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CLIMATE CHANGE AND THE FINNISH ECONOMY

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ABSTRACT: The objective of this paper is to study the economic effects of the climate change on Finnish economy and welfare. The year under focus is 2050. Firstly we survey the impacts on general level and secondly we analyse the economic effects in different sectors. A short discussion on policy options is also included. We will mainly use traditional cost-benefit analysis to study the economic effects of climate change. Natural scientific research results concerning climate give the basis for estimations. According to our current calculations Finland will benefit nearly FIM 6,000 millions in 2050 in 1993 money from climate change. This is 1.2 per cent of 1993 GDP. The benefit originates mainly from agriculture, forestry and energy. Highest costs come from biodiversity and international responsibilities. Thus, a small Nordic country like Finland may benefit from climate change if there are no extreme events. However, it must be emphasized that there are still huge uncertainties concerning both climatic scenarios and the impact estimates.

KEYWORDS: Climate change, cost-benefit analysis

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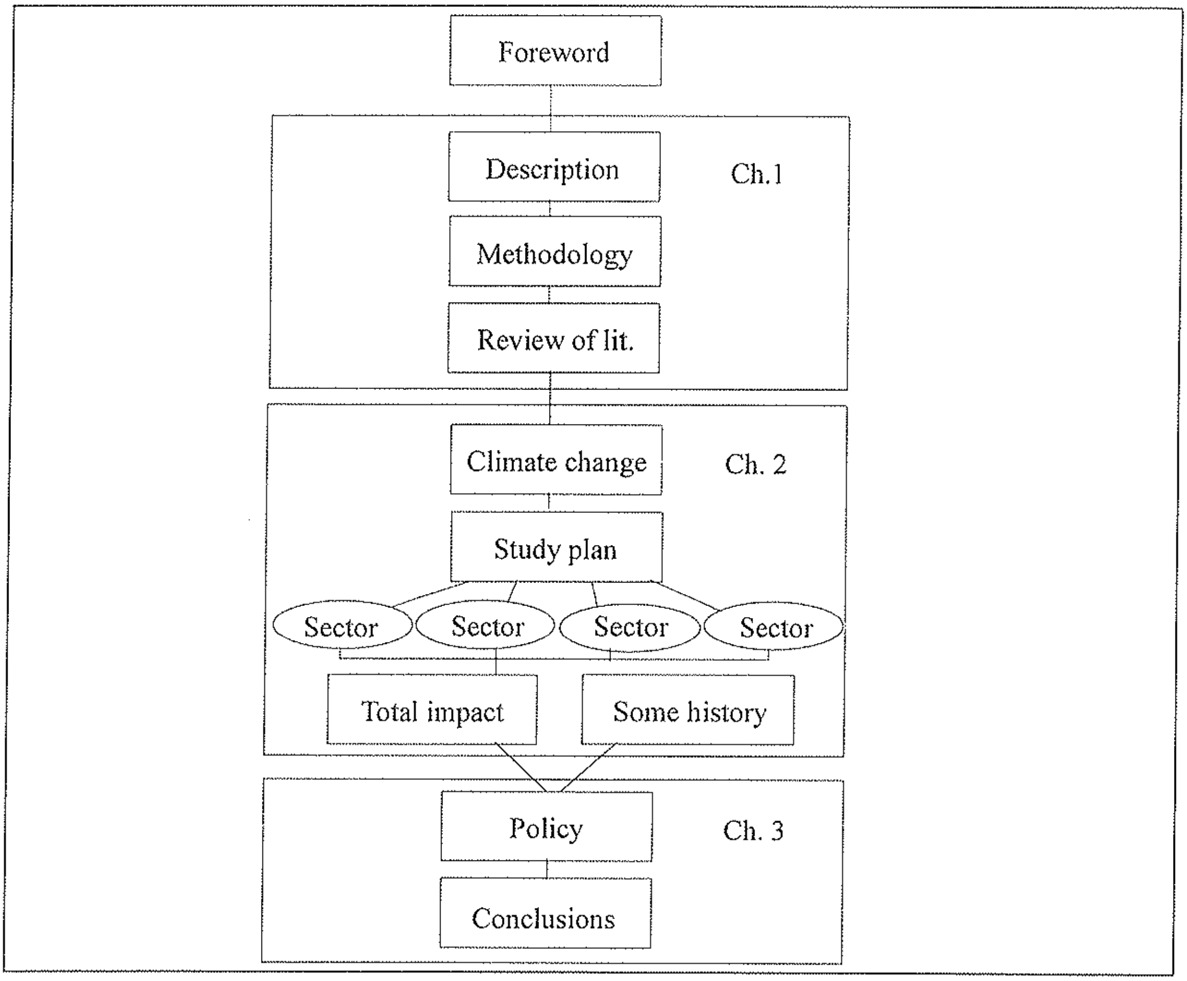
TIIVISTELMÄ: Tutkimuksessa tarkastellaan ilmastonmuutoksen vaikutuksia Suomen talouteen ja kansalaisten hyvinvointiin. Tarkasteluajankohdaksi on valittu vuosi 2050. Tutkimuksessa kerrotaan vaikutuksista ensin yleisellä tasolla ja sitten analysoidaan taloudellisia vaikutuksia talouden eri sektoreilla. Mukaan on liitetty myös lyhyt kappale politiikka- vaihtoehdoista. Analysoimme ilmastonmuutoksen taloudellisia vaikutuksia lähinnä perinteisen kustannus-hyöty-analyysin keinoin. Perustana käytetään luonnontieteellisistä tutkimuksista saatuja arvioita ilmaston muuttumisesta. Tämänhetkisten laskelmien mukaan Suomi hyötyy ilmastonmuutoksesta lähes 6 miljardia markkaa vuoden 1993 rahassa vuonna 2050. Tämä on 1,2 prosenttia vuoden 1993 BKT:sta. Hyöty tulee lähinnä maataloudesta, metsätaloudesta ja energiasektorilta. Suurimmat haitat tulevat biodiversiteetin vähennyksestä ja kansainvälisten velvoitteiden täyttämisestä. Pieni pohjoinen maa kuten Suomi saattaa siis hyötyä ilmastonmuutoksesta, mikäli mitään voimakkaita luonnonmullistuksia ei tapahdu. Sekä ilmastoskenaariot että vaikutusarviot ovat kuitenkin yhä erittäin epävarmoja.

AVAINSANAT: Ilmastonmuutos, kustannus-hyöty analyysi

Preface

This paper is about climate change in Finland and its socio-economic consequences. It is an attempt to study the impacts of climate change from different viewpoints and present the problems and uncertainties related to the analysis. In a way this is also an interim report on the project and as such contains unfinished material. Furthermore, by definition this is a discussion paper, not a scientific article.

The next figure shows the organisation of the paper. Description of the underlying project is given at the beginning of the first chapter.



First chapter is a short introduction to climate change impact assessment literature and a description of the goals and methods. Second chapter is the substance of the paper containing the scenarios and the analysis of the economic effect of climate change on the different sectors and the aggregate assessment. Many of the sectors are currently covered only with a short qualitative assessment. Third chapter includes a short review of policy discussion and the concluding remarks.

This paper was written by research fellow Pasi Kuoppamäki, M.Sc. (Econ). Research director Kari Alho and researcher Markku Lammi from ETLA have commented some parts of the text and many other people have given ideas. However, the usual disclaimer applies and the author has sole responsibility of the text. Furthermore, the language has not been checked and contains some errors.

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Progress of the project can be partially followed through World Wide Web URL: *http://www.etla.fi/pkm/absr.html* and *http://www.etla.fi/pkm/pkm.html*

YHTEENVETO

Tämän tutkimuksen tavoite on selvittää ilmastonmuutoksen vaikutuksia Suomen talouteen ja hyvinvointiin seuraavien 50 - 100 vuoden kuluessa. Tutkimus on osa ilmastonmuutoksen taloudellisia vaikutuksia käsittelevää projektia joka alkoi 1994 ja päättyy 1995 lopussa. Tämä paperi toimii samalla väliraporttina, jonka tuloksia tarkennetaan myöhemmin. Tutkimuksessa keskitytään tarkastelemaan vuoden 2050 tilannetta, jota voidaan pitää perusvuotena pitkän aikavälin vaikutuksia analysoitaessa. Lisäksi parhaat luonnontieteelliset arviot on yleensä tehty kyseiselle vuodelle. Tutkimuksen aineisto saatiin useista eri lähteistä mukaan lukien Suomen ilmakehämuutosten tutkimusohjelma (SILMU). Tämä tutkimusprojekti on myös osa SILMU-ohjelmaa.

Ilmastonmuutoksen vaikutusten analysointi on yhä puutteellista ja olemassa olevat arviot ovat erittäin epävarmoja. Muutamia kokonaisvaltaisia tutkimuksia on tehty koskien lähinnä Yhdysvaltoja ja koko maailmaa. Näiden lisäksi on tehty analyyseja muutamille sektoreille kuten maataloudelle. Useimmissa näistä tutkimuksista arvioidaan maailmanlaajuisten haittojen olevan luokkaa 1 - 2 prosenttia BKT:sta. Ensimmäisen suomalaisen tutkimuksen, Kinnunen (1992), mukaan Suomi todennäköisesti hyötyy ilmastonmuutoksesta. Myös muutamissa muissa tutkimuksissa on pohjoisten alueiden mahdollisesti hyötyvän ilmaston lämpenemisestä. Joka tapauksessa maantieteelliset ja sektoreiden väliset erot vaikutusten suuruudessa ja suunnassa tulevat olemaan merkittäviä. Tämä tutkimus pyrkii selventämään tilannetta Suomen osalta ja luomaan perustaa jatkotutkimukselle.

Pienen avoimen talouden kuten Suomen kohdalla ilmastonmuutoksen analysointi on monella tavoin hankalaa. Ilmastostonmuutosta koskevat ennusteet pienille alueille ovat yhä varsin epäluotettavia ja Suomen integroituminen Eurooppaan ja muuhun maailmaan vaatii varsin laajaa perspektiiviä. Sopeutumisella tulee olemaan suuri merkitys useilla aloilla kuten maataloudessa. Valitsemamme skenaarion mukaan ilmasto lämpenee tarkastelujaksona noin 0,3 ^{0}C vuosikymmenessä vuoteen 2100 saakka. Vuonna 2050 Suomi on Euroopan Unionin jäsenmaa, jossa asuu noin 5 miljoonaa ihmistä. Tarkastelumme tapahtuu kuitenkin pääsääntöisesti vuoden 1993 yhteiskuntaa muistuttavissa olosuhteissa, koska emme pysty ennustamaan koko talouden ja yhteiskunnan rakenteen muutosta vuoteen 2050 asti.

Tarkasteltavia sektoreita oli useita, ja niistä merkittävimmiksi hyötyjen lähteiksi osoittautuivat maatalous, metsätalous ja energiasektori. Maatalous on yksi Suomen ilmastoherkimmistä toimialoista ja samalla tulevien institutionaalisten muutosten johdosta yksi vaikeimmin analysoitavista. Ilmastonmuutos siirtää viljelykelpoisen alueen rajaa kohti pohjoista samalla kasvattaen satopotentiaalia. Myös kasvukausi pitenee lisäten karjan laidunkautta. Toisaalta erilaisten kasvitautien tuomat riskit lisääntyvät vähentäen hyötyjä. Tutkimuksessa käytettiin

kahta eri menetelmää taloudellisten vaikutusten analysointiin ottaen EU-jäsenyyden vaikutukset huomioon. Ensimmäinen menetelmä on perinteinen kustannus-hyöty -analyysi. Luonnontieteellinen tietämys ilmaston ja kasvien kasvun muutoksista luo perustan analyysille. Toinen menetelmä pohjautuu Ricardolaiseen maankorko -käsitteeseen. Näiden menetelmien mukaan Suomen maatalous hyötyy vuodessa 1 - 3 miljardia vuoden 1993 markkaa ilmastonmuutoksesta. Hyöty tulee lähinnä tuottajille ja mahdollisesti veronmaksajille alentuneiden tukiaisten kautta. Vaikutuksia maatalouteen on tarkemmin käsitelty aikaisemmassa tutkimuksessa, Kuoppamäki (1994): Ilmastonmuutos ja Suomen maatalous.

Suomen metsät kuuluvat boreaaliseen metsävyöhykkeeseen, jonka ennustetaan siirtyvän kohti pohjoista ilmaston lämmetessä. Metsien kasvun ennustetaan paranevan ja puustorakenteen muuttuvan koivuvaltaisemmaksi. Aiomme tulevaisuudessa tarkentaa metsätaloutta koskevia arvioitamme uuden tutkimusaineiston pohjalta. Tämän hetkisten arvioiden mukaan metsätalous hyötyy 1993 hinnoin noin 4,8 miljardia markkaa vuoden 2050 tasolla. Tässä ei ole kuitenkaan mukana puun maailmanmarkkinahintojen muutoksia eikä vaikutuksia tuholais- ja myrskyvaurioihin. Energiasektorilla hyötyjä saavutetaan lähinnä lämmitysenergian tarpeen vähenemisen ja mahdollisesti vesivoiman saatavuuden kasvamisen johdosta.

Merkittävimmät haitat aiheutuvat lähinnä Suomen ulkopuolisista muutoksista. Ilmastonmuutos saattaa aiheuttaa tietyillä alueilla kuivuuden ja merenpinnan kohoamisen kautta vakavia ongelmia. Ilmastopakolaisuudesta saattaa tulla merkittävä ongelma, joka heijastuu myös Suomeen. Toisaalta kehitysavun tarve ja muut tukimuodot mm. Etelä-Eurooppaan saattavat kasvaa. Potentiaalisesti merkittävä, mutta vaikeasti arvioitavissa oleva kustannustekijä on biodiversiteetin muutos. Ilmastonmuutos vaikuttaa toki muihinkin sektoreihin kuten terveyteen ja turismiin, mutta tällä hetkellä niitä koskevat arviot voivat olla vain arvauksia.

Kokonaisuutena Suomi näyttäisi tutkimuksen alustavien tulosten mukaan hyötyvän ilmastonmuutoksesta hyvinvointivoittona lähes 6 miljardia markkaa vuonna 2050 vuoden 1993 rahassa mitattuna eli 1,2 prosenttia vuoden 1993 bruttokansantuotteesta. Ilmastonmuutoksen erittäin vahingollisetkin seuraukset ovat mahdollisia. Ne saattavat merkitä huomattavaa nousua maataloustuotteiden maailmanmarkkinahinnoissa ja vakavia luonnonkatastrofeja. Pieni pohjoinen maa kuten Suomi saattaa siis hyötyä ilmastonmuutoksesta, mikäli mitään voimakkaita luonnonmullistuksia ei tapahdu. Sekä ilmastoskenaariot että vaikutusarviot ovat kuitenkin yhä erittäin epävarmoja. Politiikan kannalta tulos tarkoittaa sitä, että syyt rajoittavalle ilmastopolitiikalle on etsittävä muualta kuin odotettavissa olevista haitoista. Muita syitä voivat olla solidaarisuus muita kansoja kohtaan, sukupolvien välinen oikeudenmukaisuus ja riskin karttaminen. Toisaalta Suomi on jo sitoutunut Rion (1992) sopimuksen mukaisiin päästöjen vähennyksiin. Kyse on siis paljolti oikeiden politiikka menetelmien valinnasta ja politiikan laajuudesta, mikäli pelivaraa löytyy jo tehtyjen sitoumusten puitteissa.

TABLE OF CONTENTS

Climate Change and the Finnish Economy

An Interim Report on the Impacts of Global Warming From a Small Nordic Open Economy Perspective

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"A warm climate impairs vigour. It is not altogether hostile to high intellectual and artistic work: but it prevents people from being able to endure very hard exertion of any kind for a long time. More sustained hard work can be done in the cooler half of the temperate zone than anywhere else; and most of all in places such as England and her counterpart New Zealand, where sea-breezes keep the temperature nearly uniform. The summer heats and winter colds of many parts of Europe and America, where the mean temperature is moderate, have the effect of shortening the year for working purposes by about two months. Extreme and sustained cold is found to dull the energies, partly perhaps because it causes people to spend much of their time in close and confined quarters: inhabitants of the Arctic regions are generally incapable of long-continued severe exertion."

-Alfred Marshall (1890): Principles of Economics, Eight Edition, p. 162 footnote 2

Climate change is probably the most global and far-reaching environmental problem of our future. Anthropogenic greenhouse gas emissions may cause significant increase in the radiative forcing with repercussions in the environment. The natural scientific evidence of the consequences has grown remarkably in few years. However, the socio-economic knowledge of the impacts of climate change is still insufficient. There have naturally been some elementary evaluations of the effects almost as long as there has been natural scientific knowledge but the serious interest on the subject developed only at the beginning of this decade. Furthermore, several studies have been conducted on the global and US impacts but only a handful for other areas. It may well be argued that there is a need for more local and detailed studies which take the local conditions into account. In Finland this refers to the cold climate, highly developed and open economy with large forest sector and the unique Nordic nature.

1. INTRODUCTION

This chapter firstly defines the purpose of the underlying project and this paper. Secondly we will make short survey of the methodology and thirdly overlook the current climate change economics literature. This text is not meant to be a complete introduction and survey to the literature.

1.1. Description of the project

In this paper we present our project on the effects of global warming on Finnish economy which is done for the Finnish Research Programme on Climate Change (SILMU) at the Research Institute of the Finnish Economy (ETLA). The purpose of the project concerned is to evaluate the potential influence of global warming on Finnish economy, society and well-being during the next 50 to 100 years. The project began at the beginning of 1994 and should be completed by the end of 1995. Thus, this paper is in a way an interim report covering the whole area of study in an incomplete way. In order to achieve this goal a cost-benefit analysis will be conducted which produces a quantitative estimate of the economic and partially non-economic effects of the climate change projected to happen in Finland. The analysis will utilise the natural scientific evidence produced by other SILMU projects in partial sector models. Thus, the question we try to answer is not how much the climate will change but what if the climate changes as forecasted. Also a broader view of the phenomena and the possibilities for restricting greenhouse gas emissions will be briefly discussed and surveyed. However, the calculations presented here are still preliminary and this paper concentrates mainly on methodological issues and a survey of literature.

The economic research on the subject can be divided very broadly into two groups. The first and more developed group includes the studies of the policy response and ways of limiting greenhouse gas emissions at the national and global levels. These studies strive to develop appropriate policies and calculate the welfare gains and losses related to these policies. The second group tries to estimate the economic value of costs and benefits related to the climate change, i.e. the benefits of the possible environmental policies. These studies are scarcer and the methodology underdeveloped. Nevertheless, this is exactly what we are trying to do in the Finnish case. The underlying idea is to produce information for public debate and decision making and contribute to the scientific knowledge concerning the climate change.

One very important theme in this paper is adaptation. Economy and society as a whole will have to adapt to changing environment in many different ways. Agriculture has to employ new plants and cultivation methods, forestry has to change its forest management techniques, people will have to learn to live in changed environment or migrate and so on. Adaptation has been acknowledged to be a crucial part of climate policy by many authorities, e.g. IPCC (Intergovernment Panel on Climate Change). Still, research on ways of adaptation are scarce and they have been carried out with limited scope mainly in natural sciences, e.g. forestry and biology. Some damage estimation studies admit that adaptation will take place but omit the consequences in their calculations. Thus, it seems that there is a gap between the importance of adaptation and the effort devoted to study adaptation and this paper will try to narrow that gap.

As global warming is a world-wide phenomenon the impacts assessments are often made in global scale. Therefore, it has sometimes been questioned why to make estimates for small countries like Finland if the problem is global. However, if we are interested at all of what happens in Finland we must also study the effects of global change in Finland. The objective of a government policy in a country could be defined as to promote the welfare of its own citizens without compromising its international commitments. Thus, environmental policy like climate change policy in Finland is not inherently different in that respect and must be directed to improving predominantly the welfare of Finns. To be able to pursue advantageous policies decision-makers must know the importance of different problems and the possibilities to affect them from the country's own point of view. Therefore, it is important to know what climate change means locally and not just the global average consequences.

The trustworthiness and unbiased attitude of some greenhouse studies have sometimes been questioned. Now and then these studies do not make the uncertainties clear confusing readers to believe that the results represent the truth without serious qualifiers[1]. Therefore, we find it important to make it clear from the beginning where the results of this study stand. First of all, this study does not try to be an all embracing study covering everything there is to say about climate change or even about its economic impacts. The approach is intended to be positivist but to cover as widely as possible the different opinions presented about the subject. Theory is used or developed only as to facilitate empirical analysis, i.e. we do not intent to develop theoretical models that have no direct practical usefulness. Quantitative analysis is conducted whenever seen possible. Qualitative assessment is possible in most cases and we will use it as a substitute and complement for quantitative assessment. We avoid quantitative estimates based on pure

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1 For example the forecasts by Greenpeace have been said to be biased and non-scientific.

guesses without 'reasonable' support from scientific research. Therefore, this study contains many nil quantitative results unlike Kinnunen (1992) who guessed if nothing else was possible. We do not generally try to outguess him and prefer zero to pulling a number out of the sleeve. Undeniably some of our results are close to pure order of magnitude guesses but we resort to them only when the sign of the number is fairly clear and the number is of special interest to us.

1.2. Methodology of Climate Change Cost-benefit Analyses

In this section we will briefly describe the methods used in economic climate change impacts assessment and discuss many of the problems related to the analyses. The methodology of climate change related CBAs has been mainly based on pragmatic empirical analysis which uses simple partial models for the main sectors of the economy and related welfare generating things like biodiversity. Most often the estimates are made for the impacts caused by CO_2 atmospheric concentration doubling from the pre-industrial levels with some base year economic structure, or for some specific year. The partial estimates are then summed up to reflect the nation wide change in welfare. This is based on the assumptions that the influences across sectors are negligible and that the social utility function is separable[2]. The approach is built on the traditions of neo-classical welfare and environmental economics. However, the climate change research calls for a multidisciplinary approach which implies that also the current project has to expand beyond the traditional boundaries of economic analysis. This is only natural taken the goal to provide information for an audience with multitude of backgrounds. Yet, the core of this study is economics, not ecology, meteorology or something else. There are still many unsolved problems with the methodology because there is no consensus over certain things like the discount rate, value of human life and likelihood of extreme weather events. This can be seen also from the huge differences between the sectoral damage estimates in different studies, though the estimates of aggregate damage are surprisingly close to each other varying between 1 and 2 per cent of global GDP.

The basic task of the project in a very simple formulation is presented in figure 1. Climate change per unit of time is on the horizontal axis and the vertical axis shows the costs, damages or welfare losses (whichever chosen) of the change. The figure shows three slightly different convex curves presenting damage functions. Uncertainty increases with the magnitude of the

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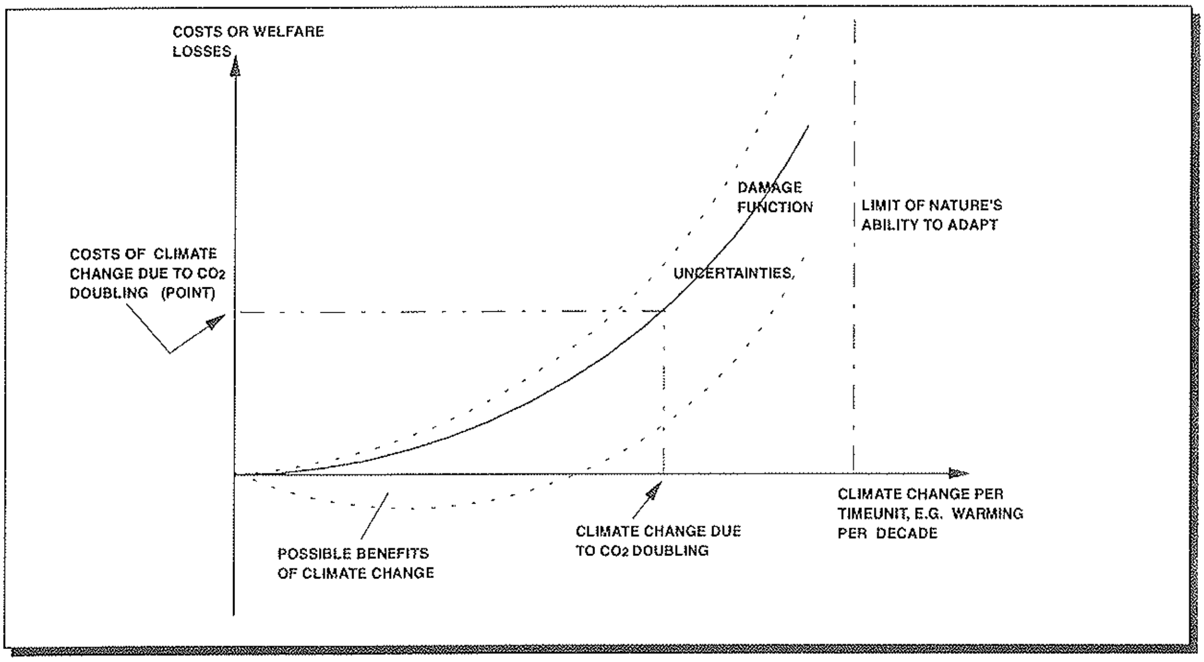
[2] Aggregation over goods and consumers always produces difficulties which are often solved by making simplifying assumptions, see e.g. Varian (1992)

climate change. The vertical line at the right hand side represents the limit of Nature's ability to adapt to climate change, i.e. Nature is able to adapt to environmental changes to certain extent but there are limits after which life vanishes from Earth. This limit is not known with certainty, but in theory the costs rise to infinity as the climate change approaches the limit which is presumably quite high. However, the lowermost damage function shows that there may be an area of potential net benefit for the country in question, i.e. benefits from climate change are not categorically excluded from the set of possible outcomes. The chosen point on the 'best guess'[3] damage function shows the typical case studied both in natural science and economics, namely the point estimate of the impacts of doubling of the CO_2 equivalent concentration. However, the point estimate is not an adequate answer to the problem and lot of research work remains to be done before the whole damage function can be estimated with a satisfactory precision.

Figure 1: Damage function of the climate change



The time path of the damage is also unknown, a constant temperature change per year will not cause a steady damage per year. Economic and social systems will in any case adapt to the changing environment as far as possible. Alongside the adapting society Nature may be able to adapt to the changing climate for some time but a continuous change will eventually lead to severe damage as the adaptive capabilities of existing species and their offspring reach their

3 Term 'best guess' has been widely adopted in climate change literature. It is probably meant to describe the uncertainties and ad hoc nature of the estimates. The closest statistical match is medium.

limit. On the other hand, most probably climate will not change constantly over time but the change will level down at some point in the future. Thus, for a total assessment we should estimate the above described damage function for each year for all climatic histories. In practice this is a pure impossibility and we must concentrate on a few relevant scenarios and benchmark years which give an outlook of the overall situation.

Impact estimates are always comparisons of conditions with climate change to conditions without climate change. The future levels of GNP (especially up to 2050) are impossible to forecast with any acceptable level of uncertainty[4]. The economic structure may change in many ways and this change is even more difficult to foresee. Therefore, most climate economists are cautious about making any baseline estimates of the time path of GNP or future economic structure and use alternative methods to carry out the comparisons. (There are some dynamic growth models for climate change impact assessment, e.g. DICE by Nordhaus, but they rely on impact results from other studies.) The usual way to handle the problem is to use some recent year for which exists adequate data as a base year, i.e. impact is estimated as it had happened that year. We are assuming that the climate change is taking place in 1993 business environment with some modifications. Finnish economy 2050 is assumed to be similar to 1993 economy except that we take EU membership into account and qualitatively anticipate some changes in the structure of economy. We choose 1993 because it is the latest year for which there exists enough data. We admit that 1993 was atypical in economic terms but claim that the error due to this fact is quite minor. After all, no year is a perfect one. All this creates number of problems which we attempt to address during the text.

There have been attempts to formulate a function which could capture the basic properties of the damage caused by climate change. Fankhauser (1994) uses the equation $D[T(t)]=D[t^*][T(t)/T(d)]^\Lambda(1+\phi)^{(t^*-t)}$ where T(d) is the forecasted temperature change due to CO_2 doubling at time t*, D[t*] is the estimated damage at time t*, T(t) temperature change at time t, Λ is a parameter greater than one reflecting the convexity of the damage function, ϕ is a parameter related to the speed of the climate change assumed to be slightly greater than zero and t* is the time when impacts underlying D[t*] estimate are expected to happen. It can be easily seen that when t*=t and T(t)=T(d) (i.e. when CO_2 concentration has doubled as predicted) D[T(t)]=D[t*]. If the impacts occur earlier than t* the effects D[t*] are augmented. The

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4 Growth models are not accurate enough to forecast GNP over 50 years as even a half per cent difference in growth rate of GNP over 50 years causes a difference of nearly 30 per cent in the final GNP forecast.

estimation of the model parameters is based on thin empirical knowledge of the phenomena and ad hoc guesses. Fankhauser (1994) uses T(d)=2.5 ^{0}C, t*=2050, Λ=1.3 and ϕ=0.006. However, as the above formula is not based on robust empirical findings one might conclude that a linear function would be adequate for our purposes. The temperature dependent damage function could be D[T(t)]=D[T(d)]{[T(t)-T(0)]/[T(d)-T(0)]}, where T(0) is the current temperature.

These damages related to the climate change may be estimated at various levels reflecting the accuracy and uncertainties related to them, i.e. market based valuations are more accurate than estimates of non-market impacts. Some people argue that there may not even be any problem, the whole idea of global warming may be a bubble or the consequences may be insignificant. Moreover, criticisers of the approach used in economic evaluations say that it is impossible and therefore misleading to estimate the impact in monetary terms. Particularly, the computations of amenity value or value of the change of biodiversity have been under attack. Despite the criticism we attempt to estimate as many impacts as possible in monetary terms, although we are going to make a clear distinction between the levels of accuracy and tangibility of different effects. A detailed study also helps to evaluate the risks and uncertainties related to the phenomena; it may be possible to identify certain risk areas which helps the policy maker to allocate the available resources correctly. These considerations may have deep implications for possible adaptation and transboundary co-operation policies as we learn what kind of impacts and risks we are facing in the future.

One problem is created by the fact that the partial sector analyses ignore the relations between sectors like energy and forestry. These links could be partially handled in a general equilibrium model. However, we have neither the resources nor the data needed for that kind of study. CGE models have also many problems which may bias the estimates produced by them. However, there exists some integrated models that try to describe the whole system of economy and environment. The most well known of these models is IMAGE[5] which is a multidisciplinary integrated model designed to simulate the dynamics of the global society-biosphere-climate system. The model consists of three linked subsystems: energy-industry, terrestrial environment and atmosphere-ocean. The spatial grid in these submodels is different. The objective of the models is to investigate linkages and feedbacks in the system and to study the consequences of climate policies. Yet, this kind of models are very large and have to rely on scarce data and simplifications making the results of the simulations highly uncertain. However, the models can help to understand the interrelations and dynamics of the systems.

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[5] Alcamo et al. (1994), Image 2.0 Integrated Modeling of Global Climate Change

Due to all these problems related to climate change impacts assessment it is a just question whether some number is better than no number. Estimates are so uncertain and potentially subjective that one may argue that it is dangerously misleading to present any numbers[6]. It might be better to only qualitatively assess the impacts. We respond to this kind of critics by saying that this kind of number crunching gives some insight into the magnitude of the different impact, forces to see the relative sizes of the impacts, reveals the areas of highest risk and uncertainty and eases international comparisons. To avoid misunderstandings the uncertainties will be stressed through the paper in order to make it clear that the calculations should not be taken too literally. It has been said that policy makers are tired of hearing about uncertainties, but the fact is that we cannot escape from the complex reality with probabilities. A quick overlook reveals that word uncertainty and its derivatives are very common throughout the paper.

1.3. A Short Review of Studies on Climate Change Damage

The first serious study in this field was conducted by Nordhaus in the USA in 1991. Since 1991 there have been few attempts to elaborate those results and expand them outside the USA. Kinnunen (1992) conducted a study in Finland and presented an estimate of the Finnish climate change impact. Here we will present a short survey of the methodologies and results of these studies. Nordhaus (1991) used available scientific knowledge to estimate the possible magnitude of the impact of global warming on the US economy. He estimated the impact for some sectors considered to be especially climate sensitive. His original estimation produced a figure that was a loss of only 0.25 per cent of the US GNP. This was criticised heavily and Nordhaus himself admitted that it was too low, he then made an ad hoc estimation and proposed that the likely magnitude of the damage is from 1 to 2 per cent of the GNP. Cline (1992) built much of his analysis on the criticism against Nordhaus' report and presented an estimate of the damage of 1.1 per cent of GNP damage for USA. Their guesses were that the damage is likely to be much bigger in the developing countries. Nordhaus used his yearly damage estimation to produce a net present value for the damage and then calculated the social cost per coal tonne. Nordhaus' latest estimate (1993) was time dependent varying from $5 per ton of carbon in 1995 to $21 by 2095. One important question related to the net present value calculations is the choice of appropriate discount rate. Majority of environmental economists probably agree that the market rate of

6 See The Journal of Economic Perspectives, Fall 1994 issue for discussion on the credibility of CV studies.

interest is too high and Cline even proposed the use of zero discount rate. This is still a question to be solved although there is a widespread agreement that the discount rate should in principle come from the equation $r_t = \rho_t = \delta + \eta(C_t)\frac{\dot{C}_t}{C_t}$, where ρ is the time preference for consumption, δ is the utility rate of discount, $\eta(C) = -\frac{U''(C(t))}{U'(C(t))}C_t$ is the elasticity of the marginal rate of consumption and $\frac{\dot{C}}{C}$ is rate of growth of consumption[7]. This question is discussed below in more detail. Fankhauser (1993) made one more estimation for the USA and for the whole world which was divided into six areas. The highest damages were reported for China and lowest for Former USSR. Developing countries seem in general to be more vulnerable. The most recent published study that has come to my knowledge is Tol (1994) who has also the highest damage estimate below. Although, he states that Europe is likely to be the least damaged continent. He even concludes that the area of former Soviet Union may benefit from climate change. Kinnunen (1992) has made an estimation for Finland following the methods of Nordhaus and Cline. His finding was that Finland is likely to gain from the climate change and only his pessimistic guess showed a net damage. The main results of these studies are presented in the following table.

Table 1: The best guess estimate for damage for USA and Finland

Sector or Industry	**Nordhaus 1991 USA**	**Cline 1992, USA**	**Fankhauser 1993, USA**	**Tol 1994, USA**	**Kinnunen 1992, Finland**
Unit	1988 bn$	1988 bn$	1988 bn$	1990 bn$	1990 mFIM
Coastal defence & loss	10.7	6.1	7.9	8.5	35
Agriculture	1.0	15.2	7.4	10.0	-1,665
Forestry	Small	2.9	-1.8	-	-3,880
Energy	1.0	9.0	-	-	-655
Migration	x	0.4	0.5	1.0	2400
Water	x	6.1	13.7	-	-
Life/morbidity	x	>5.0	16.6	37.4	100
Other	x	8.8	19.8	17.3	-280
Total damage	**48.6**	**53.5**	**64.1**	**74.2**	**-3945**
% of GNP 1988/1990	**1.0**	**1.1**	**1.3**	**1.5**	**-0.86**

Source: Fankhauser (1993, in Kaya et al.) and Tol (1994), p. 102. x is an estimate of 3/4 % of GNP

According to Kinnunen Finland benefits significantly in agriculture and forestry, which seems to be a reasonable outcome also in the light of the present knowledge. The highest costs originate from the possible flow of 'climate refugees' into Finland and potentially from losses in biodiversity. However, Kinnunen did not construct explicit models for all sectors and the

7 This is the form of discount rate used in typical optimal growth models, see e.g. Lind (1994) in Nacicenovic et. al. (1994).

scientific grounds of his estimates are not very solid in every case even if his predictions are realistic. That gives the justification for more comprehensive analysis with updated natural scientific information. At the moment, it seems that the highest costs for Finland come from international responsibilities, not from domestic sources. However, this assumes that human made climate and environmental change as such is not considered fundamentally wrong, i.e. Nature and human made goods are easily substitutable. Deep ecologists sometimes argue that human race has no moral right to cause damage to nature and other species. Less extreme environmentalists say that damages and benefits are not in same units and there are cases when damage is considered to be so high that no benefit justifies it, e.g. sinking of Venice could be thought to warrant almost any measures to save the art treasures regardless of the costs.

Currently there are no other monetary estimates of the economic impacts of climate change in Finland. Finnish Carbon Dioxide Committee II (Hiilidioksitoimikunta II 1994) estimated that the damages are likely to be fairly minor in Finland but risks are significant. Tol (1994) estimates that the area of Former Soviet Union behind the Finnish eastern border is likely to benefit and many others admit that benefits from climate change for some areas are not impossible. In this paper we try to establish a new estimate which is still a preliminary one.

The above studies concentrated on the damage estimation which is also the main task of the current project. However, there exists a large body of literature on the other economic aspects of climate change. There exist a number of studies concentrating on the abatement, adaptation and prevention. By prevention we mean the studies suggesting use of climate engineering to stop the warming. The methods include sending small particles or 'mirrors' into the stratosphere where they would reflect the sunlight back. These methods, however, seem to include such risks and uncertainties that it is better to resort to more familiar and tested methods: adaptation in agriculture, forestry and settlement or abatement of the greenhouse gas emissions via technological development and government intervention with taxes and permits. There are plans and research projects which concentrate on the development of appropriate environmental policies. Both taxes and tradable emission permits have certain individual characteristics, although they in principle can lead to the same abatement outcome. Also the EU has considered the implementation of either CO_2 /C tax or marketable emission permits. However, there is no political consensus on this issue, yet. Furthermore there are important welfare and income distribution issues related to abatement and adaptation policies which are important both at the global and national levels which have not been addressed sufficiently. Thus, much remains to be done both theoretically and empirically. We return to these questions in the last chapter.

One very important point related to the actions to stop the climate change is that the policies adopted now would be of little significance before 2050[8]. Thus, there is nothing we can do to stop the climate change in the short run if we exclude climate engineering and very extreme social changes. In this light short run policy is to adapt and abatement is a very long term policy. Intergenerational fairness plays a crucial role if we want to engage an active climate policy. Current generations and even their children will not see any significant results of those policies.

The earlier discussed choice of discount rate is also related to the discussion of intergenerational fairness. Already Ramsey (1928) argued that discounting is unethical because it means lower value for the future generations. However, as can be easily seen from the above presented equation,$r_t = \rho_t = \delta + \eta(C_t)\frac{\dot{C}_t}{C_t}$, the discount rate consists of both time preference and growth of consumption multiplied by rate of relative risk aversion. Intuitively this means that as the future generations will most probably be much richer than us (depending on the growth of consumption) intergenerational equity actually requires discounting. Thus, even if we do not use positive pure time preference we have to use positive discount rate in order to get the different consumptions at different times to fair and comparable levels. If future generations are poorer it could mean the use of negative discount rate. The choice of discount rate always requires the use of some ethical standpoint.

The level of discount rate used in different models for climate change analysis has varied a lot. As the empirical evidence concerning time preference and risk aversion is somewhat inconclusive one can choose the discount rate based on subjective belief. Toth (1994) has listed some of the discount rates and found that the rate of time preference varied from 0 to 3 per cent; elasticity of marginal utility of consumption varied from 1 to 2.5; growth rate of consumption ranged from 1 to 3 per cent and consequently the discount rate varied from 1.5 (Cline) to 6 (Nordhaus) per cent. It is quite clear that a dispersion of this kind leads to very different policy conclusions.

On the other hand, the relative "richness" of different generations depends on many things including also the state of the environment. If the environment deteriorates drastically simultaneously with a rapid growth of consumption it is difficult to determine if welfare has risen, it becomes a question of sustainability. Sustainable development means in principle a

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8 T. Wigley (1994) and Cline (1992). Greenhouse gases are stock pollutants with lifetimes of several decades. Furthermore, there are many leads and lags related to the climate change.

non-negative growth of welfare[9]. Sustainability can be divided into *strong* and *weak* sustainability depending on the opinion of the substitutability between natural and human made capital. The strong sustainability school believes that the substitutability is very limited implying that environmental damage inevitably leads to lower welfare and vice versa. Thus, those who support strong sustainability are also more likely to oppose the use of discounting.

As it is conventional in mainstream economic thinking to assume that the substitution between natural and human made capital is possible to large extent at least in the longer term, we adopt here the weak sustainability thinking. However, we do not rule out possible extreme events in which case the future levels of consumption and welfare could be much lover than today. That is to say that downward risks are potentially much larger than upward opportunities; the probability distribution of expected environmental damage is lopsided. Climate change may prove to be less harmful or even slightly beneficial but on the other hand it may prove to be very harmful or even catastrophic. Climate change may cause many irreversible impacts, e.g. lost species of vegetation cannot be recovered which can be very expensive as the option value is lost. Thus, irreversibilities imply very difficult valuation problems and demand precautionary policies.

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9 See for example Models of Sustainable Development (1994). The best known general definition of sustainable development is the "Bruntland Committee" (1987) definition. They describe sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*"

2. THE IMPACT OF CLIMATE CHANGE IN FINLAND

This chapter is the core of the paper. We will first survey the natural scientific evidence on climate change. Secondly we sketch the plan for the impact assessment and select the necessary scenarios. Thirdly we go through the sectoral analyses and lastly make a summary of the impacts. Many of the results are preliminary and especially the numbers may change.

2.1. Climate Change in Finland and Elsewhere

As we all know the greenhouse effect is a necessary condition for life on Earth. Without it Earth would be much like Mars. The phenomenon is caused by the concentration of so-called greenhouse gases (e.g. carbon dioxide, methane, ozone, chlorofluorocarbons, etc.) in the atmosphere. However, the increasing emissions of greenhouse gases are causing an increase also in the atmospheric concentration of these gases leading to enhanced greenhouse effect[10]. The probable direct consequences of these emissions are an increase in the global average temperature and change in the atmospheric profile[11]. Global warming may in turn lead to changes in rainfall, oceanic circulation, storms, etc. The changed atmospheric profile has also other impacts like the increase in photosynthesis due to higher CO_2 concentration. All these impacts are, however, very uncertain and unpredictable of their nature. Theoretically, ceteris paribus it is clear that increased atmospheric CO_2 concentration leads to an increase in global average temperature but the speed and size of this change depends on many other variables, too. Other climatic variables like change in the intensity of winds are even more difficult to forecast. The climatic scenarios for some relatively small areas like Finland are much more uncertain due to number of uncontrollable factors. Nevertheless, the knowledge concerning Finnish climate under some realistic future scenarios is increasing and it is possible to make rough estimates of the "second order" impacts of climate change on Finland. These assessments include analyses on forest ecosystems, agriculture, water systems among others. The Finnish SILMU-programme has a goal to produce much new information by the end of 1995.

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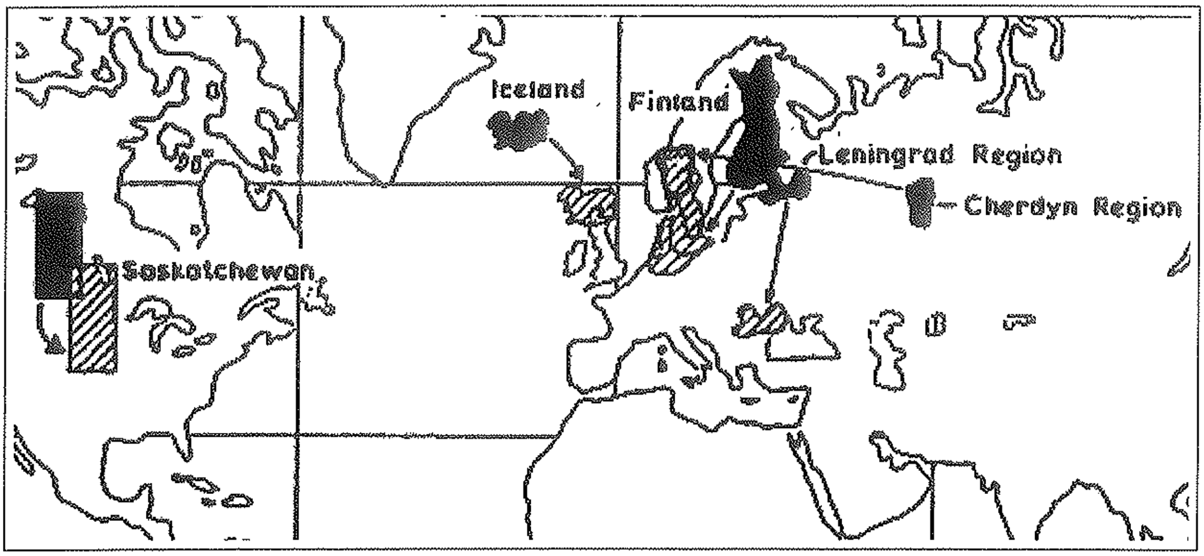
10 See IPCC reports for detailed description of the phenomena

11 The leading "forecaster" of global warming is IPCC (Intergovernmental Panel on Climate Change). Their 1990 forecast was that $2xCO_2$ will lead to an (equilibrium) increase in global mean temperature of 1.5 to 4.5 ^{0}C with a best guess of 2.5 ^{0}C. The rate may be an increase by 0.3 Celsius degrees per decade over the next century. The new estimates hear to be slightly lower. These estimates are widely used in the impact assessment.

Following map demonstrates with geographical analogies the climate change in some chosen areas (Parry & Carter 1988). Finland "shifts" from its present climatic location to south-west so that the climate will be much like the climate of present day Denmark by the time when the CO_2-concentration has doubled, i.e. around mid 21th century. However, this analogy like all the forecasts is not to be taken too literally.

Figure 2: The Climatic Shift of Certain World Regions (Parry & Carter 1988)



It is difficult to give a uniform climate change scenario for all sectors considered in this study. We have to resort to studies based on different scenarios and this creates problems. Generally we assume a smooth 0.3 ^{0}C per decade increase in average temperature over the next century. Changes in precipitation do not always step into calculations but when possible we use the same scenario as Kinnunen (1992), i.e. increase of 3% per decade. These changes are usually assumed to be evenly distributed over the whole country and seasons.

It must be understood that these guesses based on global circulation models are not presently very reliable as the climatic systems are complex and the models do not take into account all the factors affecting climate. Currently some top level climatologists claim that the models do not tell much about future climate mainly because they do not correctly include aerosols[12]. Sulphur dioxide and other acid rain precursors from power plants using fossil fuels may be reflecting heat away from the Earth masking the true dimensions of climate change, i.e. sulphate aerosols may have a cooling effect which is strongest in northern hemisphere. Thus, the present estimates

12 T. Wigley (1994). For Finnish sulfate aerosol research see Kerminen et al. in Kanninen & Heikinheimo (1994).

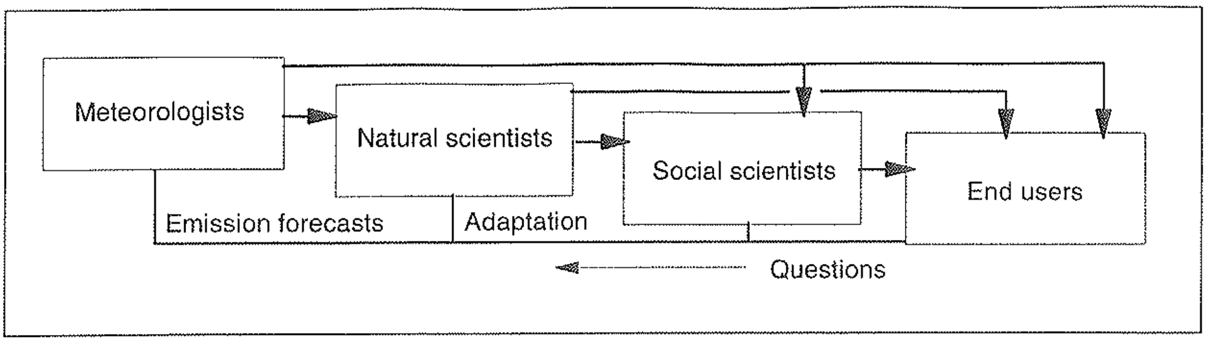
of climate change in local scale are suspect. Furthermore, regional cooling of climate is not impossible even if global average temperature rises. Global estimates may be better but it may still take few years or more to have even a correct sign for some local climate change estimates. Nevertheless, we have to use some best guess estimates and the SILMU-scenarios represent the best possible available scientific information what comes to Finland and climate change.

2.2. Plan for the study and scenarios

Based on the analyses above and some simple models it is possible to compute rough estimates of the economic effects of climate change on the sectors concerned. The main emphasis in the analysis will be on the market based sectors of the society. The focus is on year 2050 which may be considered as a benchmark for long term effects. The impacts for 2050 have in many ways already been determined even though we do not fully understand what they are. Furthermore, the best natural scientific evidence is for that year. Nevertheless, it has been argued that estimating the damage cost for a certain benchmark climate change is not adequate. What we need are cost functions and confidence intervals. These are difficult to obtain, but we attempt to obtain some rough estimates based on the sensitivity analyses made by natural scientists. There will also be impact estimates for time slices 2020 and 2100 when we have the data needed to carry this out.

The information flow between different disciplines is crucial as the atmospheric, natural and social aspects are interrelated in many ways. Next figure (3) represents the flow of information between three groups of researchers: researchers of atmosphere have to have some knowledge of the future emissions of GHGs and Nature's state in future, meteorologists in turn give their estimates of the climate change to other natural scientists who make their impact estimates based on these figures. Social scientists including economists are the final scientific group who need to have information from natural scientists in order to make sound socio-economic analyses. There are or there should be feedbacks as meteorologists need to know the future emission rates (depends on economic activity) and changes in vegetation etc., natural scientists should base their estimates on adapted natural resource management and all groups need to know what are the questions the end users are interested in.

Figure 3: Information Flow Between Interest Groups

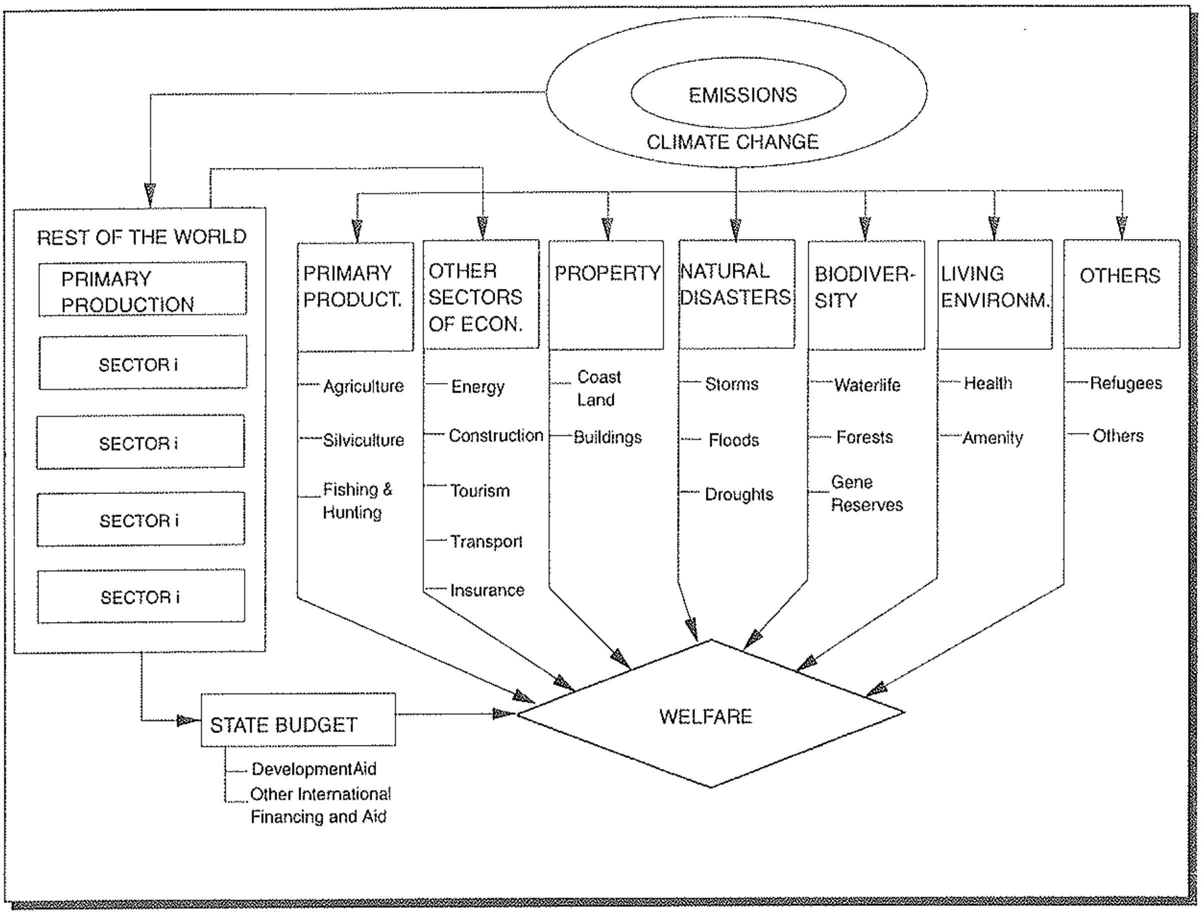


Without good communication between different disciplines there may be misunderstandings leading to erroneous impact estimates. One way to handle these is to have an integrated project including all the subfields like in the IMAGE project. The last group shown in the figure is rest of the society (end users) including politicians as an important group as users of the information. These in many ways lay people depend very much on the information given by experts who have a great responsibility to give as reliable and objective information as possible. Misleadingly presented information and manipulation of research results can lead to wrong decision-making and public confusion. Although healthy and diverse debate is always good thing it sometimes seems that information is far too often presented in an misleading or incomplete way confusing end users and even many specialists.

Next we will shortly present the sectors to be considered. The following figure (4) presents the layout of the analysis in a flow-chart form. Climate change has a direct impact on many sectors of economy and other society which in turn effect the welfare of Finns. Climate change has also an impact on other areas of the world which in turn effects many domestic sectors and creates pressure on government budget. All these sectors will be covered later in detail. We have chosen the sectors that a priori seem to be climate sensitive and thus excluded many sectors.

We must also have a scenario of Finland in the 21st century to enable us to do the analysis. It is likely that Finland will begin the century by being a relatively wealthy and politically stabile member of the European Union with ageing population. We assume that the membership in EU extends over the whole century and economy continues to grow. Although population is usually expected to start to diminish at the beginning of next century we assume that population stabilises to 5 million with the help of immigration from other countries. The resulting error from this assumption is likely to be small. However, we must consider also other possible future development paths. The most relevant ones from this viewpoint are rapidly deteriorating environment and a closed economy scenario. Currently it seems that Finland will be a member of EU during the next decades and trade barriers will be lowered. Nevertheless, history teaches that many things can happen over 50 years. Therefore, it is interesting to see what kind of effects there would be if Finland was a closed economy as an alternative scenario.

Figure 4: Sectors Included in the Impacts Assessment



All the sectors of economy and social life will adapt to climate change in one way or the other. Some of the sectors are more able to adabt than the others. Nevertheless, the inherent dynamics of capitalism will naturally force firms to optimise over time in respect to prevailing climate, i.e. some adaptation will automatically occur. To be able to adapt in time and with the right measures firms need to know what kind of changes to expect and what are the options. Government can ease the adaptation process by providing information on climate change and infrastructure, e.g. protection of coastal areas. However, the research efforts on adaptation have been relatively minor compared to other studies like abatement or impacts without adaptation. Thus, it will be important to study more the adaptation possibilities in future studies. We will try to consider adaptation opportunities in each of the sectors we analyse in this paper and take the consequences of adaptation into account in the welfare calculations.

2.3. Sectoral analyses

In this sub-chapter we analyse all the chosen sectors following the above described scenarios. First sector is agriculture which we have already analysed more thoroughly in Kuoppamäki (1994).

2.3.1. Agriculture

Agriculture is one of the most climate sensitive sectors of the Finnish economy and one of the most difficult to analyse because of future changes in the institutional setup. Current climate model simulations show warming in Finland with a rate of approximately 0.3 ^{0}C per decade. These estimates are very uncertain and subsequent changes in rainfall are even more uncertain although it is likely that winter rains will increase. Climate change will shift the boundary of arable land northwards and increase the crop potential. Also the growing period is lengthened increasing the time cattle can be kept and fed outdoors. However, the risk of pests is increased reducing the benefits. We applied two different methodologies to analyse the economic effects taking the effects of the Finnish EU membership into account. First we used traditional cost-benefit analysis to study the economic effects of climate change on agriculture. Natural scientific research results concerning climate and plant growth changes create the basis for the analysis. The second method was based on ricardian land rent concept. The problem with the CBA is that it can't take all the possible ways to adapt into account. Next we will briefly go through the calculations[13].

Finnish agricultural prices have to adapt to the price level of common markets. The relevant shadow price of agricultural production in Finland seems to be the EU price level. There is a risk of increasing food prices in the long run as population grows and environmental problems cause difficulties with production. However, there has been no long run upward trend in real food prices this far and most studies fail to show reliably that the price will rise due to climate change. Therefore, we assume that the price of agricultural products in Finland 2050 is at the current EU-level. Furthermore, we assume that the steady-state agricultural production in Finland is near the self-sufficient level without climate change. The natural scientific estimates of the impacts show approximately that the crops will increase 40% (supported also by the

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[13] See Kuoppamäki (1994) for details

analogy to present day Denmark), cattle food costs decrease by 10% due to longer growing period, fruit harvest increase by 50% and increase in damage costs of pests by Danish analogy 100%. Armed with these assumptions we can calculate the change in producer surplus and the sum of these figures gives FIM 1255 millions benefit of climate change.

The second method is based on the idea of Ricardian land rent calculation developed into its present form by Mendehlsohn et al. (1993 and 1994). Climate is one of the most important exogenous inputs in agricultural production and it is reflected in the crop. The market value of the harvest or any other output of the land will then determine the market price of land which in aggregate reflects the value of agricultural production. Thus, in competitive markets climate impact on agriculture may be approximated with the use of projected change in the value of agricultural land. The advantage of the Ricardian approach is that it will automatically assume the best land use option, i.e. perfect adaptation is implicitly assumed. The value of an environmental change, $E_A - E_B$, is then $V(E_A - E_B) = \Sigma(P_{LEB} - P_{LEA})L_l$, where P is the price of land before the change (B) and after the change (A) and L is the amount of agricultural land in the area in question. First we had to find the empirical relation between land prices and climate in Finland. By testing three different explanatory variables (average temperature, average rainfall and population density) it was found out that average temperature was the best explanatory variable. On the other hand, the aggregate value of land reflects the opportunity cost of the farmers work, $\Sigma P_{L,t} = [\Sigma G_{t-1}] * \frac{1}{y}$, where G is the income of the land and y is the discount rate on agricultural income reflecting the risks related to it. Assuming a drop in the farmers expected entrepreneurial incomes (G) to steady-state level of 4 billion FIM per year[14] and further assuming a uniform temperature change of 2.4 ^{0}C by 2050[15] we can estimate the value of the temperature change to be 2.2 billions FIM. This does not take into account the possible beneficial fertilisation effect of higher CO_2 level. By approximating the "CO_2 multiplier" to be 1.2[16] we get the final figure of 2.7 billion FIM benefit from climate change. This result is bigger than from the traditional CBA which is natural given the more optimal behaviour.

As there are huge uncertainties and simplifying assumptions we can say that according to these methods Finnish agriculture will benefit 1-3 billions 1993 FIM per year from climate change the best guess being 2 billions. The benefit is distributed mainly to producers and possibly to taxpayers through diminished subsidies. Consumer surplus will not change noticeably because of the unchanging price.

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14 This is only a guess of the level based on 1993 level and effects of EU membership.

15 SILMU scenario 1992

16 This is another guess based on crop growth simulations, it may be too high.

However, there exists a non-zero probability of extreme effects of climate change. These may imply significant increases in world agricultural product prices and serious famines. Food is difficult to substitute with other goods. This could mean higher food prices but even under these conditions Finnish agriculture will probably improve its profitability alleviating the effects of the damage on Finland. On the other hand, under non-integration scenario where Finland would somehow be closed economy and highly reliant on its own agriculture the potential benefits might be even greater. Thus, even if the climate change on the world scale is harmful for agriculture that condition does not seem to hold in Finland.

One globally important point which may have some importance also in Finland is the change in land use structure. The area needed for agricultural production may shrink releasing land for other uses like reforestation. The profitability of different uses of land naturally influences the allocation of land. Thus, climate change may have an impact on land use profiles in many areas including Finland.

2.3.2. Silviculture

Forest ecosystems will be affected by climate change throughout the world. Forests also serve as a sink for carbon dioxide reducing the concentration of greenhouse gases. Finnish forests are part of the boreal forest zone that covers more than 1000 million hectares globally and over 20 million hectares in Finland. The boundary of boreal forests will most likely shift northwards chancing the structure of Finnish forests[17]. The adaptation and damages of forest ecosystems depend highly on the speed of the climate change. According to Finnish forest experts there is no risk of large scale forest damages in Finland if the climate changes as predicted. In fact, Finnish forests will probably grow faster giving more raw material for industry and enlarging the sink for carbon dioxide as long as the forests can sustain the growth. There exists number of studies forecasting forest growth but we will wait for the newest SILMU results in order to be able to properly update the results compared to Kinnunen (1992). Here we will present some preliminary calculations which may change significantly after we have better data. Nevertheless, it is important to note that most of the trees that have been planted this year will be still growing after 2020 and many exist still in 2050. Thus, the actions taken in forestry will effect very slowly as the timehorizon in forest management is much longer than for example in agriculture.

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[17] Kellomäki et al. (1994) and Valsta & Linkosalo (1994) in Kanninen & Heikinheimo. Spruce will probably be partially switched to pine in Finland.

Forests have multiple functions in modern economies. The traditionally acknowledged function as a source of raw-materials for forest industry is still important but the other uses have recently gained more and more attention from the public opinion and academics. The multiple uses of forests include recreational activities and resources for biodiversity preservation. These external benefits imply that the value of forests is higher than the pure market price of wood determined on the international markets. Moreover, rational forest owners are willing to sell only wood which has a stumpage price exceeding the value of the wood for the owner. The value of the wood for the owner consists of the discounted expected commercial and other gains. The other gains may include recreation, fence against highways or neighbours or it may just be 'nice to own forest'. Nowadays most forests can be harvested as there exists an extensive net of roads and techniques have developed. Thus, even if all the forest growth could not be used by industry the "surplus" growth is not less valuable than the wood used by industry as has been occasionally argued[18].

Climate is one of the major determinants of forest growth. This can be easily demonstrated by making a regression analysis between average temperature and forest land values[19]. Forest land value should reflect the productive capabilities of the plot of land in question, i.e. more productive forest land is more expensive than less productive. We made an OLS regression with average forest land trade price data from 12 provinces (lääni)[20] using average temperatures and average rain-fall as climate factors and used population density to reflect the opportunity costs of land. Only average temperature was statistically significant at the 95% t-value level and it alone gave R^2 of 0.8. The results of this regression are shown in the next figure (5).

The impact of climate change on forest sector is a very dynamic phenomenon. Forest stock may grow faster but it cannot grow infinitely. The relative and absolute forest growth between different countries will change causing changes in international forest products markets: market clearing price may change, countries trade balance in forest products may alter, the demand for forest products can change in many ways and trade flows could be diverted. These changes are difficult to anticipate even if some comprehensive world-trade models could show the main directions of the change. In any case the potential impacts for Finnish economy are high because the forest cluster is such an important sector of the Finnish economy, figure (6).

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18 Kinnunen (1992) used higher value for industrial wood consumption. He also estimated the wealth effect to be nil because of price decrease resulting from increase in supply. As we are using the open economy scenario price is determined internationally.

19 Some excluded factors like the location of forest industry may also be important.

20 Kiinteistöjen kauppahintatilasto 1993

Figure 5: Climate and Forest Land Prices

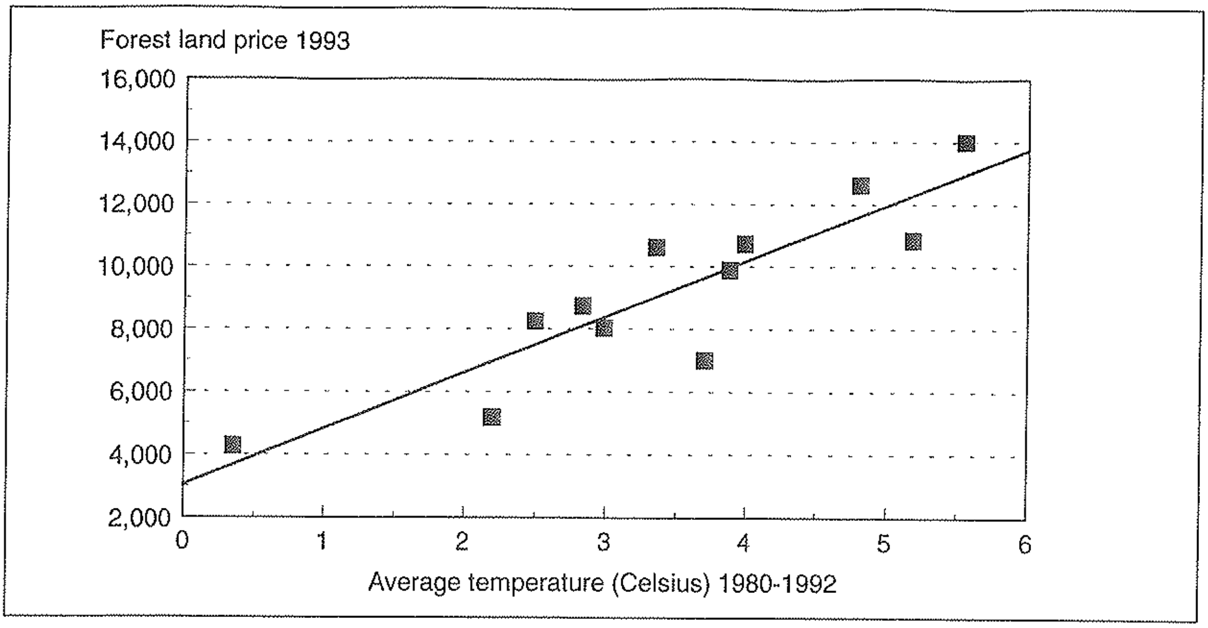
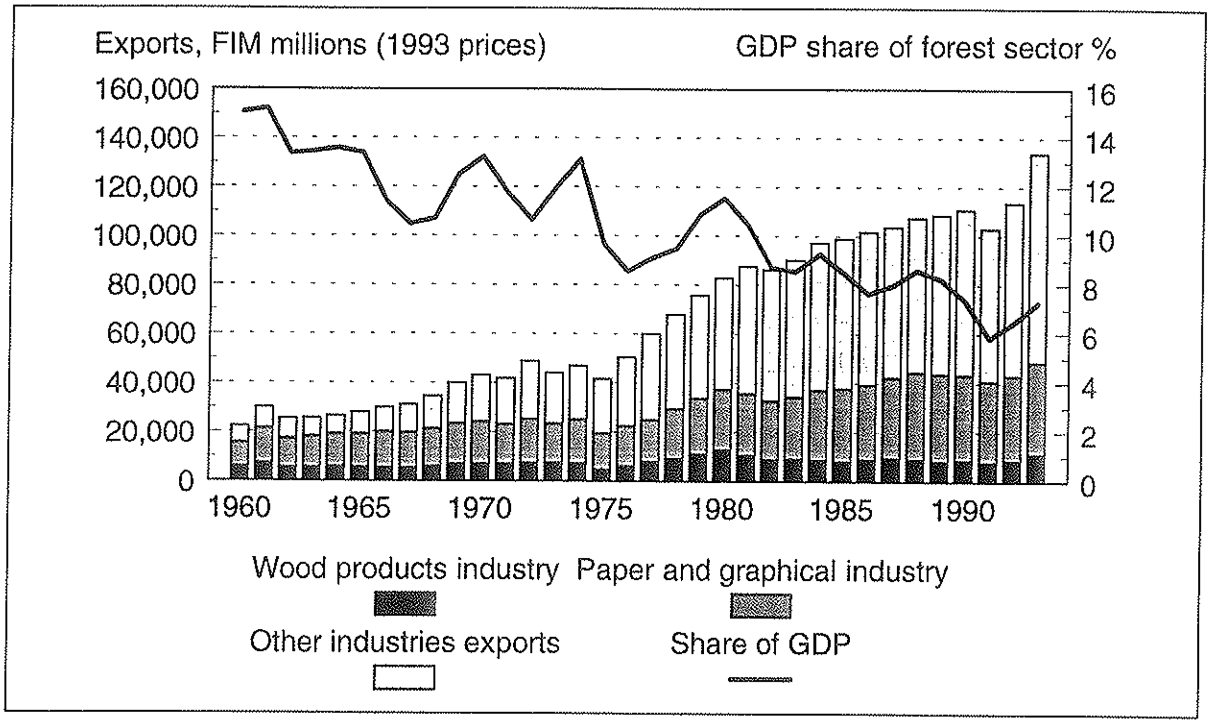


Figure 6: Forest Industry and Exports



With the plain vanilla CBA we can estimate the rough magnitude of the economic impact of climate change on Finnish forestry. The price level of 2050 is as with the agriculture difficult to forecast as there are number of influencing trends in addition to the forest growth change due to climate change. At the demand side there is a trend towards more ecological thinking both with more recycling and call for ecologically soundly cultivated raw materials, and acceptance of wood as a natural renewable raw material. Economic and population growth increase demand for wood products. At the supply side, part of the forest companies try to respond to the demand side trends. At the same time production methods are evolving, forest growth changes and forest management techniques change. Thus, the direction of price change is analytically impossible to determine. Therefore, it is at least useful to calculate the value of the change in forest growth by using current prices as indicators of the commercial value of wood.

Let us describe the value of forests with a simple model. External benefits of forests mean that the value of wood V is higher than the price P by some externality multiplier ξ, i.e. $V(Q) = \xi_t(Q_t)P_t(Q_t)$ where t is time and Q_t is the forest stock and partial derivatives of ξ and P with respect to Q are negative. ξ_t is an average value as some forests produce more external benefits than others. If negative externalities from forests are ruled out then $\xi_t > 1$.

The price of wood in the forests can be approximated by the average stumpage price of different wood species. Stumpage price reflects the price of wood as such and does not include other value added like delivery prices do. We can calculate the weighted average stumpage price P_t^S of spruce, birch and pine. ξ_t can be approximated by first counting all the money spent on other forest related activities like hiking and collecting berries and using it to approximate ξ_t by calculating the approximate net present value of the stream produced by forest during its rotation period.

The average stumpage prices and purchases of roundwood in private forests during 1992-1993 have been on average of the level presented in the next table (2):

Table 2: Average Wood Prices in Finland 1992-1993

Species & Use		**Price** FIM/m^3	**Purchases** 1000 m^3
Logs	Pine	191	3,789
Logs	Spruce	154	6,638
Logs	Birch	205	636
Pulpwood	Pine	67	4,399
Pulpwood	Spruce	85	5,271
Pulpwood	Birch	68	2,907
Weighted average price FIM/m^3			126.33

A weighted average price is then 126 FIM/m^3. Income from picking wild berries and mushrooms for sale has been roundly FIM 50 millions per year during the last decade[21]. Picking without selling the proceeds is probably at least as much. Unfortunately the data of other multiple-use activities like hiking is very limited. As the growing stock volume of Finnish forests is almost 2000 millions m^3 it means that the value of collecting berries is only a very small fraction of the value of the forests, i.e. ξ is close to unity. If the forest stock grows ξ converges towards unity but if the stock reduces ξ grows as the marginal benefit of the remaining forests increases. As there is plenty of forest in Finland it may well be argued that at the marginal even fairly significant increases in forest stock do not create external benefits as nearly all the benefits can be achieved with the current forest stock. The forested area is unlikely to grow much implying no major changes in land use. Slight benefits may be created if conservation of old forests becomes easier as the wood can be procured elsewhere. Let us make an ad hock estimation that the value of wood in 2050 is FIM 120 per m^3 in 1993 prices. Assuming that the change in forest stock by 2050 is approximately[22] 40 millions m^3 implies that the value of the change would be FIM 4.8 billions including increased commercial use and rise in wealth. Thus, not all of this gain will show up in the GDP statistics. At the moment we make no guesses on the division of this benefit between wealth and income. This is a fairly high estimate and it is not sustained throughout the 21st century. Furthermore, it does not take into account the changes in forest profile and market prices[23]. Thus, this estimate is only a very rough order of magnitude guess which we try to improve in the future by taking the possible price changes into account.

Climate change may make Finnish forests more vulnerable to different pests and possibly wind-induced damage[24]. Also forest fires may increase due to warmer summers. At the moment we do not have possibilities to estimate the damage caused by these factors and will not draw a number out of the sleeve. Thus, the magnitude of this damage remains ambiguous for the time being.

Forest sector has also been a major determinant of Finnish current account through trade balance and deflationary exchange rate policy. Thus, climate change may have an impact on Finnish

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21 Yearbooks of forest statistics 1993-1994

22 Same figure was used by Kinnunen (1992), from Dykstra & Kallio (1988). See also Hari et al. in Kanninen & Heikinheimo (eds. 1994)

23 Even if wood supply increases in Finland it may be that total world supply diminishes leanding to price rises. Fankhauser (1994) predicts worldwide net damage.

24 IPCC (1990) impacts assessment, Kellomäki et al. (1994) in Kanninen & Heikinheimo

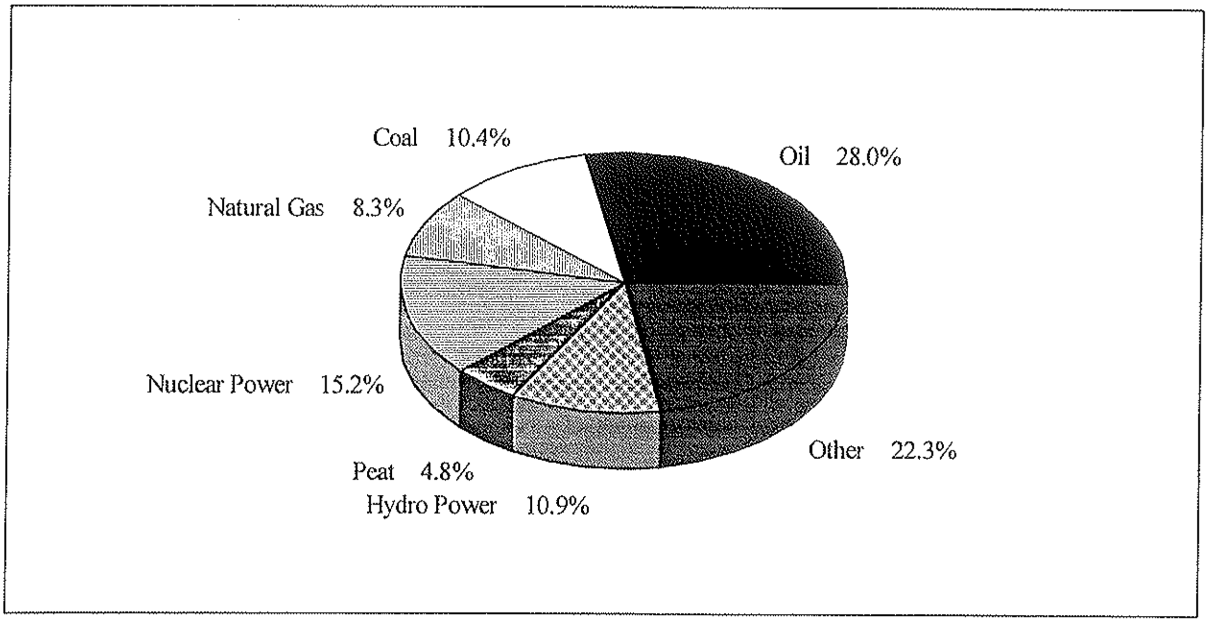
current account. If we consider the closed economy scenario there are potentially very significant differences compared to the best guess conditions. Difficulties in forest products export could dampen the otherwise beneficial effects of climate change on Finnish forest sector.

2.3.3. Energy

One of the main sources of greenhouse gases is energy production and combustion of fossil fuels. Energy production will also be affected by climate change because the demand for heating energy diminishes with higher temperatures and the demand for energy for cooling systems increases. Also the availability of hydropower may be altered. Next figure (7) shows how the Finnish energy was produced in 1993 and we can see that the share of hydropower was over 10 per cent of energy production.

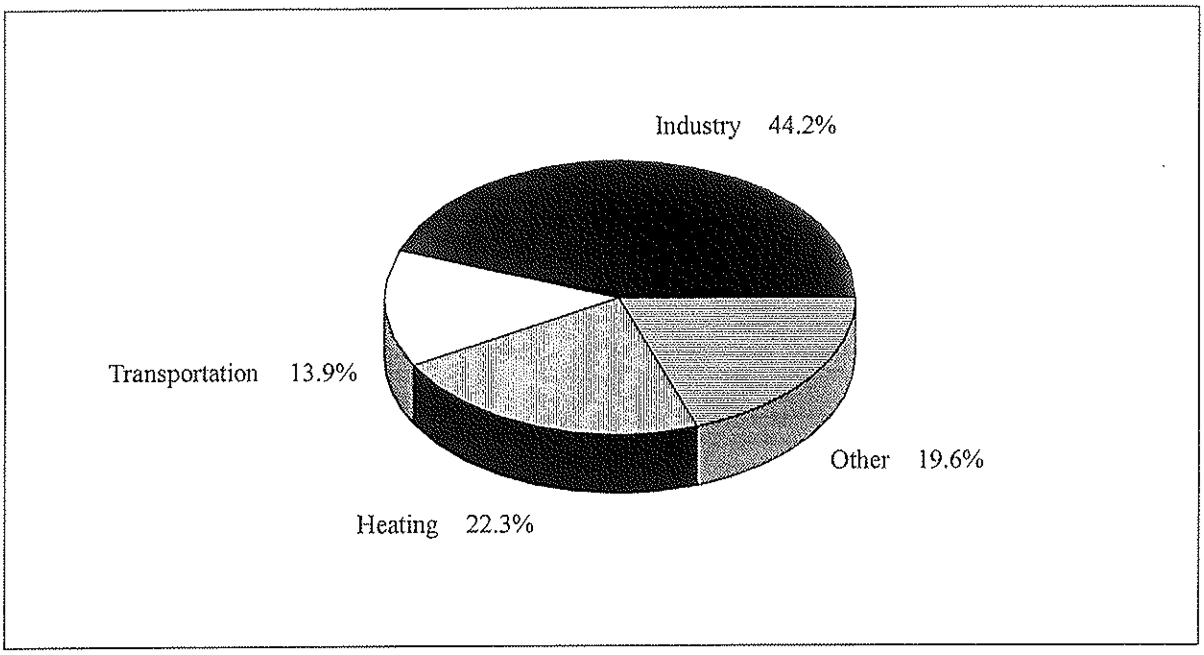
Energy supply benefits from increased precipitation contributing to higher hydropower capacity and increased wood supply provided that the combustion technology develops. If all the increase in the run of the harnessed rivers can be used effectively we can approximate the change the power production with the associated percentage increase. The effect of the change in forest growth can be dropped from the analysis as we have already calculated the impact of the forest growth change.

Figure 7: Finnish Energy Production in 1993 (Energy Statistics)



Heating energy demand will probably drop significantly during the wintertime and cooling energy demand slightly increase during the summertime. If we model monthly heating energy demand of households as a linear function of monthly energy prices and average temperatures $E_t^D = aP_t^E + bT_t + \varepsilon_t$, then we can estimate the sensitivity of energy use to temperature and use the coefficient (b) to forecast the drop in energy demand. Unfortunately the unavailability of monthly energy statistics do not permit this kind of analysis. In future we will approximate the sensitivity parameter (b) from oil and other statistics. Next figure (8) shows how the structure of energy consumption in Finland in 1992. Heating was almost a quarter of the use of energy implying that the savings from warmer climate can be important.

Figure 8: Finnish Energy Consumption 1992



World scale effects may also have some significance for Finland through changes in relative and absolute prices but the magnitude of the total impact is impossible to determine. In any case there are huge uncertainties related to the future development of energy markets. In the shorter term before 2020 there may be increases in energy prices as demand still increases. In the longer run it may be possible to develop new technology producing fairly cheap energy in large amounts, e.g. fusion reactors and solar energy. Thus by 2050 the energy sector may look much different from present day not to talk about 2100.

For the time being we use the rounded central estimate of Kinnunen (1992), FIM 655 millions, based on Aittoniemi (1990) who made an estimation of the impacts of climate change on

Finland. Thus, the impact of climate change on Finnish energy sector is a benefit of FIM 700 millions.

2.3.4. Construction

The need for insulation diminishes with increased average temperature lowering the construction costs. The size of this reduction is difficult to assess as there is a trade-off between insulation and heating. Costs may be created by the rise of sea level which requires some additional work at the coastal areas. Coastal problems are considered as a separate group of costs. Changing climate may also damage existing buildings increasing repair costs and shortening the duration of buildings' life cycle.

Insulation costs of the future buildings became lower especially as the cold winter climate is expected to become warmer. Unfortunately we do not know at the moment how much insulation costs comprise of total construction costs in Finland. Higher precipitation and warmer climate may have some negative effects on the current building population and may require use of new material in new construction projects. These material may be cheaper or expensive. As the old materials are not any more optimal for the changed climate the value of buildings could depreciate more rapidly. This cost is likely to be small and difficult to estimate. Wintertime construction as a weather and climate sensitive sector will probably benefit from warmer climate, e.g. less working time will be lost due to low temperatures. For the time being we do not have enough information to estimate properly the value of the impact of climate change on construction sector.

2.3.5. Transportation

Land, water and air transportation are likely to become easier and safer as the difficult winter period is shortened. Researchers expect that even small climatic changes will show up drastically in the ice conditions, i.e. the ice cover of Baltic Sea may be diminished (Leppäranta et al. 1994). This results in better conditions for winter period shipping with less need for ice breakers. On the other hand, Finnish shipyards have been famous of their ships built for Arctic conditions, i.e. this know-how may become obsolete but over long period giving time to adapt.

The planning horizon of Finnish road administration is about 30 years which barely includes the change in climate. However, the shortened winter period implies less stress on roads by winter tyres. The use of salt on roads might also diminish improving the nearby environmental conditions. However, this is not certain as the salt and sand are needed most badly near 0 ^{0}C when the road is most slippery. The use of salt per road kilometre may decrease in future but road system grows also. Reduction in snow fall means also reduction in need for road management. Accidents are often caused by bad winter conditions and improved road conditions could save us from few accidents. However, car traffic system may in 2050 look somewhat different from today being for example less sensitive to weather conditions. Therefore it is preferred not to estimate this impact in 2050. At the moment we do not have enough data to make needed calculations.

Air traffic could slightly benefit from warmer winters but the benefit is difficult to quantify. Costs of shipping on the Baltic Sea could drop in wintertime but stronger storms could create new threats. As there is no information on the magnitude of the change we will not try to estimate this impact.

2.3.6. Tourism

One of the most fundamental reasons for travelling is climate. People seek recreation from different climates and escape the cold Finnish winters to warmer countries. People from rest of the world come into Finland for other reasons like skiing and unique Nordic nature. The comparative advantages and attractive features of different sites are very different. This implies that even if all areas suffered from climate change the least damaged areas may gain because their relative attractiveness has grown. Even in this case there may be domestic costs from environmental change. In Finnish case this may mean diminished opportunities for skiing and other winter sports but longer and warmer summer season.

Northern Finland is possibly one of the biggest beneficiaries in tourism as the natural snow cover will still be available for winter sports even after 2050. Also the warmer nightless night summertime may be a tourist attractor. Southern Finland is likely to suffer from warmer and moist winter periods but may also gain during the summertime as the climate will be more comfortable than elsewhere in the world.

Domestically the skiers suffer in southern Finland as they are either forced to shift to other areas like Lapland or forced to change to other hobbies. Recent years have also shown how difficult it is to arrange skiing competitions in southern Finland when weather is warm. On the other hand, summer holidays may become more comfortable in Finland. Whether the conditions for local tourism in Lapland will improve or deteriorate is a more difficult question to answer. The change will probably not be very large and the population in relation to rest of Finland is small.

Thus the direct effect is likely to be negligible. However, the possible flow of tourists may crowd some areas causing discomfort to the local population accustomed to peaceful environment.

If as presumable the possibilities for skiing weaken world-wide the price of skiing will increase. This implies probably higher sales revenue for Finnish tourist sector but also diminished consumer surplus through price rises. Next table (3) summarises some of the conceivable natural ja "comparative advantage" impacts for different areas in Finland. The plusses and minuses are related to the attractiveness compared to the rest of the world.

Table (3): Climate change and Tourism in Finland

	Summer		Winter	
Coastal area	Warmer summers, possibly more rains and slight sea level rise.	+	Warmer and more moist	-
Lake area	Warmer summers	++	Warmer and more rains, less or no snow	-
Northern Finland	?	?	Warmer, shortened snow cover period.	++

On the other side of travel balance Finns may travel less to southern countries as the climate there becomes more arid and less Arctic in Finland. Thus, the combined effect may be that the Finnish travel balance improves significantly. At the moment we do not present any quantitative estimates of the impact of climate change on Finnish tourism.

2.3.7. Coastal areas

Higher average temperature causes a rise in the sea level because of ice core melting and thermal expansion of water. Currently the rise is estimated to be relatively small at the Finnish coast (app. 20 cm during the next 100 years). There is even a counter force as the land is still rising at the western coast after the last glacial. Some costs may be incurred at the southern and more densely populated coast. In fact, the City of Helsinki has already acknowledged this in some building projects near the coast line. Government can make the adaptation easier by providing information and training on needed changes in construction techniques. If sea level rises significantly some cities may need to build expensive dams. Legislators should also consider changes in related laws in order to avoid future damage. However, it should be remembered that well-informed citizens should not be too restricted by too rigid laws.

The value of the lost coastal land can probably be best approximated by using average market value of land at the coastal region, i.e. the value of the lost land is simply the lost area in hectares times the average price of a hectare. However, at the moment we do not have information on this and the value of this change per year is likely to be negligible but negative. Higher costs may be suffered if flooding becomes more frequent. At the moment we assume the damage for coastal areas in 2050 to be zero.

2.3.8. Fishing and Hunting

Higher average temperature lead also to higher lake and sea water temperatures affecting the fish population and other sea fauna and flora. In Finnish water areas this may mean a northward shift of cold water fishes and difficulties for fisheries[25]. However, once again adaptation can alter the damage profile significantly. Wild animals like deers also have to adapt to changed climatic conditions. For some species it is a disadvantage but for others it may be an improvement. In any case fishing and hunting are such a small part of the economy that the economic impact from climate change via these sectors is small.

Warmer climate would also mean higher water temperatures meaning weakened conditions for cold water fishes and improved environment for warmer water fishes. Recreational fishing concentrates mainly on fishes like salmon and the number of these may diminish especially in southern parts of the country. This implies a loss mainly for sport fishers because the available studies for commercial fisheries in Finland show no significant losses. In fact, fish population is likely to increase due to warmer climate[26]. However, losses may come through international markets if the price of fish is increased. For example changes in sea surface temperature may cause a reduction in biomass or a shift in the location of fish stocks, creating local, national, and international political, economic, and social problems[27]. These problems probably have directly quite little to do with Finland.

Hunting customs may change as the warmer climate animals start to conquer the wildlife areas from colder climate animals. Deers and rabbits as the usual hunters prey are likely to survive also in the changed climate. Thus, we conclude that there is unlikely to be any significant damage on this sector even if the structure of the sector may be significantly changed.

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25 Koskela, Juha & Pirhonen, Juhani (1994) in Kanninen & Heikinheimo (eds. 1994)

26 Riista- ja kalatalouden tutkimuslaitos (1992)

27 Glantz (1990)

2.3.9. Insurance

As the risk of extreme climatic conditions increases and causes forest fires, storms, etc. there will be an effect on insurance companies and their policies. Some of the natural disasters of last years have been very costly to insurance companies, for example hurricane Andrew 1992 cost nearly FIM 120 billions to insurance sector causing 8 bankruptcies among insurance companies[28]. Some scientist and many environmental NGO's like Greenpeace see these disasters as clear indicators of climate change and warn insurance companies of further catastrophes. However, the evidence is inconclusive as these disasters still fit into the range of normal climatic variability. Undeniably the number of hurricanes in the USA has been high in the early 1990's, see next figure (9)[29], but that does not necessarily imply global warming due to increase in the concentration of greenhouse gases.

However, if the insurance companies have rational expectations they will correspondingly increase their fees and payments thus transferring the costs to the buyers of the insurance policies. As the uncertainties grow it may in fact mean that demand for insurance increases benefiting the insurance industry and the costs will be incurred by others. It would actually be double counting if the damages suffered by other sectors would be calculated also as costs for insurance sector. Thus, if insurance companies act rationally as they should if they are to maximise their value there should not be any significant expected damages. This does not rule out the possibility of extreme events causing surprisingly high level of damages. Insurance sector may also be affected by the growing demand for insurance against climatic surprises and by the corresponding increase in the insurance premiums. The insurance industry may slightly enlarge or get smaller as a consequence but arbitrage will ensure the sustained return on investment comparable to return in other sectors adjusted for risk. Anyway, insurance sector has an important role in adaptation as it facilitates hedging against climate born risks in climate sensitive locations and sectors[30].

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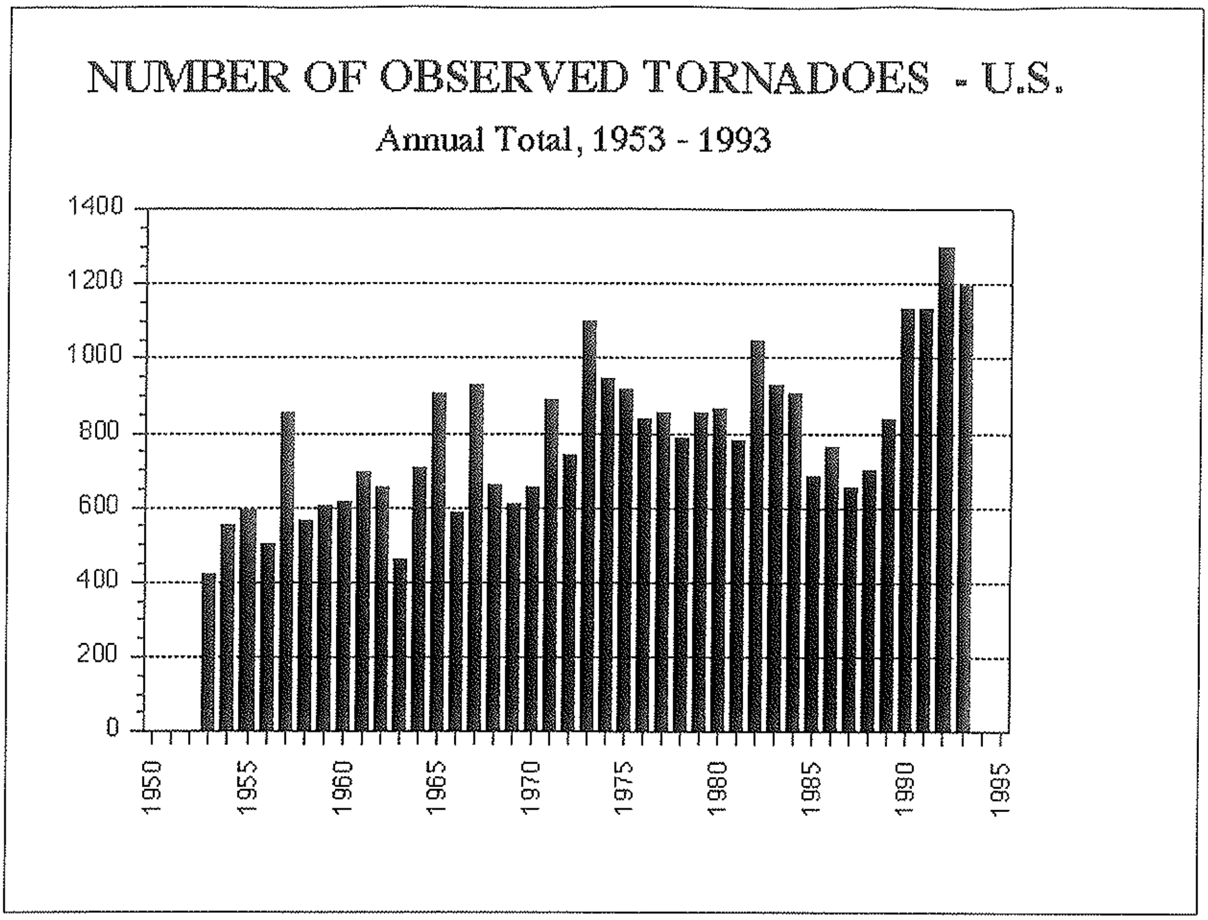
28 HS 21.11.1994 (Finnish newspaper article)

29 NOAA Global Warming Update World Wide Web page on February 6, 1995, URL: http://www.ncdc.noaa.gov/gblwrmupd/global.html (/images/fig11.gif) by Karl, T. R. & Baker, C. B. (1994)

30 However, insurance companies seem to become somewhat wary to insure against natural hazards, e.g. it may be difficult to get a flood insurance in Central Europe.

Figure 9: Observed Tornado Frequency in USA 1953-1993



Thus, our best guess is that there will be no damage from insurance sector with the provision that no big surprises occur, i.e climate change happens as predicted.

2.3.10. Property & Natural Disasters

Changed climatic profile and possible increased storms may cause damage to buildings and other property. This damage may hurt many different sectors including the above mentioned insurance, housing and harbours. Natural disasters can be considered as a group of its own although most of the effects are already considered in the above described damage categories. However, the regional and even global change in the frequency and intensity of storms, floods and droughts is one of the most difficult things to forecast. Globally the main fears are related to the increase in tropical storms and droughts in some important agricultural areas. Recent floods in Central Europe have demonstrated that Nature can take over large areas and lead to economic difficulties. Extreme weather conditions are unlikely to occur in Finland although infrequent harmful storms do happen. However, as the scientific knowledge is inconclusive the best guess at the moment is that there will be no damage due to storms in Finland, i.e. the best guess is that the impact in this sector is nil. However, hedging against the possibility of disasters might be wise as disasters can be very expensive if they happen unexpectedly and hedging can be costly.

2.3.11. Government Budget

Public expenditures are directed also to development aid and other international payments. The pressure to increase these payments may grow if developing countries or other poor regions suffer from the climate change. Bad famines for example in Africa have proven to be very difficult to handle and an increase in the frequency and severity of that kind of disasters may cause very high increase in need for emergency and development aid. Higher development aid in addition to emergency aid in case of famines may be needed to reduce the climatic sensitivity of the developing countries. The payers of the aid are found from the richer and less climate vulnerable temperate zone economies including Finland. However, development aid is always a political decision, not an automatic cost.

Ayres and Walter (1991) estimate that supporting one person per one year in the developing world costs USD 1000. Climate change increases the number of human beings without possibilities to live without help which leads to pressure to increase development aid. Finnish development expenditures were nearly FIM 3 billions at the beginning of 1990s[31] but have dropped since 1991 due to the depression and expenditure cuts. There is no possibility to forecast the climate change induced increases in future aid outlays but in the light of the above numbers it may well be from hundreds of millions to a billion FIM. Our best guess is a rather pessimistic pure guess of FIM 500 millions per year. Additional costs may come from other EU member states if their damages will be compensated through EU budget.

2.3.12. Health

Higher average temperatures probably imply health benefits for Finland. However, some greenhouse gases like CFC's have negative impacts like the destruction of ozone layer with known consequences for human health. There exists an optimal temperature area for humans and costs may be incurred if the temperature shifts beyond the limits of that area. Many researchers speak also about mortality and morbidity, i.e. climate change may cause such changes in our environment that the result is lower lifetime expectancy. There seems to be a U-shaped relationship between mortality and outdoor air temperature ceteris paribus. The optimal temperature level for health is 16-25 ^{0}C (Kunst et al. 1993). The average temperature in

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[31] Yearbook of Statistics 1994

Finland is far below these figures, in Helsinki it is slightly over 5 ^{0}C, and even the warmest months do not exceed the limit. On average there are ten days during a summer when temperature exceeds 25 ^{0}C. As the warming is excepted to be higher than average in wintertime and lower than average in summertime the increase in average temperature is on average good for health. However, during the heatwaves the stress on health may be increased. Warmer climate could be especially beneficial for outdoor working. In addition to health benefits there may be less lost days due to cold weather.

Ozone depletion is partly a coincident phenomenon to climate change as both are partially caused by the same factor, CFC gases. Thus, broadly speaking the problems are linked and they have often been handled together. Furthermore, warmer climate may increase depletion by upper atmosphere cloud formation. Ozone depletion means more ultraviolet radiation and thus more skin cancer and cataracts. The negative impact of these on health could be serious without proper adaptation with precautionary measures against the ultraviolet radiation.

It is possible that even malaria might be able to survive 2050 in Finland. However, presumably the 2050 health care systems will be much more effective making that threat ineffective. As there seems to be opposite health effects the total impact is difficult to estimate. At the moment we assume zero cost of climate change on health. Future elaborations of this result are to be expected.

Analysis will then be extended also to some non-market sectors in order to gain a more comprehensive idea of the total effects of climate change on the Finnish well-being. These more intangible sectors include:

2.3.13. Biodiversity

Some species may be lost because of their inability to adapt fast enough to the chancing climate and environment. The value of this loss can be approximated by using and extrapolating the results of some *willingness to pay/accept* studies. The value of species can be divided into three categories the first being *use value* which reflects the would-be market value. We must also consider the *option value* of species as there exists the possibility of some animal or vegetable being valuable for medicational or other purposes. Thirdly, each thing has an *existence value* which is the value of knowing that something exists even if you never get any direct or indirect benefit of it. An example could be the life of an unknown human being for which you may be willing to pay if it saves the person from dying even if you get nothing but good feeling. Thus the existence value has much to do with morale which is always difficult to connect to any specific monetary value.

As we do not know which species will became extinct because of climate change there is no simple or robust way of calculating the value of the loss. We employ here a simple method but expect to study biodiversity more thoroughly in the future.

Some international studies (e.g. Fankhauser 1994) on average assume the loss to be USD 30 per person. The number is based on few WTP studies. Using 5 FIM/USD as the exchange rate we get 30 USD/person*5FIM/USD*5.000.000 person = FIM 750 millions loss of biodiversity. This could be conceived mainly as the loss in world-wide biodiversity excluding local differences and use values. This kind of valuation makes it possible to ease the comparison to other damage estimates as the basis of the numbers is the same.

2.3.14. Migration

Some areas especially in the developing world (e.g. Egypt, Bangladesh, Pacific islands)[32] may be severely damaged by the climate change. This means that masses of peoples may have to emigrate to other countries including Finland. The impact of the migration on Finnish people is difficult to calculate but it is likely that at least in the short term climate refugees cause extra expenditures for the government. After an adaptation period new population may even be advantageous as a source of new labour and human capital (Much of USA was built with the work of poor migrants.) This thinking naturally ignores the suffering of the actual refugees and takes only the impact on Finnish population into account.

Any forecast of the magnitude and impact of environmental migration on Finland 2050 will be a mere guess without any strong backup from theory or empirics. Even if we can say that there will most certainly be masses of climate refugees and quantify this number for some areas like Africa as has been attempted[33], it is impossible to say how many of these will migrate into Finland and what is the economic impact of those refugees. In 2050 Finland may be without the present unemployment problems and it may desperately need new young population.

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32 Fankhauser (1994)

33 For example Ayres & Walter (1991) and Cline (1992), the estimates are usually order class of 100 million people worldwide that would be forced to migrate.

From the climate refugee point of view it probably is usually uncomfortable to leave their homes. However, migration is a better option than staying and migration can be also described as part of adaptation. Without migration the human suffering in world-scale could be much higher as there would be no possibility to escape the grim conditions. Although migrating includes risks as well.

Climate is one of the most fundamental factors that have allocated human population round the globe. The importance of climate has naturally diminished but not disappeared as trade has made it possible to transport large amounts of foodstuff, energy and other goods. Finland may have had a disadvantage as a dwelling or business place from the average person point of view as a cold, small and distant country as implied by the low population density. The climatic disadvantage may be removed by global warming and Finland may in fact become relatively comfortable place in climatic sense, even if many of the current population may prefer the prevailing climate. The climatic preferences of future generations are unknown but people usually are happy with the climate they have born and grown in. From the point of view of neo-classical economics optimising agents will live in the optimal environment including climate as a factor. If the agent feels uncomfortable he or she will move to better location if possible. Thus, it is possible that there could be climatic migration into Finland because they are either forced to leave their home and have to be placed somewhere or because they feel that Finland has become an attractive place to live. On the other hand, as Finns have very little migration barriers (institutional, financial or cultural) to other OECD countries emigration provides possibilities for adaptation.

Let us assume that the Ayres & Walter (1991) estimate of 100 millions climate refugees is correct and that the migration takes place over a century with one million people per year. (Ayres & Walter assumed that the migration would take place over 50 years.) Half of that amount could well migrate within the OECD or migrate into OECD region. If we further assume by modified "grandfathering" approach that Finland absorbs one per cent, i.e. app. twice its share of the OECD GNP, of that flow then (100.000.000/100 a)*0.5*0.01 = 5.000 climatic migrants annually move into Finland during the 21st century. By 2050 there could be over 250,000 climate migrant living in Finland if we count their childrens also thus changing Finnish population structure quite significantly. However, the estimate is modest compared to Kinnunen's guess of 20.000 immigrant per year.

The current mass unemployment in Finland implies that low skilled immigrants would at first be a financial burden. Most of the climate refugees probably are uneducated people even if some inter-OECD migration occurs. However, the age structure suggests that new labour will be needed sometime in future. The first immigrants at the beginning of 21st century may first be a burden but after schooling actually contribute to the economy. After some point the immigration becomes increasingly unproductive and costly for the government as the problems with integrating the immigrants to society grow. Let us think a country as a firm and the population as shareholders with a certain equity value. Then immigrants are new shareholders who bring in new capital. The question is whether the original shareholders benefit from the added capital or do their share depreciate, i.e. are there economies of scale in working population when some factors like land area are fixed[34]. With a common sense overlook one might conclude that there is no strong positive relationship between GNP per capita and population growth if we control other factors. In fact, the countries with fastest growing population seem to be the poorest in many cases. Without going in depth into any growth studies we conclude that rapid population growth seems to depreciate the "equity value" of the original population.

We could make three possible scenarios for the cost of an immigrant. Firstly, we could imagine that if some of the immigrants are educated and economy needs more labour the immigrants produce a positive cash flow in tax payments. Secondly, we could assume an initially costly but later self supporting immigration. Thirdly, the immigration could be such that most of them should be supported for long time. The relative size of these groups is unknown and as an ad hoc approach we could choose the second group as a representative one. A problem is that there exists no clear data on the costs of immigration and at the moment we do not know how long immigrants are supported on average. Kinnunen (1992) used FIM 80.000 per year per refugee as cost estimate and we will use the same number. We make a further optimistic ad hoc assumption that the climate induced immigration is such that the immigrants must be supported on average one year and since then will be integrated into the society as self-supporting individuals or will emigrate to other country. Thus, the total cost of climate immigration per year is 5,000 persons x 80,000 FIM/person/year x 1 year = <u>FIM 400 millions</u> per year. This is a much lower figure than even the "optimistic guess" by Kinnunen (1992) of FIM 1.200 millions but in our opinion more realistic. On the other hand we include a monetary estimate for increasing development aid whic reduces the need for climatic migration.

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[34] For example pre-war USA may not fit this description as the populated land area grew over a century. Furthermore, the welfare system was back then undeveloped, i.e. the original population did not have to pay social security in taxes.

2.3.15. Amenity

Climate change and the following environmental change will naturally have an impact on the human amenity. Some species will be lost and some new ones will migrate in Finland. It is impossible to calculate the value of this change but it is interesting to speculate the changes at qualitative level. The best way we could try to quantify the amenity values of climate is hedonic pricing. Another method could be the use of contingent valuation. However, these studies would require really vast dataset and even then the guessing of the amenity value for future generations would be difficult. Thus, we do not give a quantified estimate of the amenity value by pretending to know what the present and future generations feel about the changing climate.

The change in flora and fauna will change the appearance of our environment. More temperate zone species may appeal positively to some people but others may feel longing for the past. Warmer climate and longer summer may create a new kind of life style influencing the whole culture. It seems that even if actual economic effects are small the potential amenity or cultural effects are potentially very large. Whether these effects would be on average be considered harmful or beneficial is quite impossible to predict.

Global warming changes also the Finnish cultural landscape by changing much of the traditional Finnish environment with four very different seasons and unique nature. In this way we may lose some of the cultural heritage embodied in the Finnish nature. Milder and darker winters may not be welcomed with cheer even if the change is slow. By 2050 Southern Finland may start to resemble present northern Central Europe. Furthermore, flow of climate refugees may change the whole ethnic structure of Finnish population. These are highly controversial subjects and impossible to study in a quantitative framework, what can be said is that the immigration may have significant impact on Finnish culture over the 21st century.

However, there are many other more powerful social trends like the integration of Europe that have much more important and visible effect on Finnish culture. The combined outcome of these changes cannot be foreseen.

2.3.16. Other sectors

There are number of other sectors which may or may not be largely affected. Globally water resources may be one adversely affected sector. Banking could be in trouble due to bankruptcies of firms from adversely affected industries. Clothing industry may have to steer its production from winter clothing to warmer style, etc. Some impacts may occur on many sectors, e.g. lost working time due to cold weather could diminish. Furthermore, international markets are important for many industries like electronics and other high tech. If international demand diminishes significantly due to expensive natural disasters many industries which are neglected here may be affected. These effects are here assumed to be relatively insignificant and/or impossible to analyse more accurately. However, if someone wishes to do a long run (several decades) prognosis for any sector he or she should take the potential impact of climate change into account.

2.4. Aggregate Impact of Climate Change on Finland

The total impact on Finnish economy and society as whole is calculated by summing all the sectoral impacts. These impacts differ very much by their nature as some are strongly market based and others quantified uncertain non-market impacts. Comparing the aggregate figure to for example GNP will not tell the magnitude of the change in welfare as sometimes seems to be argued. The denominator does not include all the non-market sectors of society included in impacts assessment, thus the above mentioned rate overstates the impact even if some impacts are ignored. In order to be at least roughly of the same scale we should calculate green GNP and currently there are generally no such figures available. Nevertheless, what we can gain by comparing the absolute impact figure to some other national aggregate figure is that we get a very rough order of magnitude impact figure and we can make international comparisons. The impact estimates on different sectors and the total impact are given in the next table (10).

Thus, in total the impact of climate change on Finnish economy 2050 seems to be positive FIM 5,850 millions in 1993 money[35]. This is a welfare gain of 1.2 per cent of Finnish GDP in 1993. Therefore, we are more optimistic than Kinnunen (1992) who estimated the benefits to be 0.86 per cent of 1990 GDP. These figures are not high compared to the GDP even if 6 billions is a significant amount of money by any standards. Per capita benefit is FIM 1200 per year or FIM 100 per month.

[35] This is USD 1,170 millions if we use FIM/USD = 5/1 as the approximate excange rate.

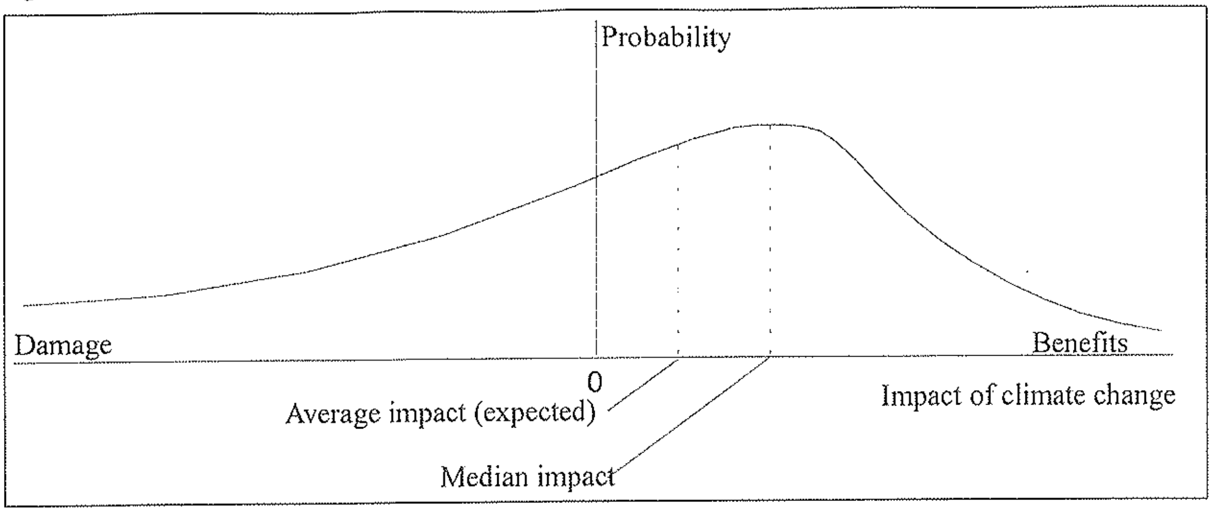
Table 10: The Aggregate Impact of Climate Change 2050

Sector	Millions of 1993 FIM	Millions of 1993 USD [1 FIM = 0.2 USD]	Confidence Level
Agriculture	2,000	400	**
Silviculture	4,800	960	**
Fishing & Hunting	0	0	***
Energy	700	140	**
Construction	0	0	**
Tourism	0	0	*
Transport	0	0	**
Property & Disasters	0	0	**
Insurance	0	0	**
Budget	-500	-100	*
Coastal areas	0	0	***
Health	0	0	*
Economic Benefits	7,000	1,400	**
Biodiversity	-750	-150	*
Migration	-400	-80	*
Amenity	0	0	*
Total	5,850	1,170	**

*** denotes fairly accurate estimate, ** includes significant uncertainties, * is very uncertain [these confidence levels are based on subjective assessment]

We do not present here any "optimistic" or "pessimistic" guesses like Kinnunen (1992). The reason we make only best guesses is that there is no possibility to know the probability distribution of the impact, i.e. how probable the estimated impact is. Making a pessimistic guess would only show that serious damages are possible under some scenario - a fact we know already from assuming a continuous probability distribution for the impact. Furthermore, as was stated earlier the distribution is probably lopsided so that damages can be quite significant. Next figure (10) shows an asymmetric distribution with positive impacts expectation (benefit) which could be measured either by expected value or median. Prudential approach should use the average impact but it is difficult to estimate it correctly without knowing the exact shape of the distribution. Therefore, best guesses may usually be closer to median impact than average.

Figure 10: Lopsided Distribution of the Climate Change Impact



With the above described probability distribution there is a high possibility that the impact is slightly better than the best guess. However, the tail at the worse end converges towards zero probability much slower, i.e. the probability that the impact is 'much' worse is significantly higher than the probability of the impact being 'much' better. Furthermore, our list of quantitative estimates contains currently many zeros, this is due to our refusal to make many subjective ad hoc guesses needed in many calculations. Some of these impacts may be significant making the current estimate biased. This situation is likely to change by the time of final report on the project even if some effects may remain nil.

The dynamics of the impact are difficult to establish. If we assume the earlier in Chapter 1 described linear relationship between impact and temperature rise we get the following figure (11). The central line describes the best guess damages up to 2100 if the impact is assumed to start 1993. The two other lines show the best guesses for two other climate change scenarios shown in the figure. Areas of uncertainty are not shown but one must always remember that damages are not an impossibility. Furthermore, it is likely that warming has diminishing returns implying concave impact curves over time. Faster climate change per decade implies more stress on ecosystems and more concavity. Thus, the case presented in figure (11) is an optimistic oversimplification. We can only guess the dynamic behaviour of the impact. Without showing areas of uncertainty the timepath of the impact is more likely to be a concave curve like shown in the next figure (12). However, this is pure speculation and the exact form of the curve unknown. With the linear function the benefit would be approximately FIM 2800 millions in 2020 and FIM 11000 millions in 2100.

Figure 11: A Linear Impact of Climate Change Over Time

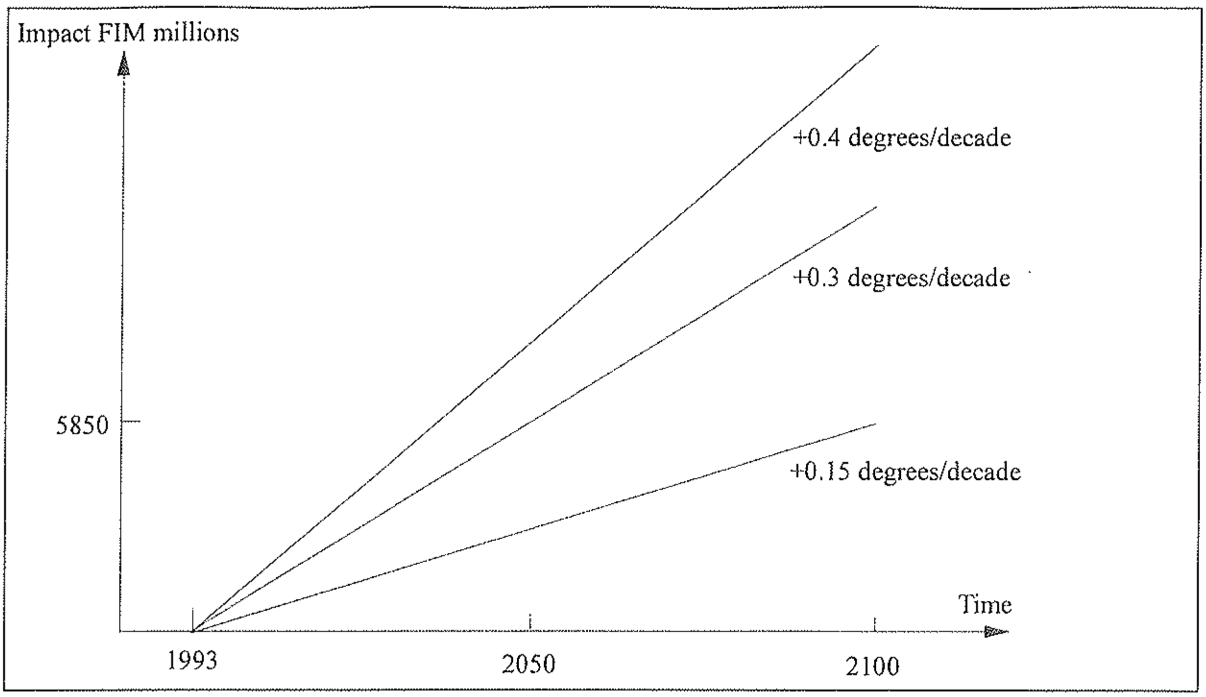
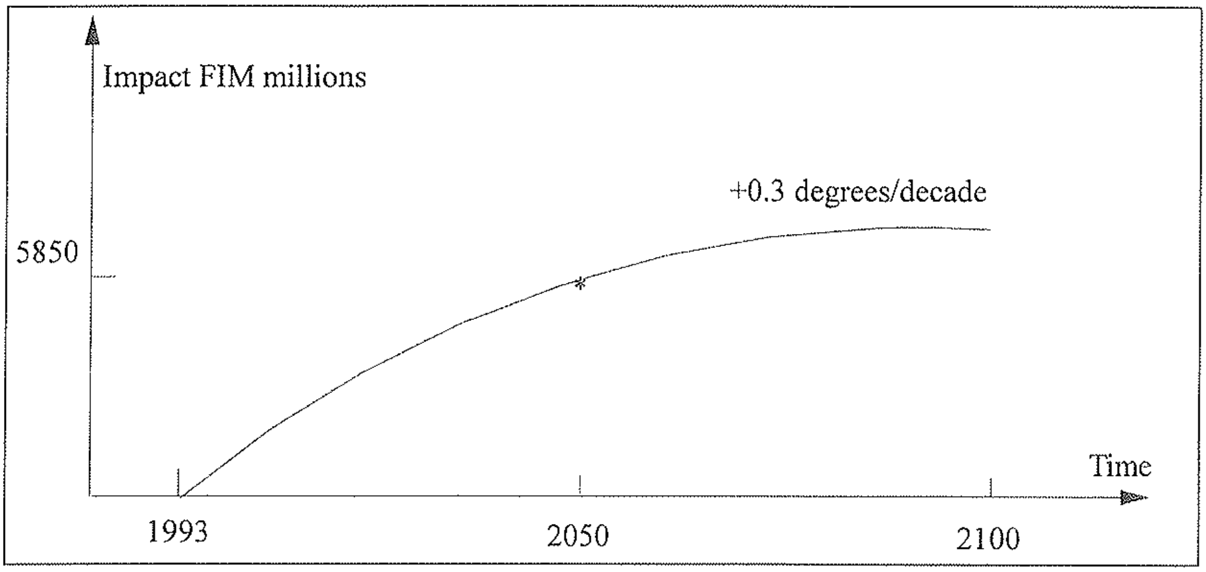


Figure 12: A Concave Impact of Climate Change Over Time



Doubling of atmospheric CO_2 concentration is not necessary a steady state. Moreover, continued climate change may lead to serious damages after 2100. Positive estimates for 21st century Finland may turn to be negative during the 22nd century if nothing is done to stop the climate change. Thus, our 50 - 100 year perspective may be myopic. However, we do not present any quantitative estimates for 22nd century for two main reasons. Firstly, forecasting economy and society for periods of several hundreds of years is shaky ad hoc guessing. It can be interesting but unusable for decision-making. Secondly, even if climate change policy requires several decades to be effective there are many things that can be done over centuries, i.e. we can afford to wait before making any guesses for several centuries. Nevertheless, it is good to bear in mind that climate change is a very long term phenomenon.

We have not calculated the impact of climate change per tonne of CO_2 as it is mainly done for policy purposes in comprehensive CBAs and our current figures do not warrant the comparison of marginal benefits and costs of CO_2 mitigation, i.e. the optimal control approach fails here. Furthermore, impact per tonne of emissions calculations add new uncertainties as we would have to forecast the future levels of emissions and choose the discount rate. However, our future calculations may include the estimate if seen advisable.

We stated earlier that other scenarios should also be checked at some level. Closed economy scenario does not seem to make the situation much worse or better, in a closed economy it would be good to have more productive agriculture but the benefits from sectors like forestry would diminish. A global catastrophe scenario would naturally mean difficulties also for Finland. In a catastrophic situation it might even be better to be an isolated economy. Numbers are extremely difficult to produce for these scenarios as we do not know the probabilities and because there are many uncontrollable factors. As every economist knows - it all depends.

2.5. Economic Effects of Climate Change in European History - Some Observations

This section may seem to be isolated or even excess. However, we wanted to include it because it demonstrates some of the long run effects of climate. It is good to acknowledge that this is not the first time in the known history when climate change has influence on human activities, although it is most probably the first time when atmosphere produces a feedback into the economy. Therefore, it is interesting to see what kind of effects climatic changes have had in the past. The history of Europe and Finland include many famines caused by detrimental weather, or as in the 14th century by deteriorated climate. Germany and Northern Italy had close trade connections for many centuries over the Alpine mountains. The roads were in good shape for traders, but when the climate conditions declined during the 'Little Ice Age' (app. 1550-1850) roads over the Alps became unsuitable for trade. Consequently German foreign trade turned to other countries, noticeably to Netherlands helping the country to increase its welfare and to become a giant in trade. Furthermore, bad weather during the Little Ice Age caused a famine in Finland in 1696-1697 which may have killed one third of the population. These events were caused by decline in temperature, but draughts and storms have also caused many unhappy incidents in the past. These lessons from the history show that although industrialised countries are now much better hedged against variations in climatic conditions, there exists a potential for significant impacts due to even fairly small changes in the state of climate.

Climate has according to some scientists also contributed to the success of different nations. Nordhaus (1994 in Nakicenovic et al.) has reminded that until the beginning of this century climate was considered to be among the chief determinants of the differences among nations. Geographer Ellsworth Huntington from Yale University has summarised this in 1915 as follows: "*The climate of many countries seem to be one of the great reasons why idleness, dishonesty, immorality, stupidity, and weakness of will prevail.*" Although Ellsworth's views cannot be generally shared some later economists have also acknowledged the importance of climate. Todaro (1991) states that "*It is a historical fact that almost every successful example of modern economic growth has occurred in a temperate-zone country*", without explaining his observation. In any case, economies are developing so that the dependence on climate is diminishing. Historically there still seems to have been a relation between climate and development. Interesting question raised is if the warmer climate makes people lazier as working becomes more uncomfortable in comparison to leisure. This seems to have been the opinion of Alfred Marshall (1890) as was quoted at the beginning of the paper.

One of the controversial issues is the long run impact of climate change over several hundreds of years. The last 10.000 years have been said to have been very stabile in climatic sense[36]. It is possible that climate loses its stability in the longer term leading to major changes in biosphere. One prediction is that the current warm interglacial is nearing its end and the climate change is only lengthening this era by leading to a "super interglacial". Eventually climate may again cool and new ice age begins. If this is true then global warming might be a good thing in some time interval. These longer term considerations are usually beyond the human planning horizon but are nevertheless important as a reminder of our short-sightedness in Nature's terms. Even with very small positive discount rates the ice age scenario is economically irrelevant. Nothing certain can be said about the real long term impacts.

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[36] Schotterer & Oeschger (1994)

3. POLICY OPTIONS AND CONCLUDING REMARKS

In this last chapter we will firstly shortly discuss some policy topics related to climate change. Secondly we summarise the results of this preliminary assessment. Similarly to the previous chapters this chapter does not attempt to be a complete survey of climate change policy discussion.

3.1. Players, Prayers and Payers - Some Economics of Climate Change Mitigation Policy

The main purpose of this paper is not to study the possibilities for emission abatement. However, for completeness we have included a short discussion and review on the climate change mitigation. We attempt to describe the problem from many different points of view but this sub-chapter is far from being even a complete survey of most important studies. To be more precise in our language we define climate policy as any measure intended to either stop the climate change or alleviate the impact of climate change.

Climate change has internationally been recognised as one of the most important environmental problems which needs to be solved at the intergovernmental level. As the greenhouse gas emissions spread globally into the atmosphere no nation can alone influence significantly the concentration of GHGs. Thus, every nation has through its emissions of GHGs an impact on every other nations' climate and therefore climate change in every location is determined mainly by other nations emissions[37]. The implication is that no nation has an incentive to reduce its emissions alone as the reduction will not significantly affect the country's climate. Furthermore, countries may have a free rider incentive to escape the burden of GHG emission reduction if other countries reduce their emissions. Therefore, the emissions reduction can be effectively dealt only through an international enforceable agreement where emission reductions can be observed and deviations punished through some mechanism. Finland has already agreed in Rio (1992) to stabilise its CO_2 emissions at 1990 level by 2000. The discussion concerning the right measurement of national CO_2 emissions continues as many countries including Finland want to use net emissions instead of gross emissions. In Finland the difference is significant due to rapid forest growth which serves as a sink for carbon.

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[37] The problem of common access to some resource has been extensively studied in economics, see e.g. Baumol & Oates (1988)

The basic approaches to climate policy can be demonstrated with two simple equations. Climate change occurs because of greenhouse gas emissions, GHG, (mainly CO_2) and these are given by the tautology occasionally called the Kaya identity: *GHG=(GHG/E)*(E/C)*(C/N)*N*, where E is use of energy, C is consumption and N is population. (Time index has been dropped.) Impact (D) is given by equation *D=D{CC[S(GHG, X)]}*, where S(GHG, X) is the concentration of greenhouse gases as a function of GHG and sinks (X), CC[..] is the climate change as a function of S(..) and D{..} is the damage due to climate change, CC. This system gives seven basic ways to reduce damage D: (1) adapt by changing D{..} function; (2) engineer climate, i.e. change CC[..] function; (3) change the value of S(..) by managing sinks, X; (4) improve GHG/E ratio by energy production technology; (5) improve E/C ratio by production technology; (6) reduce consumption per capita including heating and traffic; (7) reduce population growth. The four most basic tools to implement these policies are (a) price, (b) direct control, (c) R&D subsidies and (d) preferences. There are many different variants of these tools. We will next discuss these policies in a more pragmatic way.

If we do not accept change as such as bad we have to have reasons for environmental policy. The question is then why to reduce emissions of GHGs? This is a relevant question as it has been given many different answers. Possibly the most rudimentary answer has been that we have no right to change the atmospheric profile, i.e. the mere change in the concentrations of GHGs in the atmosphere justifies rapid policy action. However, this approach is not justifiable from the basic economics. An argument of nearly the same level is that climate may change and that is a bad thing even without important consequences. Second level argument is that many ecosystems suffer from the climate change and humans should not violate the right of the species. These are mainly argument based on ethical considerations. Thirdly it has been argued that active climate policy is justified as some people will suffer from the climate change even if it was not generally harmful or is even beneficial for other people. For example, some indigenous people may lose the possibility for their lifestyle and this harm is such that it cannot be compensated. Fourthly, damages may be such that there is a significant decline in welfare in a Pareto sense, i.e. beneficiaries cannot compensate the losers. In this case the cost-benefit ratio determines the desirability of climate policy. The first two categories fall outside the scope of economics but that does not rule out their potential importance in political decision-making. Third level of reasons for policy could be defensible from economics point of view with special utility functions. However, only the two last reasons fall within the usual realm of CBA. Therefore, we will not use the arguments based on ethics other than underlying basic economics, i.e. Pareto or Kaldor criterion.

The main players in the international game are naturally national governments and intergovernmental organisations which have been founded to facilitate international co-operation. Furthermore, different pressure groups including environmental organisations, industry, labour unions, academic organisations and civic movements have their opinions which may sometimes be really important in decision-making, especially at the political level. Naturally, whole population is involved in one way or the other as the climate change affects everybody and climate policy is also likely to affect all. The interactions inside and between these groups determine the outcome of international and domestic negotiations.

There are number of difficulties related even to the basic elements of climate. As was stated earlier there are uncertainties related to the effect of aerosols. Aerosols have a cooling effect and their lifetime in the atmosphere is much shorter than GHGs lifetime. If the use of fossil fuels is drastically reduced it means that the cooling effect vanishes faster than global warming implying faster warming in the short term. Thus, long term policy expected to stop climate change may in short run speed up the climate change. This makes the occasionally myopic political decision-making even more difficult in relation to the climate change.

There are many policy options to address the climate change problem as we showed earlier. Most commonly presented economic methods are tax on polluting activity and emission permits trading system. Bureaucracy provides also possibility for command methods where polluting activity is directly controlled. Direct control has its own problems and many economists find it ineffective. One tool which has not been paid much attention in economics literature is active influence on public opinion, i.e. the utility functions of economic agents can change through time. Sociologists interested in climate change often talk about necessary change in our lifestyle[38]. If the utility functions of individuals can be shifted by the means of information and social pressure it might be an effective policy tool. However, it is questionable how much individual preferences can and should be influenced. Individual rights are at stake if one starts to actively force people behind some behavioural pattern. Change in lifestyles is hardly a painless process. On the other hand, also taxation leads to changes in pattern of consumption. Klabbers et al. (1994) state that if one wishes to promote the "sustainable lifestyle" it should be based on three A's: the lifestyle change should be achievable, acceptable and attractive. The question is essentially about freedom of choice. Appendix (1) describes the main policy options and what can be achieved with these options.

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[38] Klabbers et al. (1994). See also Järvelä & Wilenius (1993) for discussion.

GHG emissions are global and international co-operation can also provide ways to reduce them[39]. Joint-implementation is one way to co-operate but there are still several unsolved problems related to the implementation of JI. Technology transfer to countries like China may be very important as their energy production is very pollutive and growing rapidly. These international issues will be discussed in future in more detail.

Carbon dioxide is only one of greenhouse gases. Therefore, one must consider also the possibilities for reducing the emissions of other GHGs like methane. However, emissions of CFC-gases have already been restricted by Montreal Protocol (1988) and the sources of methane emissions are difficult to even locate. Thus, more research is needed to be able to include a broader variety of GHGs in climate policy.

As was stated at the beginning of the paper there are more studies on the GHG emission reduction cost evaluation than on the impacts assessment. The quantitative emission abatement studies can be divided into two classes using different approaches. *Top-down* studies are typically based on neo-classical models and are with increasing frequency computable general equilibrium (CGE) models. *Bottom-up* or *engineering* models approach the question from different angle by studying the possibilities of technology and business process reorganisation. The results of these studies differ significantly as top-down models often show significant cost of emission reduction and engineering models show that technology provides possibilities for substantial savings.

Top-down models are usually either energy sector models or CGE models assuming profit maximising behaviour in firms and given consumer preferences. Therefore, firms are assumed to be efficient and it is clear that the only way to reduce emissions are different tax or emission rights trading schemes (command methods are excluded). CGE models enable fairly detailed analysis of the impact of different policies to emissions and the structure of industry. The most well known CGE models for climate policy analysis are OECD's GREEN model and DICE by William Nordhaus. There exist also models for Finland, e.g. Jerkkola et al. (1993) and Mäenpää (1993). These models are normally used either to find a tax for some fixed level of CO_2 emissions or to calculate the emissions given the level of CO_2 tax. Furthermore, these models usually give the change in GDP and industrial structure. The taxes needed to stabilise CO_2 emissions vary a lot between different models but it seems to be hundreds of FIM per tonne of

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39 Nakicenovic et al. (eds. 1994)

CO_2. GDP losses do not seem to be high but industrial structure changes are significant in some cases like Jerkkola et al. (1993).

Bottom-up models do not assume a priori efficient technology and they strive to find the most efficient ways to produce and use energy[40]. Thus, the approach is very pragmatic at the firm level. Engineering models produce quite often results that show significant inefficiencies in the current technology which could be replaced with new and much more efficient technology with reasonable cost actually reducing the total costs of the firm. i.e. win-win strategies are possible. Economist usual response to this is that these are unlikely to exist as if there really were potential win-win strategies they would already have been adopted, i.e. there is no free lunch. Thus, the existense and implementation of no-regret options is still an open issue.

However, climate policy and reduction of GHG emissions are not equivalent. Climate policy involves also other policy measures than emission reduction, e.g. coastal protection and R&D efforts. On the other hand, GHG reductions imply reductions in fossil fuel consumption CO_2 cannot easily be cleaned from emissions, i.e. also emissions of other pollutants like SO_x from fossil fuel combustion will be diminished. Active climate policy has also other useful environmental effects as also other than GHG emissions are reduced and R&D development may create external benefits. Thus, adaptation of climate policy should not depend only on its results in climate change prevention. The estimation of the total impact of climate policy is then much more difficult than just the transformation of climate change damages into policy benefits. Surprisingly, the impact of climate policy on climate may be small compared to other impacts and environmental benefits it creates.

Environmental policies are sometimes advocated on the basis that the cash flow from the environmental tax revenues facilitates reduction in other taxes like income tax. Adoption of a Pigou tax and reduction of a distortionary tax combined is being called "double dividend". However, many governments are highly indebted and the revenues are more likely to be used to pay the debt away and to finance new expenditures. Thus, the "double" seems often to be an exaggeration even if the pressure on other taxes is relieved. The public finance and income distribution issues should be studied more carefully before implementing high CO_2 tax.

Risk aversion is one powerful argument for early action. We cannot possibly know all the consequences of climate change. The non-zero probability of catastrophic events may justify an

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40 For example IEA (1994) and Nakicenovic et al. (eds. 1994).

active climate change policy. Thus, the level of risk aversion determines the level of action and it may vary between countries. What we need is a hedging policy, i.e. tools for individual risk management. One option is the earlier mentioned insurance policy which could allow individuals to choose a hedge against risks originating from climate change based on their own risk aversion. At the national and international level we may need a "climate fund", i.e. a fund which could collect and manage funds financed from national budgets which could then be directed to helping the victims of the possible catastrophic events. However, the creation of this kind of institution is not easy. All in all the optimal policy is always likely to be some portfolio of different actions.

What kind of climate policy should Finland adopt? This is a difficult question to answer and subject to political decision making. At the moment Finland is one of the few countries which have adopted significant taxes on fossil fuels. Our calculations do not seem to warrant active climate policy if we consider only the economic welfare of Finnish citizens. However, there is much more to that question as we have discussed. Moreover, among many other countries Finland has partially tied its hands by signing the Rio (1992) agreement, i.e. we should stabilise our (net)emissions by 2000 to the 1990 level. Many countries seem to have trouble meeting this requirement and it is likely that the target will not be completely met. This gives some room for arguments against being the first to meet the stabilisation goal especially if it seems to be costly in the short run during a period of mass unemployment. However, at the moment we do not give any expert opinion on the question of policy measures except that it seems that research on the climate change and policy tools should be continued. It is the task of democratically elected political decision makers to choose the best action. Our purpose is to produce information and tools for decision-making.

3.2. Concluding Remarks

The first thing to note is that although the economic effects of the climate change may be negligible in the Finnish case, the potential for really large changes exists. Finland may gain economically if only domestic impacts were considered. Our current calculations show a net benefit of nearly FIM 6 billions in 2050 in 1993 money. The benefits come mainly from agriculture, silviculture and energy. Largest damages originate from the loss of biodiversity and international impacts. Thus, Finland seems to be relatively well off. However, international agreements, economics and responsibilities seem to cause significant costs also for Finland.

Furthermore, blind trust to best guess impacts is fallacious as there exists a positive probability of disastrous events. The implication is that only from the selfish economic point of view without high risk aversion an active climate policy is not justified. We must instead consider other things like solidarity and equity and possibly to hedge against the risks. The justification of the climate policy in Finnish perspective must originate from ethics, risk aversion and international justice and possibly from intergenerational fairness - not from best guess economics. A carbon tax may be bad for Finnish economy but a good way to give development aid in the form of better climate. Thus, even if we may see no emergency coming in Finland during the next century, Finland is not the only nation on this globe and it is very dependent on other more climate dependent nations as a small and open economy.

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Appendix 1

Basic Policy Options and Tools

<table>
<tr><th>Options</th><th>Less GHG
Reduce the use of GHG intensive fuels</th><th>Less net GHG
Reduce net GHG emissions without reducing energy production</th><th>BaU
Business as usual, no reduction of emissions</th></tr>
<tr><td>R&D
Develop new cleaner technologies with the government help</td><td>* more efficient production with less energy
* more efficient energy production technology
* substitution of fuels for cheaper ones</td><td>* cleaning technology at the source of GHG emission
* sink mgnt like more efficient forestry</td><td rowspan="3">*no policy</td></tr>
<tr><td>Control
Manage emissions with laws and bureaucracy</td><td>* quota for GHG emissions
* favour low GHG intensive fuels in policy</td><td>* compulsory use of cleaning technology at the source</td></tr>
<tr><td>Tax / Permit
Tax emissions/energy or set up a system of tradable emission permits</td><td>* save energy (income)
* substitute for other fuels (substitution)
* may lead to development of more efficient technology</td><td>* incentive to use cleaning technology (with emission charges, not energy tax)</td></tr>
<tr><td>Climate Engineering
Business as usual but use advanced technology to manage climate</td><td>* laissez faire</td><td>* enhance sinks like biomass in oceans</td><td>* reduce radiative forcing, e.g. with particles in the atmosphere</td></tr>
<tr><td>Lifestyle
People must collectively adopt a new ecological way of living</td><td>* people adopt a new lifestyle with lower level of consumption of GHG intensive goods</td><td colspan="2">* adaptation (only reduces the climate sensitivity)</td></tr>
<tr><td>Population Control</td><td>*less consumption</td><td colspan="2">* adaptation (only reduces the climate sensitivity)</td></tr>
</table>

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