end estimates of EPA (Environmental Protection Agency) are applied in agriculture and energy consumption, the GNP share of losses rises from 0.25 to 1.5 per cent. Thirdly, unvalued use, option and existence values of the environment may be considerable.

Ayres and Walter (1991) estimated that only coastal protection, loss of land and relocation of refugees would cost the world annually 2.1-2.4 per cent of gross world income. According to them the most probable cost estimate for greenhouse warming is about 10 times greater than Nordhaus' central estimate.

3.3 Cline's results

The calculations of Cline (1991a) are mostly based on reports of the IPCC. In some cases, Cline has used greater impact estimates than those of the IPCC. Cline calculated both the costs of CO_2 doubling (2.5 °C increase in medium temperature) and a long-term cost estimate (a rise of 10 °C). The results of his analysis are summarized in table 3.

Cline argues that the cost of warming will rise geometrically in the long term. The rate of growth varies among the sectors; for example, the costs of leisure will level off as the adjustment has taken place. On the other hand, the probability of hurricanes will rise sharply.

In the very long term the costs will rise 5.5-fold to 6 per cent of GNP. Amenity values, gains in construction costs and costs of other air pollution than ozone were not given any monetary value.

At the shorter end of the time scale Cline's damage estimate amounts to 1.5 per cent of GNP, which coincides with Nordhaus' ad-hoc estimate.

Table 3. Annual damage from global warming to US economy on a 1990 scale (USD bn, 1990 prices), Cline (1991a)

Sectors	$2*CO_2$ (2.5 °C)	Very long-term warming (10 °C)
Agriculture	17.5	95.0
Forest loss	3.3	7.0
Species loss	4.0	16.0
Sea level rise		35.0
Dikes, levees	1.2	
Wetland loss	4.1	
Drylands loss	1.7	
Electricity requirements	11.7	67.0
Non-electric heating	-1.3	-4.0
Human amenity	X_a	Y_a
Human life	5.8	33.0
Migration	0.5	2.8
Hurricanes	0.8	6.4
Construction	$+/- X_c$	$+/- Y_c$
Leisure activities	1.7	4.0
Water supply	7.0	56.0
Urban infrastructure	0.1	0.6
Air pollution		
tropospheric ozone	3.5	19.8
other	X_o	Y_o
Total	$61.6 + X_a + X_o +/- X_c$	$338.6 + Y_a + Y_o +/- Y_c$

Source: Cline, 1991a.

In planning the future abatement strategy, it is important to know which of the estimated damages are avoidable. According to IPCC's "accelerated policies" scenario, the growth of radiative forcing by the year 2025 falls from 4,59 W/m^2 to 3.52 W/m^2. The largest part of the rise to take place after the preindustrial level has already happened. The accelerated policies of abatement would still leave the rise in temperature to 2 °C, as opposed to 2.6 °C in the business as usual scenario. This would accrue benefits of only USD 16 billion annually.

For the very long term, it is possible to stabilize the climate change to 2.5 °C if the accelerated strategy is followed. On this basis, the net benefit from policy action can be counted as a difference between the long- and short-term damages. This net gain would amount to USD 277 billion on the 1990 US economic scale, or approximately 5 per cent of GNP (Cline, 1991a). This result gives strong support for the current action against the GHG emissions, which is exactly the opposite to the conclusion by Nordhaus.

4. ECONOMIC ESTIMATES FOR THE FINNISH ECONOMY

Finland belongs to the industrialized countries. However, our country is very dependent on one raw material, timber. Forest industry yields about 40 per cent of Finnish export earnings. Some 90 per cent of the timber used comes from domestic suppliers.

Finland is more than self-sufficient in the production of agricultural products in spite of unfavourable production conditions. The protectionist agricultural policy that has preserved both a small farm size and high producer prices is responsible for the high percentage share of productive resources used in agriculture. Due to these reasons, the share of climate sensitive sectors is greater in Finland than in the USA. This is shown in table 4 below, which follows Nordhaus' example.

The share of Finland's agriculture, forestry and fisheries output within GDP is twice as high as the corresponding share in the US. Moderately impacted sectors have a 10 per cent share in US economy, whereas their share is about 17 per cent in the Finnish economy (here the owner-occupied dwellings are included in this group as opposed to that in Nordhaus (1991b)). Moreover, manufacturing based on the potentially affected primary production is considerable in Finland.

Table 4. Vulnerability of Finnish economy to climate change, 1990 data.

	FIM bn.	GDP share
Potentially severely effected		
Agriculture	14.3	3.1
Forestry	13.1	2.9
Fishery and other primary	0.8	0.2
Total	28.2	6.2
Manufacturing of potentially severely affected primary sector products		
Food manufacturing		
Manufacturing of non-metal furniture	11.7	2.6
Manufacturing of pulp, paper and paper products		1.8
	8.2	2.7
Total		
	12.5	2.7
Potentially moderately impacted sectors		
	32.4	7.1
Electricity, gas and water		
Construction		
Restaurants and hotels		
Recreation and culture		
Owner-occupied dwellings	10.8	2.4
Public sanitation	44.6	9.8
	9.6	2.1
Total	9.3	2.0
	28.6	6.3
Other sectors	3.7	0.8
Gross domestic product in basic values,	106.6	23.4
FIM bn.		
	290.8	63.3
	458.0	100.0

Source: Central Statistical Office of Finland, National Accounts, 1991.

4.1 Effects on agriculture

Cline has formed estimates of the effects of climate change on the agriculture for several countries, also for Finland. Cline assumed a productivity increase of 15 %, which he considered to increase the value added of agriculture by 11-19 %. In 1990 values this amounts to FIM 1.7-2.7 bn.

Let us reassess the matter more closely. The European integration will affect Finnish agriculture more in the coming years than the climate change does. According to the estimates of the IPCC, agricultural productivity would still be more productive in other European countries, so the productivity gap would not disappear. Primary determinants of agricultural production are thus dependent on institutional factors like agricultural subsidies and import barriers.

The Agricultural Research Institute in Finland has published data on the production and profitability of grain production. With the help of the simulation results of SILMU (Kanninen, 1992, p. 99) a nation-wide approximation is made. The integration is supposed to raise the medium farm size to 50 hectares. At the moment, farms of 10-50 ha. account for 83 % of the cultivated land area. Table 5 shows the increase in agricultural incomes with different productivity estimates.

Table 5. Change in agricultural income as productivity of grain cultivation increases.

Change in productivity, kg/ha	15 %	30 %	44 %
Increase in incomes, FIM/ha	621	1 242	1 822
Increase in nationwide incomes, FIM bn.	0.62	1.24	1.94

Increase in wild hay growth due to a longer growing season and higher temperatures can also lower the costs of livestock production. The fodder costs in livestock production are about FIM 1.4 billion. A 10 per cent reduction in these costs combined with 50 per cent reduction in fodder prices would produce a gain of some FIM 70 million.

Consumers would gain from increased productivity through lower prices. In 1990 consumption of agricultural products was FIM 20 billion. Assuming a low price elasticity, 0.2, for agricultural products and price reductions of 1, 3 and 5 per cent, we reach an increase in consumer surplus of FIM 400, 600 and 1 000 bn., respectively.

Climate change increases the risk of pests and diseases. These risks can be lowered by intensified use of pesticides and also by increasing the research in that field. These outlays are assumed to increase annually by FIM 100-400 million.

Summing up these effects, we get a pessimistic estimate of FIM 670 million, a central estimate of FIM 1660 million and FIM 2930 million in the optimistic case.

4.2 Effects on forestry

Finland belongs to a boreal forest zone that stretches over the globe via northern Eurasia and North America. The boreal zone covers more than 1 000 million hectares and its share of the worlds' forests is about 25 per cent. Approximately 20 million hectares of them are in Finland.

The influence of climate on vegetation is channelled through precipitation, ground moisture and the length of the growing season. Changes in these factors have impacts on vegetation varying from immediate impacts at the cellular level to changes in the whole ecosystem in the course of several hundred years.

According to climate forecasts the forest zones would shift considerably due to climate change. The net change would amount to a decline of 40 per cent of boreal forests, whereas tropical forests would rise by 12 per cent. These figures refer, however, to equilibrium changes after a long adjustment period of three centuries or more (Cline, 1991a).

Northward migration of the boreal forest zone is calculated to increase the forested area in Finland by 20 per cent, while broad-leaved trees of the temperate zone would spread to larger areas in south-west and southern Finland.

Dykstra and Kallio (in Karjalainen et al.,1991) have analyzed the changes in felling possibilities of forests due to the climate change. Table 6 presents their results.

The economic importance of the growth of forests is difficult to estimate, as it seems that already at the moment the growth of exceeds the needs of the forest industry:

annual felling rates have fallen behind those of forest growth in the 1980's. Utilization of forests is also endangered by the increasing demand for recycled fibres.

Table 6. Change in felling possibilities, million m^3 (percentage change from the reference path)

Year	Reference	Climate change
1990	49.6	
2000	52.2	54.3 (4.0)
2010	57.4	67.8 (18.1)
2020	60.0	79.5 (32.5)
2030	65.2	101.6 (55.8)

Source: Karjalainen et al. (1991) and Dykstra - Kallio (1987).

During the period 1960-1989 the average total use of timber stayed in a little over 50 million m^3 per annum. Industrial use increased while domestic use declined. If there are no substantial changes in timber use, e.g. for heating, the development of the timber use depends solely on the demand for it by the forest industry. During this time period the GDP grew by 3.9 per cent p.a. as the industrial forest use increased 1.8 per cent.

In line with the results of Dykstra and Kallio, we assume that felling potential rises by 40 million m^3 by 2040 from the present level of 53 million m^3.

If the GNP grows 2.5 per cent p.a. during 1990-2040 and the ratio of growth rates of industrial timber use and GNP stays the same, timber use would amount to 95 million. m^3 by 2040. This estimate may be too high in the light of the recycling requirements of the waste paper (see e.g. Forsman et al. (1993)). Let us assume that the industrial use of timber increases by 30 million m^3 and that the total use amounts to 80 million m^3.

The felling possibilities would increase also without the climate change. Following and interpreting the results of the YSI simulation model of the University of

Joensuu, 10 million m^3 of the felling potential and a growth of 260 million m^3 in the forest stock are explained by climate change (Luonnonvarainneuvosto, 1990; Kinnunen, 1992).

The evaluation of the effects of these changes is done using the following formulation on the change in forestry incomes:

$$\Delta I_f = p_v \Delta M_t + \Delta p_m (M_m + \Delta M_m) + p_m \Delta M_m$$

where

I_f = forestry income and wealth

p_v = export price of forest industry products per million m^3

M_t = industrial timber use before climate change

p_m = stumpage price of timber

M_m = amount of the timber stock in forests

Δ = change in the variable

The first term on the right-hand side describes the effect of the increased timber use on economic growth. The second and third terms constitute a wealth effect. The export prices are assumed to be unchanged in real terms. The stumpage price is expected to decline as the gap between the use and growth of timber widens, i.e. Δp_m is negative. The term p_v is approximated by the value added of the forest industry divided by the industrial timber use. This was FIM 388/m^3 in the year 1990. Analogously, p_m is the value added of the forestry divided by the total use of timber, which gives in 1990 figures FIM 265/m^3.

Using these estimates, the first term gives a benefit of FIM 3 880 m. The wealth effect is more difficult to estimate. If p_m declines by 8 percent and the timber stock grows as assumed, the wealth effect would be zero. This decline may be larger. On the other hand, the wealth effect is realized over the long term. Furthermore, increased silviculture costs due to pests and diseases may increase the costs of forest owners and increase the stumpage price. Also the international market situation may change markedly, taking into account that boreal forests may decline considerably. So, let us assume that the wealth effect is zero.

For our analysis, we shall use FIM 4.0 billion as a central estimate of the gains in forestry. The pessimistic and optimistic estimates are FIM 2.5 billion and FIM 5.5 billion, respectively.

There is one further effect to be considered in the area of forestry, namely the economic costs of pests and diseases. The scientists of the IPCC (1990b), for example, have considered the northern boreal forest zone to be very vulnerable to so-called biotic causes of forest damages, i.e. insects, fungi and rodents.

Abiotic damages are caused by storms, snow and fires. Most abiotic damages create better living conditions for biotic pathogenes, too (Karjalainen et al., 1991).

There are only a few economic estimates of the forest damages, but according to the statistics of the Federation of the Finnish Insurance Companies the yearly damages are roughly FIM 300 million. All the damages are not indemnified and thus not included in the insurance statistics. For all the above damages, an estimate of some FIM 1.2 billion seems plausible.

There are no quantitative estimates for the forest damages due to climate change. Hence we have to resort to guesstimates: 0, 10 and 25 % increases in damages would mean annual costs of FIM 0, 120 and 300 million, respectively.

4.3 Effects on fishery

The climate change is reflected in the changing living conditions in the Baltic Sea and the inland waters. The baltic herring, which is the economically most important fish species, is not very sensitive to the water temperature changes or to changes in the salinity. The prevalence of sea fish in the Baltic Sea is restricted by the low salinity. The changes in the salinity due to increased precipitation and changes in the ocean currents are not yet possible to estimate in quantitative terms (Kanninen, 1992).

In the inland waters fish have almost no possibilities to adjust to temperature changes. The warming waters would favor warm water fish at the expense of cold water fish. Salmonoids, for example, are accustomed to cool waters. That is why fish farms would experience damages from warming climate.

At the moment, even tentative monetary estimates are difficult to make. At the national scale, however, the economic costs could hardly be significant as fishery is a very small industry in Finland.

4.4 Economic importance of biodiversity

Species loss has numerous socioeconomic consequences. The earth has approximately 5 - 30 billion species. Only 1.5 to 1.7 million are known to scientists. At the moment, about 20 plants account for most of the food production. In the course of time man has used 7000 plants as nourishment. A vast potential is hidden in the unknown species. Also the medicine industry has made use of wild plants. About half of the present medicines are derived from natural plants.

The forests, especially the tropical forests are rich in biodiversity. They are also threatened by the climate change and by the growing human population.

Economists have identified use, option and existence values as the three types of value of species for economic purposes (Cline, 1991a). Together they form the total economic value (OECD, 1989). Empirically these three components are quite difficult to handle. In the contingent valuation studies a common result is that the existence value accounts for the largest part of the economic value of a species (Cline, 1991a; Johansson, 1989).

Finland has about 42 000 species from which 1692 (4 per cent) are considered as threatened according to a follow-up study for the years 1986-1990. The growth of the number of endangered species was 60 per cent from the previous follow-up. The species are endangered by forestry (41 per cent of cases) and different cultural environments (21 per cent). Future risks are environmental pollution and climate change (Committee report 1991:30). Mushrooms and fungi account for the largest part of the endangered species. Their role in the forest ecosystem is not thoroughly known, but some of them are essential for the nutritional balance of other plants.

The central government of Finland uses FIM 2 million yearly on the protection of the endangered species. Private wildlife organisations use also about FIM 1 million for the same purpose. According to the committee for the endangered species the disbursements should be raised to FIM 35 million.

Over 40 % of our species live in the forests. The use of forests is, however, directed according to the interests of the forest industry. On the other hand, the natural scientists may overvalue the need for protection for their own sake (e.g. in hope of more funds for further research).

Let us approximate the value roughly in the a following manner. Let us say that the risk of extinction of an endangered species is 10 per cent during a year. There are about 1 700 endangered species. The government has allocated FIM 2 million for their protection. Calculating simply with these assumptions and data, we get an average value of a species FIM 2 000 000 / 0.1 * 1 700 = FIM 12 000. If we take this value to correspond to the use value of the species, we get a four or five-fold total economic value according to the results of a Swedish study (Johansson, 1989). This would amount to FIM 48 000 - 60 000 per threatened species.

Let us assume that 25 per cent of our species will be endangered by the forest migration caused by the climate change. If the above valuation holds, the central government should use FIM 12.5 million for the species protection. If the private disbursements develop in the same manner, the total amount used for protection of the endangered species would rise to FIM 20 million.

Finland suffers damages indirectly from species loss abroad, too, e.g. in failure to develop new medicines or in reduced possibilities to visit nature parks that are rich in wildlife. Let us take FIM 15 million as an ad-hoc estimate of these losses.

If we compare this result with those of Cline (1991a), our result may be quite conservative. His estimate for species loss for the USA only amounted to USD 4 billion yearly.

As these figures are only more or less educated guesses, we could take the obtained FIM 35 million as an optimistic estimate. FIM 65 million will serve as the central estimate and 165 million as the pessimistic one.

4.5 Hydrological costs

4.5.1 Effects of the sea level rise

The rise in the sea level causes problems especially for certain coastal and island countries. Many of these are developing countries where the population increases rapidly. A rising population reduces the possibilities to adjust to reduction of arable land. The following countries (in alphabetic order) are the most vulnerable to the sea level rise according to OECD (1991a): Bangladesh, Egypt, Maledives, Mozambique, Pakistan, Senegal, Suriname, Thailand and Gambia. Three of these, namely Bangladesh, Egypt and Mozambique, are included in the Finnish bilateral development aid programme. The rising sea level may cause a greater need for bilateral aid in the future to these countries.

Finland is in a lucky position in regard to the sea level rise. As a result of the previous ice age, the earth crust is still rising, about 90 cm per century in the Pohjanmaa region, where the land is especially lowlying. Table 7 below gives two estimates of the sea level rise in Finland. Parameter p desibes the probability that the sea level rise stays under the figure stated in the table. In other words, according to Jäger (1988) there is only a 5 % chance that the sea level would rise more than 2 meters by the year 2090.

Table 7. Two estimates of the sea level rise in Finland (cm).

Year	Jäger (1988)			Oerlemans (1989)		
	p=0,05	p=0,5	p=0,95	p=0,05	p=0,5	p=0,95
2010	-15	-3	19	-27	-5	17
2040	-30	2	82	-44	0	44
2090	-55	16	200	-63	19	100

Source: Kahma - Boman, 1990.

According to General Manager Kakkuri of the Finnish Geodetic Institute, it is very probable that the sea level will rise only 50 cm at the highest (information divulged in a personal interview 9.4.1992).

The possible sea level rise is already taken into consideration in urban planning in Finland. The planning has to prepare not only for the medium sea level, but also for the variation in the sea level. That is why a minimum ground floor level of 3 meters above the present sea level was applied in a newly constructed coastal housing area Ruoholahti in Helsinki.

If the medium sea level rose by one meter, a dam would be needed in the Helsinki area. The construction of a dam would cost from FIM 185 million to FIM 1 600 million depending on the material choices (Ravea, 1991).

Other possibly affected areas are Hanko, Turku, Loviisa and the Åland islands. The Finnish islands in general should not be affected to a great extent by the sea level rise.

4.5.2 Precipitation and sewers

The water supply seems not to be a problem in the coming decades in Finland. On the contrary, the increasing precipitation is foreseen to raise the ground water level by 20 to 40 cm (Kanninen, 1992).

Increasing precipitation affects the city sewers. If the rain water flows to the same pipes as waste water, the adjustment costs are greater. There are separate pipes in almost all the places in Finland. The centre of Helsinki has a one-pipe system, though.

There are basically three ways to cope with the problem. Capacity of sewage treatment plants can be increased, separate pipes can be constructed and rain water reservoirs can be constructed underground. The most expensive way is to construct new pipes. In Sweden, modernization of the sewage systems would cost SEK 3.5 billion. Rain water reservoirs are being planned in Helsinki.

4.5.3 Cost estimate for hydrological changes

Hydrological changes generate costs in protection and improvement of the constructed environment. Let us assume that investment needs would amount to FIM 10 billion if the sea level rises one metre. Calculated for 30 years of service life and using a 5 per cent interest rate, the annual investment cost would be FIM 650 million. When service and maintenance costs are included, an annual cost of some FIM 700 million is reached. As the rise of the sea level is very uncertain, we expect in the optimistic case no costs, a probability of 5 per cent in the central case for the materialization of the above costs and 10 per cent chance in the pessimistic case. Hence we have annual expected costs of FIM 0, 35 and 70 million, respectively.

4.6 Effects on energy consumption and supply

Aittoniemi (1990) has studied the effects of the climate change in energy production and consumption in Finland until the year 2025. The analysis was based on the energy scenarios of the Ministry of Trade and Industry from the year 1990 and on the results of the international general circulation models. Moreover, the watershed models of Imatran Voima, a Finnish electricity power company, were used for the hydroenergy production simulations.

The study used three climate scenarios A, B and C, in which assumptions were made about temperature, precipitation and evaporation. The temperature rise was estimated at 1.2 to 4.6 °C, while precipitation increased 10-36 per cent and evaporation rose 3 - 14 mm per month.

Scenario A had the slightest climate changes. Its changes corresponded for one fourth of changes obtained in the GISS climate model. Scenario B is based on the work of the National Natural Science Committee. Its temperature rise corresponds to that of the GFDL model. Scenario C presents the largest changes. Its assumptions are in line with the results of the GISS model for carbon dioxide doubling in the atmosphere.

The scope of the study was to estimate changes in electricity consumption. In measuring the changes, both heating and cooling needs were taken into account.

The total use of electricity declined in all the scenarios in comparison with the reference of the Ministry of Trade and Industry as follows:

Scenario A	1.2 %
Scenario B	2.9 %
Scenario C	4.4 %.

About 60 per cent of the reduction in the total consumption was due to the reduced need for heating. The rest followed from the changes in the use of households and industry (Aittoniemi, 1990).

Increasing precipitation added to the hydroenergy capacity considerably. The electricity production from hydroenergy increased 12 - 41 % from the reference case.

As a consequence of these changes, the costs of separate heat production and district heat production fell in the manner depicted in Table 8.

Table 8. Annual savings in the energy production from climate change, FIM m. (in 1990 prices).

Scenario	Separate heat production	District heat	Total
A	210	30	240
B	440	70	510
C	690	110	800

Source: Aittoniemi, 1990.

The temperature rise for the years 2030 - 2050 corresponds more or less to the scenarios B and C. The results are for the year 2025, so the results of the scenarios B and C seem to approximate most closely the changes in the coming 50 years. This depends naturally on the assumptions made in the energy consumption scenario of the Ministry of Trade and Industry.

The changes in the investment needs were not included in Aittoniemi's study. He mentions, though, that more investments might be needed in hydroenergy production in order to reap the calculated benefits. On the other hand, growing hydroenergy production would offset some of the condensation power investments. According to Aittoniemi, at least 500 MW of coal power capacity could be offset by investments of 300 MW in hydropower. The investment costs of these power stations are more or less equal. Hydropower has higher fixed operating costs (Lehtilä - Pirilä, 1991).

Scenario C is used as an optimistic estimate and B as the pessimistic one. The central estimate is arithmetic mean of these two.

4.7 Health effects

4.7.1 Health effects of temperature rise

A rising content of carbon dioxide in the air is no health risk as such. Besides, rising summer temperatures would hardly cause serious trouble in Finland, where summer heat exceeds 25 °C only on 10 days a year (daytime temperature). On the other hand, as north as in Hamburg, deaths of elderly people and children have been reported during heat waves.

The Danish government estimated in its report on the climate change that new contagious diseases would spread in Denmark because of the climate change. Already now an insect that carries a parasite causing malaria lives in the southernmost island of Denmark. The prevalence of this insect as that of many others is restricted by the temperature. The rise in temperature would increase premature deaths and absenteeism from work due to sicknesses.

In Finland, cold weather increases respiratory infections. In this sense climate change might bring in some benefits, too. The Finnish National Road Administration has estimated that respiratory infections cause losses of FIM 180 million annually in sick leave. Let us assume that in the optimistic case costs fall by FIM 40 million and in the pessimistic case the costs increase by the same amount annually.

4.7.2 Health effects of ultraviolet radiation

About 400 people got skin cancer in 1987. In the same year 150 people died of it (Central Statistical Office of Finland, 1989). Skin cancer is expected to increase three-fold because of sun-bathing has become more popular.

Prevalence of skin cancer rises 0.6 to 4.6 per cent if the stratospheric ozone layer is reduced by one per cent. The ozone layer becomes thinner as the CFC gases are emitted into the atmosphere. The same gases are also responsible for greenhouse warming. This is why also this question is handled by the IPCC.

Let us assume that UV radiation increases by 20 per cent in Finland. This will cause an increase of skin cancer by about 40 per cent. This means 160 more patients annually. The patients will get treatment for five years, during which time half of the patients will die. Let us assume that deaths occur evenly during the five-year period, 20 by year. On an annual basis, 600 patients are thus given treatment (operations and radiotherapy).

Using the cost estimates of The Finnish National Road Administration (1992a), we get yearly costs of FIM 92 million.

Another disease caused by ultraviolet radiation is cataracts. This disease is treated with operations in which the destroyed lenses are replaced with artificial ones. Cataracts were treated in 1989 in 12 000 treatment periods. One period took 5.9 days on average. Let us assume that 1 per cent reduction in ozone layer causes a 0.45 per cent (0.3-0.6 according to the IPCC) increase in cataracts, so a 20 per cent increase in the UV radiation would increase the number of patients with 4.5 per cent. Yearly treatment costs would thus rise by FIM 3 million. Inclusion of the costs of home care increases the costs to FIM 5 million a year.

Total health costs of the reduction in the ozone layer is about FIM 100 million. This is the central estimate and pessimistic and optimistic estimates are, say, 25 per cent higher and lower, respectively.

4.8 Construction

Weather affects construction mainly in wintertime. Trade unions have frost clauses, which determine when the weather is too cold for work. These clauses are adjusted so that the limits are exceeded more or less as often in all the parts of the country. During the latest winters these limits have not been reached.

The cold weather restricts the techniques that are available for construction. All in all, wintertime construction costs account for 2-3 per cent of the total construction costs. A average of some FIM 50-60 billion is used annually in domestic construction activities. Let us assume that the increase in the wintertime temperature decreases wintertime construction costs by 30 per cent. This would reduce the construction costs by FIM 400 million.

4.9 Leisure and tourism

The warming climate changes our ways of using our free time. During the winter, snow coverage will be thinner and it will last for a shorter time. According to results of the GISS model, the snowy period in Lapland after the climate change is estimated to be as long as it is in southern Finland at the present moment. Southern Finland would become almost snowless.

One has to remember that the GISS model gives a stronger wintertime warming than has been foreseen in the latest estimate of the Finnish SILMU project. Our base assumption is that the snow coverage period will be shortened by one third.

The demand of wintertime recreation is described with the following equation:

$$D = p_{Ss}*S_s + p_{Sn}*S_n + p_{Cs}*C_s + P_{Cn}*C_n$$

where

S_s= number of slalom skiing days in southern Finland, accommodation near home (2 million days per year)

S_n= number of slalom skiing days in northern Finland, staying in hotel

C_s= number of cross-country skiing days in southern Finland, accommodation near home (6 million days per year)

C_n= number of cross-country skiing days in northern Finland, staying in hotel
p_{Ss}= FIM 100 per day
p_{Sn}= FIM 310 per day
p_{Cs}= 0
p_{Cn}= FIM 250 per day.

The data is based on the studies of the Finnish Tourist Board (1992) and Art-Travel (1990).

Slalom and cross-country skiing are assumed not to be substitutes for each other, whereas geographical distribution of the skiing days depends on the difference in the price of a skiing day between northern and southern Finland.

Let us further assume that skiing becomes impossible in southern Finland and that prices in the northern Finland reflect the cost at which the demand for skiing in the southern Finland is zero. Then we get the following costs related to the shortened skiing period.

slalom = $(p_{Sn} - p_{Ss})S_s*1/2*1/3$ = FIM 70 m. per year
cross-country = $(p_{Cn} - p_{Cs})C_s*1/2*1/3$ = FIM 250 m. per year

(the coefficient 1/2 comes from the assumption of linear demand function and 1/3 describes, in relative terms, the shortening of the snowy period).

The central estimate for losses in wintertime leisure is thus FIM 320 million per year.

The rise in summertime temperatures can reduce trips abroad, at least those in which the main motivation is to lie in the sun. The foreign skiing resorts can also run into difficulties from the lack of snow. What will be the net effect on the Finnish travel balance?

The Finns used on average FIM 8620 million per year during 1986-1990 on tourism abroad and the foreign expenditure in our country was FIM 4270 millions in 1990 prices (Central Statistical Office of Finland, 1991b).

In the pessimistic case we assume that the foreign expenditure stays at the same level while the Finns consume 5 per cent more abroad. The travel balance would weaken by FIM 430 million. In the optimistic case, foreign expenditure increases 10 per cent and the Finns use the same amount abroad as before. Benefits of the same magnitude, FIM 430 million, would accrue to us. The central estimate is zero.

Adding together leisure and tourism, we get a loss of FIM 770 million in the pessimistic case, FIM 320 million in the central and a gain of FIM 130 million in the optimistic case.

These effects are just examples of the leisure effects. Preferences can change, however: our grandchildren may not long for snow at all.

4.10 Amenity values

One may ask if the climate change increases the every-day amenity in the Northern Europe, where the warm summer days are received with hilarious joy. On the other hand, winter days may turn into a long period of darkness and slush. It seems impossible even to imagine monetary effects for these changes.

Nordhaus (1991b) did not present any monetary estimates on this matter, but he figured that amenity gains could be great in the USA. Ayres and Walter (1991) argued in turn that changes in the environment are important for humans, which led them into the conclusion that climate change may cause great losses in the amenity values.

Finnish nature might receive new exotic plants. If we follow the thoughts of Ayres and Walter, we would end up in potential gains in this area, too. Most of the trees in the Finnish parks are broadleaved, which gain from the climate change. Anyhow, monetary valuations are not possible at the moment.

4.11 Effects of reduced snow and ice coverage on traffic

The Finnish winter causes costs in the traffic in many ways. The merchant ships need open water, for which an ice breaker fleet is necessary. The snow has to be ploughed and the roads salted or sanded in order to make driving safer.

A 2 °C increase in the wintertime temperature would reduce the ice coverage in the Baltic Sea by 30 % and a 4 °C increase by 50 %. Because of the large variation in the ice coverage, ice breakers would still be needed in the future.

In 1992, the costs of the 9 ice breakers were FIM 710 million marks. Let us assume that 3 of these would be redundant in the future. At the present price level, we would incur savings of FIM 240 millions.

The road maintenance costs were about FIM 360 million per year in 1988-1990. Some FIM 120 million were used in salting and sanding of the roads. These costs would increase in the warming conditions, let us say by 20 %. Snow removal costs about FIM 100 million per year. This cost can be halved if the amount of snowfall reduces by 50 % according to the GISS model (Kuusisto, 1989). The net effect in the road maintenance is thus a savings of FIM 25 million.

In total, the traffic would gain about FIM 270 million. The pessimistic case is some FIM 30 million less and the optimistic case FIM 30 million more savings.

4.12 Reflections of the international situation

In 2040 Finland is probably affiliated with the EC. It is not at all an impossible idea to imagine that Finland would have to bear a part of the costs of climate change in the other EC countries. The southernmost countries of the Community will receive lots of immigrants in the next century from Northern Africa (Pearce, 1992). A part of these may have left their homes because of climatic reasons (drought, sea level rise). A flood of environmental refugees would cause social unrest and even international conflicts.

The costs of immigration are easy to define for the recipient country during the first years of the stay. Finland used about FIM 80 000 per refugee and asylum seeker in 1991. Let us assume that in the future, 20 000 persons are taken into the country each year and that they receive social security benefits for the first 18 months before integrating into the society and living on their own. This would give us a cost of FIM 2 400 million per year. Half of this cost may serve as an optimistic estimate and the double as the pessimistic one.

Another question is, however, if the immigration is at all costly to the society in the long run. Immigration may, for example, increase productivity through gains in human capital, correct the age pyramid, create more jobs in small scale enterprises, etc. An adult immigrant is also less costly to educate than a national child. If the immigration is rotational by nature, i.e. each immigrant stays here for only a couple of years, immigrants are net financiers of public expenditure (Hietala, 1992).

Quantification of the above-mentioned effects would, however, require a thorough analysis. The results in the Swedish macromodels indicate that the effect on the productivity is positive in the long run, but insignificant in practice (Hietala, 1992). At this stage we omit these aspects from the analysis.

5. SUMMARY OF THE COSTS AND BENEFITS

Table 9 summarizes the results from the earlier sections. The effects of immigration, agriculture and forestry clearly dominate the overall impact. Without immigration, all the estimates would be positive. The central case is slightly positive. The possible costs of increased international responsibilities as a member in the EC are not shown in the table.

The results of table 9 must be converted into a marginal effect per ton of $C0_2$ in order to enable comparison with the carbon dioxide taxes. Nordhaus has presented a model for this, which we shall use in the following.

Table 9. Economic effects of greenhouse warming on Finland, 1990 prices.

Effects	Pessimistic	Central	Optimistic
Agriculture	+670	+1660	+2930
Forestry	+2200	+3880	+5500
Fishery	-	+-	+
Biodiversity	-165	-65	-35
Sea level rise	-70	-35	0
Energy	+510	+655	+800
Health	-160	-100	-40
Construction	+300	+400	+500
Leisure	-770	-320	+130
Amenity	-	+-	+
Traffic	+230	+270	+300
Immigration	-4800	-2400	-1200
Total	-2 055	+3 945	+8 885
Share of the 1990 GDP, %	-0.45	+0.86	+1.94

In the Nordhaus model the economy is assumed to be in its steady state. He studied the effects of an emission increase. In order to evaluate the welfare effect of a permanent change, a discounting factor is needed. In his model it is as follows:

$\Gamma = \alpha/[(r-h+\delta)(r-h+\alpha)]$

where

r = real rate of discount for the public investments

h = rate of per capita consumption increase

δ = rate of removal of CO_2 equivalent from the atmosphere, 0.5 % per year

α = delay parameter of temperature in response to radiative increase, 2 % per year.

The actual discount rate in the model economy is the difference r-h. Although this would be zero, the discounting factor Γ does not grow to infinity, because the greenhouse gases diffuse gradually into the deep ocean. The term Γ can be interpreted as the duration, in present value, of the climate damage. The discount factors are with different discount rates as follows:

Discount rate r-h	Discount factor
0 %	200,0
1 %	44,4
2 %	20,0
4 %	7,41

Source: Nordhaus, 1991b.

The cost of a ton of CO_2 emission equivalent can be calculated from a slightly simplified version of the Nordhaus model:

Cost of t CO_2 = Damage estimate of CO_2 doubling $*\Gamma/$ amount of emissions that cause the CO_2 doubling.

Using this equation, we obtain the following estimates for the marginal damage of CO_2:

Table 10. Effects of the CO_2 doubling per ton of CO_2.

Discount rate r-h	Effect FIM/t CO_2, when the estimate is		
	Pessimistic	Central	Optimistic
0 %	-43.10	+82.80	+186.60
1 %	-9.60	+18.40	+41.40
2 %	-4.30	+8.30	+18.70
4 %	-1.60	+3.10	+6.90

The figures above do not give any argument for a large scale emission tax program in Finland. On the other hand, is the scope of this calculation too limited? How should we take into account the turbulences at the international community?

According to the studies of Nordhaus and Cline, costs of the greenhouse warming may amount to 0.25 - 6.0 % of the gross world product, GWP. Let us use these values in the above equation of marginal costs. Using an exchange rate of FIM 4.5 per 1 USD, an estimate of USD 20 000 billion for the GWP and global CO_2 equivalent emissions of 29 billion ton per year, we get the results shown in the table 11. The Finland's share of the global costs is shown in the parentheses. The share is defined by the current share of the global emissions, 0.32 %.

Table 11. Global costs of climate change per ton of CO_2 emission

	COST FIM/tCO_2, as damage estimate is			
Discount rate r-h	0,25 % GWP	1 % GWP	2 % GWP	6 % GWP
Finland's share, FIM m.	720	2 880	5 760	17 280
0 %	15.10	60.40	120.90	362.70
1 %	3.40	13.40	26.80	80.50
2 %	1.50	6.00	12.10	36.30
4 %	0.60	2.20	4.50	13.40

However, as the figures above show the marginal costs of the climate change without any measures to control the emissions, they are not suitable for measuring the marginal *benefit* of action, i.e. the emission abatement. One has to know how much of these foreseen costs can be avoided and to compare this potential against the emission abatement costs. According to Cline (1991a) only about 25 % of the costs of CO_2 doubling in the atmosphere can be avoided by 2040-2050. This again emphasizes the finding that in the 50 years' perspective, there are no strong incentives to curb emissions.

A longer time perspective changes the picture. Following Cline (1991b), we assume that it is possible to curb the CO_2 emissions so that the CO_2 concentration will be stabilized at a level double that of the preindustrial time. The marginal benefit of emission abatement from a long-term perspective is thus the difference between the long- and short-term scale effects. For long-term costs let us use the high end values in the table 11. Then we also adopt the idea of perfect international burden sharing in the long run.

Table 12. Estimate of the marginal benefits of emission abatement from a 200-year perspective, FIM/t CO_2.

Costs, FIM/t CO_2	Time scale		Long-term benefit
Discount rate	A: 2*CO_2, 50 years	B: long, 200 years	B-A
0 % 1 %	-82.80 -18.40	362.70 80.50	445.50 98.90

In the table the central estimate is used for the Finnish CO_2 doubling costs. From the international solidarity point of view, emission taxes exceeding FIM 400 can be defended. However, one has to remember that these calculations are still on quite an arbitrary basis. By discounting with greater rates than 1 %, abatement benefits turn insignificant.

6. SUMMARY AND CONCLUSIONS

This study has analyzed the economic effects of the climate change on Finland by the end of the first half of the next century. According to the estimates, Finland seems to be in a rather favourable position compared to many other countries. Due to uncertainty inherent in climate change, the economic estimates in this study are presented in three different scenarios: pessimistic, central and optimistic. According to these scenarios the annual economic effects would amount to from a loss of 0.5 per cent to a gain of 1.9 per cent of 1990 GDP. The central estimate shows a slightly positive effect, 0.9 per cent of 1990 GDP. The largest potential for benefits is in agriculture and forestry.

However, the social unrest due to climate change that is foreseeable in the international community will be reflected in increased migration, stagnating international trade and political conflicts. Finland may also have to support other countries, e.g. as a future member of the EC or by increasing its development aid.

The emphasis on the study is on a 50-year time span. However, when the benefits of the emission abatement are considered, a longer perspective is needed, as only 25 per cent of the foreseen global warming will be avoidable during the next 50 years. According to Cline (1991b), the warming can be stabilized on a longer perspective at a level which corresponds to the business-as-usual scenario of the coming 50 years. Following Cline's (1991b) example, we compared this to the projected development without preventive measures taken during the next 200 years. The benefits amount to FIM 100-450 per reduction of a tonne of CO_2 emission, calculated with 1-0 per cent discount rate. However, this calculation rests on an assumption that the global costs are evenly distributed between the nations, either voluntarily or involuntarily. Furthermore, the figures are far from being an accurate estimate of the matter. In conclusion, after the economic evaluation, the study emphasizes the need and the importance of value judgements in the face of a long-term threat to human society and to the global environment.

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