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Appraising the socio-economic impacts of climate change for Finland

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FINADAPT Working Paper 12

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APPRAISING THE SOCIO-ECONOMIC IMPACTS OF CLIMATE CHANGE FOR FINLAND

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FINADAPT WORKING PAPER 12

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Preface

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"[1]. The IPCC lists two reasons why adaptation is important in the climate change issue. First, an understanding of expected adaptation is fundamental in evaluating the costs or risks of climate change. Second, adaptation is a key response option or strategy, along with mitigation. Even with reductions in greenhouse gas emissions, some climate change is regarded as inevitable, and it will be necessary to develop planned adaptation strategies to deal with the associated risks as a complement to mitigation actions.

In Finland, there has been substantial progress during the past decade in investigating the potential impacts of climate change on natural and human systems. In contrast, there has been much less attention paid to adaptation. This was recognised by the Finnish Parliament as early as 2001, when it recommended that a separate programme for adaptation to climate change be initiated. As a result, a task force co-ordinated by the Ministry of Agriculture and Forestry completed Finland's first National Strategy for Adaptation to Climate Change in 2005.[2]

At about the same time as the Strategy document was being drafted, a research consortium named FINADAPT also began its work. The goal of the consortium, involving 11 partner institutions co-ordinated by the Finnish Environment Institute, was to undertake an in-depth study of the capacity of the Finnish environment and society to adapt to the potential impacts of climate change. FINADAPT was funded for the period 2004-2005 as part of the Finnish Environmental Cluster Research Programme, co-ordinated by the Ministry of the Environment. It comprised 14 work packages (WP) covering: 1) co-ordination, 2) climate data and scenarios, 3) biodiversity, 4) forests, 5) agriculture, 6) water resources, 7) human health, 8) the built environment, 9) transport, 10) energy infrastructure, 11) tourism and recreation, 12) economic assessment, 13) urban planning, and 14) a stakeholder questionnaire. The primary objective of FINADAPT was to produce a scoping report based on literature reviews, interactions with stakeholders, seminars, and targeted research.

This report discusses the economic evaluation of climate change impacts and adaptation. Though of high policy relevance, this has been a much-neglected area of research in Finland, in part because it is reliant on cost information derived from climate change studies in different disciplines and sectors. The work package 12 study has taken up this challenge, presenting a preliminary attempt at assessing the costs and benefits of climate change, using results from FINADAPT and from the published literature. It then discusses some of the priority issues for improving economic appraisal in the future.

Timothy Carter, Consortium Leader
Helsinki, December 2005

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[1] IPCC, 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White (eds)]. Cambridge University Press, Cambridge and New York, p. 982.

[2] MMM, 2005. *Ilmastomuutoksen kansallinen sopeutumisstrategia* (Finland's National Strategy for Adaptation to Climate Change) [Marttila, V., Granholm, H., Laanikari, J., Yrjölä, T., Aalto, A., Heikinheimo, P., Honkatuki, J., Järvinen, H., Liski, J., Merivirta, R. and Paunio, M. (eds)], Ministry of Agriculture and Forestry, Helsinki (available in Finnish, 276 pp., Swedish 212 pp. and English, 280 pp.) http://www.mmm.fi/sopeutumisstrategia/

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Executive Summary

Study context and objectives. A study of the social-economic impacts of climate change has been carried out as part of the FINADAPT project. This has been first and foremost a pre-study, which has investigated:

- the economic mechanisms relevant to understanding how climate change induced impacts on the physical environment interact with the economy
- a preliminary indication of the order of magnitude of the costs and benefits of climate change for Finland
- an inventory of research needs in the field of economics, in particular aimed at better economic impact appraisal as well as improved support for the design of medium and long term climate policy strategies.

Main findings. Any conclusion regarding the economic effects of climate change should be interpreted with caution, realising that uncertainties and lack of knowledge about various effects, notably at national and local levels, are still prominent. From a domestic economic viewpoint, the impacts of climate change on Finland are probably rather modest and in aggregate could even be slightly positive on average for the 21st century, provided that climate change does not cause abrupt, non-linear events such as disruption of the Atlantic thermohaline circulation (THC, popularly referred to as the Gulf Stream). The order of magnitude of the aggregate effects, however incomplete these are at this stage, hovers in the area between 0 and a few hundred million euro, or to put it differently the effects amount to less than a 0.1% change in GDP.

The extent to which benefits can actually be exploited and costs attenuated depends in many cases also on public and private policies outside the realm of climate policy. Examples are agricultural policy, forest policy, and urban and national spatial planning policy.

Sectors in Finland that could gain from climate change are the forest sector and agriculture. In all likelihood, reductions in demand for heating outweigh the increases in the demand for cooling, and consequently energy end-users will benefit from this but energy companies will experience some loss of sales. Furthermore, the potential for the use of hydro electricity in existing facilities will grow to some extent. Commercial tourist and outdoor leisure services could also benefit from some growth in foreign visitors as well as from Finns who may have to rely more on commercial outdoor leisure services. However, the increase of domestic demand, in fact, constitutes a cost to consumers.

For other sectors there do not exist reasonably reliable overall assessments of the economic impacts, but some indications of the order of magnitude of part of the costs are available. Given this partial tentative impression of costs it is likely that, as regards the construction and maintenance (and repair) of buildings and transport infrastructure, extra costs will occur, albeit mostly at very manageable levels, i.e. in the earlier decades of the 21st century about 10~20 million per year, with some growth over the following decades.

Climate change induced ups or downs in foreign trade are probably an important source for economic impacts for Finland. This could mean negative effects in some periods and positive effects in others. Also the kind of socio-economic and climate conditions anticipated for the future affect assumptions about developments in foreign trade. In the Global Markets (with technology emphasis; A1T) and the Sustainability (B1) scenarios adopted in FINADAPT, the impacts of climate change on foreign trade might be more favourable than in the Retrenchment scenario (A2), not least because the changes in climate are supposed to be more drastic in the latter scenario.

Volatility in the effects of climate change over time is probably much more important than the calculated (theoretical) average gradual effects. An unfortunate sequence of negative climate change impacts within a short time span, such as a clustered occurrence of extreme weather conditions, could test the resilience of various sectors or even of the socio-economic system as a whole, if not nationally then at least locally.

Recent literature stresses that continuation of the current pace of growth in global GHG emissions may well increase the – supposedly still small – probability of the occurrence of abrupt, non-linear (singular) events, in the medium to long term (i.e. at least 30 years and probably much further away). One of these, notably a sudden cessation of the THC, were it to occur, could be expected to cause major economic damage to Finland (among other countries). Observing that (1) increased occurrence of extreme weather events is regarded as probable, even though the extent of the change is as yet hard to estimate and (2) so-called singular events are considered plausible, if unlikely, it seems worthwhile to attempt to integrate impact assessments of such events with assessments of gradual changes.

If indeed we have to take extreme events more seriously into account and in conjunction with the gradual changes, it also means that it gets even more important to design integrated climate change strategies (i.e. jointly assessing mitigation and adaptation policy options) which self-evidently should have a sufficiently long time perspective.

Considering the various integrative and cross-cutting issues with respect to climate change, such as nature, human health, economics, and governance, it was felt that space and spatial dynamics should also be acknowledged as an integrative entity not only at the local (urban) level but also at a national scale. Climate change will affect land use and land values in many ways.

Recommendations for economic research in conjunction with climate change. These include:

- ensure that impact assessment of all sectors proceeds sufficiently and in such a way that within a few years reasonably adequate data on economic effects can be provided;
- step up research efforts with respect to the volatility of economic climate change effects and the related resilience of sectors and the economy as a whole;
- investigate the possibilities of the financial and insurance sector with respect to the enhancement of risk management of all (relevant) sectors, households and local public authorities included;
- step up research efforts with respect to an economically sound elaboration of the concept of Tolerable Window/Safe Landing, not least through international co-operation; ensure that this is *not* done in isolation from principal developments in economic methods;
- step up research efforts with respect to the interaction effects of different policy areas and the resulting economic impacts of climate change;
- devote at least some efforts to the economic implications of land use changes, as spatial dynamics, notably at a higher (national) aggregation level, is currently virtually a '*tabula rasa*' in Finland;
- ensure good co-ordination between the various economic research efforts and policy making as well as between all climate change research efforts aimed at support of strategic policy design.

1. Introduction

In the 1990s the Finnish Research Programme on Climate Change (SILMU) included economic assessments of the impacts of climate change (Kuoppamäki 1997). During the nine years since the conclusion of that programme the global research effort regarding the extent, pace and consequences of climate change has been impressive. Furthermore, in the meantime policies have been put in place and more far reaching policies can be expected. In industrialised countries, such as Finland, these policies were almost without exclusion so-called mitigation policies, i.e. aiming at the reduction of greenhouse gas emissions. Only recently have industrialised countries, Finland included (MMM 2005), begun to prepare for putting up policies aimed at adaptation. Adaptation means anticipating that climate change is more or less inevitable during future decades and aims to minimise its negative effects and exploit its beneficial opportunities.

Due to the relatively limited time frames of the mitigation policies implemented so far, economic assessments of mitigation policies could purely focus on the costs and benefits of measures taken compared to a given baseline development. In the case of adaptation to climate change there is no longer one single baseline, because the assessment period is much longer and the uncertainty about the extent and pace of climate change effects is large. All in all, this means that adequate economic assessments for supporting adaptation policy preparations will have to be appreciably more complex than those for the preparation of mitigation policies.

With the above challenges in mind a work package on social-economic aspects was added to the FINADAPT project plan.. The aim was to try to present:

- a synthesis of the first-order costs and benefits of climate change for Finland, while using as much as possible the results of other (sector specific) work packages;
- an assessment of the induced economic effects of climate change by means of model simulations;
- an overview of the research needs for the development of adequate economic evaluation tools.

The nature of FINADAPT is predominantly investigative and exploratory, therefore the above mentioned quantitative exercises are meant to obtain an impression of the orders of magnitude of costs and benefits, but even more so to learn about deficiencies in data, in conversions from physical to economic quantities, and in economic valuation methods and the handling of uncertainty. The above mentioned progress in knowledge about climate change relates predominantly to higher aggregation levels than single countries, hence the need for 'translation' of findings to lower aggregation levels as well as specific studies of implications at lower aggregation levels.

Apart from the very diverse physical characteristics and complicated interactions of the various climate change phenomena (meteorological, biological, and geophysical), the occurrence of economic impacts can be approached in several ways. For example, one can distinguish between effects on economic stocks and flows respectively. For this reason the report first discusses in section 2 the various valuation approaches that could be applied, as well as gives a brief account of earlier findings of economic effects of climate change.

Subsequently, the economic baseline scenarios for Finland and other points of departure are presented in section 3. Section 4 reviews the impacts per sector and to some extent for the economy as a whole. Conclusions and recommendations follow in section 5.

2. Valuation challenges

2.1. Where to measure

Climate change can have effects on production, as well as on consumption. These two factors represent flows. Next to the effects on these flows climate change can also affect the capital stock . Arguably, the concerns about climate change are closely related to its ultimate effects on welfare levels of current and future generations. This implies that an assessment of the effects on consumption is needed. However, there are several methodological complications involved when assessing very long term developments in consumption. Furthermore, changes in consumption are, to a significant extent, initiated by changes at the production side through changes in cost, quality and access. Hence an analysis of changes in consumption presupposes an analysis of changes in production.

Changes in the capital stock can either be concrete damage (with obvious effects for production and/or consumption) or can be based on changes in its market value. The latter kind of change constitutes mainly a potential impact on production and consumption, even though changes in asset values can affect a company's lending capacity and hence its capacity to finance investments.

From the above discussion it can be inferred that, when a comprehensive appraisal is the ultimate objective, the development of the method and first stage applications should focus on the production side. This logic is also followed in this report. Nevertheless, for several effects some consideration is also given to the implications for consumers. Climate change effects on the capital stock should be assessed in terms of their implications for production (and later on consumption).

2.2. What to measure

The effects of climate change on the economy always imply some cross-over from a physical effect into an economically relevant effect. Partly such effects will occur through market responses. In other cases the impacts represent something more akin to an external shock. The channelling of climate change effects through normal market mechanisms can be illustrated for agriculture.

For many commercial crops in Finland climate change is expected to bring about improved growth conditions, at least on average. This leads to higher yields per hectare. Yet, it is far too early to decide on the basis of the yield effect, that aggregate crop production and farm income would go up. In a market environment several reactions are possible after an increase in capital productivity (of land in this case):

1. if demand is neither particularly responsive to price nor to product differentiation, there is no need to produce more in aggregate, cereal prices will decline and consequently the least productive land will be taken out of production (or reallocated to other crops); an exception to this reasoning is valid when there would be room for

import substitution, that is, if domestic production would gain advantage over competing imports, a part of the marginal land would be kept in production;
2. if demand is responsive to price and there is no monopoly, the lower unit-cost of the crop are passed on to the buyers, who will start to buy more of the crop, and consequently the total production area may not decrease; in addition if improved productivity enhances competitiveness on export markets, total production volume and area may not decrease as there is more foreign demand;
3. if demand is responsive to differentiation of the product quality, the response and consequences lie in between those mentioned in 1. and 2.

In option 1 – ignoring the exception of import substitution – total physical production does not change, nor does the production value. However, the share of value added goes up. For farms that stay in production the average income will improve, while it drops to zero for those farms that terminate (apart from cultivation changes). The prices for marginal farmland could drop. In the case of agriculture the production decisions and product markets (as well as input markets) are influenced by agricultural policies. Similar kinds of factors, partly exogenous to climate change, influencing the markets may be found in other sectors as well.

In option 2 total physical production increases, but the farmed area, production value, value added and average farm income stay (approximately) the same. In option 3 the various effects will be somewhere between the levels of option 1 and 2. In addition policies, such as subsidy schemes, may interact with the market responses. In some cases the interaction is large enough to change the picture, e.g. the ultimate benefactors could be the tax payers instead of the producers.

Technical development can attenuate negative effects and reinforce positive effects of climate change. In fact history shows that agriculture has been adapting quite regularly. In a world with minimal inhibitions to information flows, such as in the FINADAPT scenarios ‘Global Market’ (A1) and ‘Sustainability’ (B1) (see Carter et al. 2005), technology transfer unfolds at a rapid pace and consequently competitors can soon benefit from the same technologies. Policies and market developments may also contain ‘wrong’ signals, meaning that these incite technological developments (such as far reaching specialisation in a mono-culture framework) which would make agriculture more susceptible to climate change effects instead of less.

The kind of market responses as discussed above will arise automatically without any policy intervention. Even though response effects in some sectors with long lasting expensive capital goods will spread out over a longer time span, in most sectors and markets the response process unfolds within a couple of years. This feature is important when distinguishing between stages of adaptation cost.

In Table 1 the various degrees of inclusiveness of adaptation effects are laid out. In the long run the differences in concentration of greenhouse gases (GHG) cause differences in the extent of climate change and therefore every emission scenario has its own social-economic baseline (first line of cells in the table). However up to the year 2050 the changes in climate characteristics do not differ much between the scenarios.

As is explained above, a distinction can be made between automatic adaptation that will occur anyhow and anticipatory adaptation. If the approach in policy making followed that of "Passive Adaptation" it would mean that next to automatically induced responses in nature and the economy, only ex post measures are taken. In other words, measures would be taken only after impacts become apparent and require action. In contrast, an approach of "Active Adaptation" would incorporate anticipatory measures aimed to reduce damage and exploit new opportunities based on a prior understanding of the expected automatic changes as well as other impacts and possible shocks. In the baselines only Passive Adaptation is taken into account. If an adaptation policy is considered it could still choose either to take on a "wait-and-see" stance or a pro-active stance. Last but not least, one could consider the combination of both adaptation and mitigation policies, in which recourse is also taken to the other types of actions. In that case, however, a passive approach would be truly less sensible. The cells with red ellipses concern the two levels of inclusiveness distinguished in this study. At this stage we refrain from assessing integrated adaptation and mitigation approaches.

Table 1 Stages of adaptation and policy response

	Passive Adaptation automatic in the natural world and economy only *ex post* measures (no anticipation)	**Active Adaptation** automatic in the natural world and economy *ex ante* and *ex post* policies
Emission scenario dependent baseline (A1-T, B1, A2, etc.)	*Reference costs and benefits*	
Selected baseline + adaptation policy	Non-optimised 'wait and see approach'	*Rational adaptation policy – but disjunct from mitigation strategy*
Selected baseline + adaptation & mitigation policy (only relevant when assessment period goes beyond 2050)	Integrated approach seems inconsistent with 'wait and see'	*Rational integrated adaptation & mitigation strategy*

The baseline alternatives used in this assessment are based on derivations from the IPCC SRES scenarios tuned to the Finnish context (see Carter et al. 2005 and section 3). The development path of the key socio-economic indicators is smooth in these scenarios. However, one has to realise that the actual occurrence of climate change effects will be subject to large volatilities. In particular, the occurrence of shock effects may crucially change the course of the baseline after the shock compared to the pathway originally envisaged. Furthermore, next to the usual practice in economic assessment of producing point estimates (expected values) for future cost and benefits, it is of increasing importance to assess the variation in climate change impacts and resulting economic effects. A large variation may test the resilience of the socio-economic system. In addition, substantial larger variations will cause larger insurance and prevention costs in comparison to a smoother build-up of effects.

Intertemporal effects stemming from the intensity with which mitigation policy is pursued are not taken into account here, since in the context of this analysis mitigation policy, as explicit (additional) effort, is assumed to stay at the current level. Furthermore, these intertemporal effects only become apparent when looking beyond 2050.

2.3. Types of economic effects

As indicated in the first section, climate changes usually affect production first, either through higher (or lower) production costs (meaning more or less effort needed per unit of output) or due to damages to the capital stock and sales stock. These are first order costs. Subsequently the induced effects in the rest of the economy depend on how these changes in first order costs are absorbed in product and factor prices. There can be also direct effects on consumption, notably through damage on property and changes in property value. In addition the changes in product prices affect consumption. Last but not least, employment and hence wage levels may change due to changed production opportunities and competitiveness across sectors and countries.

Since climate change is a global phenomenon the impacts in other countries can affect the Finnish economy as well, notably in case of significant climate impacts in the major import and export countries for Finnish trade. Effects can be 'imported' through higher import prices as well as through changes in purchasing power in export countries.

In the current scenarios for Finland, population development is assumed not to be affected by climate change. It is possible that climate change itself or its economic ramifications would affect the habitability of areas. In turn this could cause migration. Observing current levels of disaster and poverty related migration, substantial changes in migration levels within Europe and Finland seem only likely if habitability in Europe itself were to be affected. Leaving extreme events aside, a deterioration of habitability in Europe would not occur at a significant scale under the climate change scenarios taken into account in this study.

2.4. Earlier assessment experiences

The global economic assessments of Nordhaus (1994, 2002), Tol (2002a, 2002b), Fankhauser, Tol and Pearce (1997), and Fankhauser (1995) are based on simplified damage functions derived from the global temperature increases projected in different scenarios, including the IPCC SRES scenarios. These damages are translated into loss of productivity of one or several production factors. This implies that economic growth is slowing down or in the worst case even becomes negative. The assessments are on a high level of sector and geographical aggregation and are more an illustration of the modelling concepts to be applied than a reliable reflection of the probable cost levels. These exploratory exercises are important for the development of assessment models and for gaining an understanding of interactions and induced economic effects. Furthermore, the exercise provides a first impression of the orders of magnitude of various effects and the global distribution of these effects, e.g. by geographical zone and by distinguishing industrialised from non-industrialised countries.

The various studies of the above-mentioned authors point roughly at similar kinds of results. For OECD countries the simulation results usually point at modest economic effects. In more recent studies, results for OECD countries (as a group) tend to show even modest net economic benefits (e.g. Tol 2002a). However, in many cases the effects are either expressed in terms of a 1°C increase in global mean temperature (or its regional counterpart) or at least not more than a 2°C rise in most cases. Furthermore, in some cases integrated optimal mitigation-adaptation strategies are tested (e.g. Nordhaus 2002). Tol (2002b) tries to account for dynamic effects on factor productivity, in particular of the capital stock. This analysis suggests a long era of net benefits for OECD countries, but in the 22nd century that would gradually change into a net loss. In many cases the economies of less developed countries, notably most of Africa, would be significantly negatively affected by climate change. The difference in severity of economic effects between developing countries and OECD countries can be explained by the fact that nature and climate dependent sectors, first and foremost agriculture, constitute a much smaller part of the economies of industrialised countries. In addition OECD countries have easier access to modern technology to cope with problems of adaptation, in any sector, than most developing countries.

There are also various sectoral assessments at the global level, among others for food (Parry et al. 2004) and for tourism (Hamilton et al. 2005). Harvests of staple food (cereals, rice, etc.) increase significantly due to climate change. The larger rise in temperature and precipitation in A2 scenarios is expected to increase food production so that the extra demand for food in that scenario (resulting from a larger global population) can be met. Whereas the default expectation regarding prices in absence of climate is a substantial rise, the inclusion of climate change effects, especially those of increasing CO2 concentration in the atmosphere (which is likely to increase cereal yields), leads to a significantly smaller increase in cereal prices, which reduces wholesale prices of staple food. According to Parry et al. (2004) one can nevertheless expect a slight (0-5%) reduction in world crop yields and if climate change effects dominate, reduction of world crop yields may be as much as 20%. Generally, in moderate climates at higher latitudes agriculture is expected to experience larger productivity increases than in tropical and sub-tropical areas. Hamilton et al. (2005) analysed the effects on international tourist flows at a global level by estimating a set of functions for destination choice, in which ambient temperature is one of the explanatory variables. Despite its inaccuracies, the advantage of the study is its completeness and consistency regarding global tourist flows. For Finland a modest improvement in the tourist balance would result.

Canada has been running a climate change assessment programme including cost assessments of climate change effects and adaptation measures. Dore and Burton (2000) are rather critical about the application of macro-level cost-benefit studies starting from neo-classical principles. They suggest that a bottom-up approach based on case-wise information or at least exemplary cases per sector produces more reliable results when it comes to actual policy making. Once this bottom-up picture is sufficiently clear, an overall model based assessment of induced economic effects could be considered (even though Dore and Burton also dispute the reliability of such exercises, e.g. due to uncertainties of future price structures). In fact the climate change adaptation programme in the UK (UKCIP: see http://www.ukcip.org.uk/) also adheres to bottom-up approaches in impact assessments. There is a lot of attention for sector and aspect assessments at the regional level, whereas the guidelines document for economic assessment appraisal typically focuses on cost-benefit analysis of regional or sector impacts (Metroeconomica, 2004).

Kuoppamäki (1997) carried out an earlier overall cost assessment for Finland, providing figures for the year 2050. Consistent with this report, the principal sectors were agriculture, forestry and energy. New information available for this report seems to result, on balance, in smaller net effects for those sectors compared to Kuoppamäki's findings (see also section 4). In both cases the best guesses for 2050 point at small net benefits for Finland, although in this report the volatility of the results over time, and the risks to the resilience of the economic system get more emphasis.

3. Points of departure

3.1. Expected climate changes in Finland

The Finnish Meteorological Institute has analysed new simulations for Finland regarding changes in key climate characteristics (Jylhä et al. 2004; Ruosteenoja et al. 2005). A summary for temperature and precipitation is given in Table 2. Both for temperature and precipitation the expected changes in winter are larger than in summer.

Table 2 Simulated changes in temperature and precipitation in Finland compared to the reference period 1971-2000 (source: Carter et al. 2005)

Mean surface air temperature rises in °C – 30 year period averages for Finland (standard deviation in parentheses)			
Time slice	**1991–2020**	**2021–2050**	**2070–2099**
Dec–Feb			
A2	1.1 (0.8)	2.6 (0.8)	6.5 (0.8)
B1		2.5 (0.7)	4.3 (1.1)
Mar–May			
A2	1.1 (0.6)	2.2 (0.9)	5.2 (1.5)
B1		1.9 (0.9)	3.4 (1.1)
Jun–Aug			
A2	0.6 (0.3)	1.5 (0.4)	3.6 (1.0)
B1		1.3 (0.3)	2.3 (0.8)
Sep–Nov			
A2	0.7 (0.5)	1.8 (0.5)	4.5 (0.9)
B1		1.6 (0.3)	2.7 (0.6)
Annual			
A2	0.9 (0.4)	2.0 (0.4)	5.0 (0.7)
B1		1.8 (0.4)	3.2 (0.7)
Increases in precipitation in percent – 30 year period averages for Finland (standard deviation in parantheses)			
Time slice	**1991–2020**	**2021–2050**	**2070–2099**
Dec–Feb			
A2	4.7 (5.3)	9.7 (6.9)	22.3 (12.2)
B1		7.3 (7.0)	13.2 (8.3)
Mar–May			
A2	3.8 (4.2)	7.3 (7.3)	19.9 (9.7)
B1		7.6 (6.6)	12.7 (6.6)
Jun–Aug			
A2	1.9 (2.7)	4.1 (3.0)	3.8 (6.9)
B1		2.8 (4.0)	4.6 (5.4)
Sep–Nov			
A2	1.4 (2.8)	5.5 (3.4)	14.5 (6.5)
B1		5.1 (1.5)	10.4 (3.7)
Annual			
A2	2.7 (2.1)	6.4 (2.4)	14.2 (5.7)
B1		5.4 (2.7)	9.8 (4.1)

The climate scenarios for Finland do not include variants that account for very unlikely yet conceivable abrupt, non-linear changes in climatic or geophysical conditions leading to widespread and severe impacts (so called singular events).. Both the A2 scenario family and some of the fossil fuel intensive variants in the A1 scenario family of the IPCC SRES scenarios are expected to involve global average temperature increases over 3 centigrade during the second part of the 21st century. The larger the average global temperature increase and the quicker it is realised, the higher get the risks for singular events. In practice this can mean that both the climate and social-economic scenarios trajectories could take far sharper turns than the ones researchers and policy makers commonly have applied up to now. Next to these singular events there is also the expected increase in extreme weather conditions. If various extreme weather events would occur within a short time span (e.g. within a year), it is likely that this causes a disproportional increase in risks that much higher costs are incurred and the resilience of the economic system tested.

Since both the probabilities of the singular events and of clustered occurrence of extreme weather conditions as well as of their social-economic implications are still hard to assess, these impacts have usually been kept outside broad impact assessments. This also applies to this study as regards best guesses per sector and the economy as a whole. However, in relation to variation of impacts and social-economic resilience, some attention is given to singular events in this report (section 4). Even though currently it is not possible to attribute likelihoods to these events due to the large uncertainties accompanying the underlying processes that might induce them, their overwhelming impacts imply that it would make sense to somehow include them in overall social-economic assessments. It is desirable that this is taken up further, as for proper policy design both researchers and policy makers should acknowledge that key effects in climate changes scenarios do not necessarily fit a unimodal distribution nor are these changes simply gradual.

3.2. The economic baseline scenario

From the four main families of IPCC SRES scenarios three have been taken into account for producing Finnish long term social-economic scenarios related to climate change. These are:

- *Global Markets (A1T)*
- *Sustainability (B1)*
- *Retrenchment (A2)*

The economic growth in A1T is the highest, somewhat lower in B1, and appreciably lower in A2. The choice for an A1T scenario for Finland has been made in conjunction with the strong technology oriented R&D and socio-economic strategies. Furthermore, it allows for a kind of continuum regarding policy package choices ranging from Global Markets to Sustainability oriented scenarios.

Population developments in Finland are identical in the three scenarios. According to the most recent demographic scenario of Statistics Finland, the Finnish population will start to decrease just before 2030. However, the number of households – and hence the number of dwellings – will continue to grow for a longer time (up to approx. 2045). Even though demand for new homes – as far as driven by demographic reasons – will fade away after 2025. Inland migration (from North and East to South-Central and South-Coastal) is expected to continue and therefore planning of new residential areas and renovation of existing areas (and hence accounting for climate change in spatial planning and building) will remain relevant throughout the 21st century.

Table 3 Demographic and economic trends in Finland according to the FINADAPT scenarios. Source: VATT calculations (see Carter et al. 2005; MMM 2005)

SRES scenarios	Annual growth rates	1990-2020	2020-2050	2050-2100	index 2100 (1990=100)
Global markets (A1B or A1T in Finland)	population	0,28 %	-0,18 %	-0,33 %	86
	GDP	2,25 %	2,10 %	1,30 %	677
	GDP/capita	2,00 %	2,30 %	1,65 %	792
Retrenchment (A2 in Finland)	population	0,28 %	-0,18 %	-0,33 %	86
	GDP	1,65 %	1,05 %	1,00 %	368
	GDP/capita	1,40 %	1,20 %	1,35 %	424
Sustainability (B1 Finland)	population	0,28 %	-0,18 %	-0,33 %	86
	GDP	2,10 %	1,50 %	1,30 %	556
	GDP/capita	1,80 %	1,70 %	1,65 %	642

The Gross Domestic Product (GDP) of Finland in 1990 amounted to about 108 billion euro (2000 prices). With the above mentioned growth rates per scenario it means that the expected GDP levels in the year 2100 for A1T, A2 and B1 are 730 billion, 400 billion and 600 billion euro respectively. The population was about 5 million in the year 1990. It is expected to rise to a maximum of approximately 5.45 million in 2028. Just beyond 2050 it is expected to be back at 5 million and by 2100 it would be about 4.3 million in the absence of major changes in either domestic fertility or net immigration.

3.3. Choices and limitations

As indicated in section 2 the focus will be on effects on production cost and sales in various sectors. In some cases, effects for consumers can also be quantified, albeit tentatively. One of the aims of this social-economic assessment was to use as much up-to-date information as possible from the other FINADAPT work packages. For several work packages, however, virtually no prior work was available to be used, which meant that in the context of FINADAPT those work packages could not produce much input – if any – for this study. On the other hand, for several sectors, notably agriculture and forestry and to a lesser extent energy, tourism, and water resources, quantitative information could be provided. From other work packages indications about orders of magnitude of cost or economic effect could sometimes be derived. No information could be obtained that was applicable to the assessment on public health, industry (other than energy conversion), services, and transport infrastructure.. Even though more OECD countries are gradually starting to publish assessments of options and implications regarding adaptation to climate change, there is still insufficient overview to insert a meaningful effect on foreign trade to the Finnish case. Since the Finnish economy is very export-oriented, this means that potential changes in export demand due to climate change merits major attention in future analyses.

Given the uncertainties in estimates, lacking data for some sectors and for foreign trade effects, and bearing in mind the modest effects in the sectors studied, no comprehensive model assessment has been carried out.

Of the work packages that provided quantitative information only those for forestry and energy have analysed more than one scenario (usually A2 and B1, the latter also assumed to represent the climate features of A1T). Agriculture provides fairly detailed information based on the A1 scenario. The tourist information has also been applied on that scenario. This means that only for the A1 scenario could a more or less complete overview be produced.

Costs and benefits are expressed in prices at 2000-levels, which is also the base year of the socio-economic FINADAPT scenario calculations.

Economic costs and benefits attributable to climate change are expressed *in comparison to the baseline development without climate change* in each of the sectors considered. In some sectors eventual economic impacts from climate change are dependent on conditioning effects of other public and private policies. Where necessary it is explicitly mentioned that the economic effects of climate change are conditional upon the continuation or change of another policy (agriculture, forest management, hydrology, etc.) or stability in consumer behaviour. The policy interaction effects appeared to be important in various cases. This issue will be further discussed in section 4.

4. Qualitative and quantitative effects by sector

4.1. An overview of the impacts per sector

In summary it can be expected that temperature rises are, by and large, beneficial for agriculture and forestry, especially as precipitation also increases. The change in climate conditions enhances plant growth. From an economic point of view the favourable effects of enhanced plant growth seem to dominate over the unfavourable effects of loss of species and of increased risks of pests and diseases in plants and animals (Hildén et al. 2005). Since agricultural policy in the EU is expected to become more market based in the next few decades, the productivity increases due to climate change are in many cases offset by wholesale price decreases and/or subsidy decreases of various products. This trend is reinforced by the fact that the productivity also increases in potential competitor countries with currently higher levels of productivity (e.g. in western and central Europe).

Therefore, all in all the *overall* development of the agricultural sector in the next decades is likely to yield relatively small gains that are more or less neutral in terms of value added. Increasing productivity, as well as lower heating costs, means lower production costs for crops and also facilitates stronger regional concentration of production which increases specialisation and efficiency of production in all production lines. However, a significant part (close to 50%) of the positive effect of climate change is based on the assumption that the increases in cereal production can be used to support the expansion of pig farming. Yet this requires that the current relevant subsidy schemes are not dramatically cut back. So, the message is that the ability to actually benefit from climate change depends on the extent the EU and national support schemes remain intact. It should be realised that, even though reduction of subsidies would diminish the ability to exploit the productivity increase, such a reduction would mean a benefit to the tax payer (=consumer). These offsetting effects of product subsidies (enabling expansion) versus a reduction in tax levels have not been assessed in this study. Similarly, possible increases in land maintenance costs due to climate change in agriculture, such as more expensive drainage systems due to heavier rainfall events, have not been taken into account either.

The above findings are based on the Global Markets scenario (A1T), but the findings for the Sustainability scenario (B1) are probably rather similar. For the Retrenchment scenario (A2) it could well be that net positive effects are stronger in the first 40 to 50 years, after which the risks of detrimental effects of too large climate changes could (also) start to affect agriculture negatively.

The forest sector seems capable of adapting to and anticipating changes, thereby reducing some of the risks of climate change and enhancing its benefits. The growth impact for forest stands is expected to be substantial, especially after a couple of decades when current cohorts of mature stands are replaced by new ones. The applied figures for economic impacts include assumptions about adapted forest management (Kellomäki et al. 2005; Kellomäki and Leinonen, 2005). Even though the wood supply in other Nordic countries and nearby Russia will increase as well, price deterioration is supposed to be of minor relevance due to various policy pressures to use more wood (as construction material and as fuel). An uncertain factor is the development of logistic costs. The higher yields per hectare imply a reduction of unit-cost. On the other hand, milder winter conditions lead to soil conditions that cannot always carry heavy vehicles, which translates itself to an upward pressure on unit-costs of logistics.

For the energy sector both negative and positive economic effects occur. The demand for heating decreases steadily as average winter temperatures rise notably during the 21st century. Even though the demand for cooling will increase to some extent, the overall effect is a sales loss for the energy sector. Note, however, that at the same time this is a cost saving for the energy consumers. Hence the overall impact of reduced heating cost is not necessarily negative for the economy as a whole. Increased precipitation and an earlier and possibly more extended period of snow and ice melting is favourable for hydro power potential, which is a cheap and emission-free source of electricity generation. For the maximum exploitation of the enhanced hydro potential the number of turbines has to be increased in several existing facilities. Finally, it should be mentioned that changed weather conditions, notably in winter, are expected to raise maintenance costs of the electricity network to some extent. Preliminary investigations suggest however that the effects on maintenance cost are rather modest (Kirkinen et al., 2005).

The implications for hydrological management in Finland are complex. In terms of planning and management a large array of changes may be necessary (Silander et al. 2005). Yet, overall the costs of hydrological management do not seem to rise significantly. Inasmuch as preventive measures cannot be taken, the remaining effects – notably flooding – occur in other sectors, such as real estate (services and households) and transport infrastructure.

Tourism and outdoor recreation are expected to be affected significantly by climate change. This relates in particular to changes in ice and snow cover. At a European scale the relative attractiveness of Finland for both winter and summer holidays improves, even though also for Finland the period for adequate winter sport conditions is expected to shorten. The period with summerly conditions will lengthen. In *comparative* terms it seems that competitive position for winter holidays might improve more than for summer holidays. In Hamilton et al. (2005) simulations results in an increase of foreign tourists in Finland by 14% in 2030. Domestic participants for outdoor recreation in winter may have to travel longer distances and/or resort to commercial services instead of nearby free access facilities (Sievänen et al. 2005). All in all, commercial tourist services in particular, but not exclusively those related to winter sports and winter holidays, may gain from a larger inflow of foreign tourists as well as more demand from domestic tourists. For domestic consumers this can be regarded as a rise in the cost of leisure. A challenge for winter time tourism will be that more customers have to be served in a shorter annual period, thereby putting stress both on the utilisation of the capital stock as well as on nature. This could result in a situation with higher capital intensity and hence higher capital costs, some deterioration of the environment and little increase in net value added.

Both the reports on water resources (Silander et al. 2005) and transport (Saarelainen, 2005a) mention various cost figures for flooding. As regards flooding of real estate over the past two decades, the annual cost figures vary roughly between 0 and 10 million euro. For flood prevention, extended sewer capacity, natural buffers, dykes and other kind of reinforcements have to be made as well as hydrological management practices adapted. As regards public flood prevention, the level of extra cost (for prevention) does not seem to exceed 10 million per year. For the remaining cost of flooding (in spite of prevention measures) a level of 10 million per year at least for the nearby decades seems reasonable. Yet, as the value and volume of real estate will continue to grow, the damage is likely to grow as well at a similar pace.

It is worth pointing out that as regards the handling of flooding costs the distinction between passive and active adaptation could not been applied rigorously in this report. The justification is that a good part of the adaptation measures for hydrological management seem to have very favourable pay-off rates, and consequently in this case the well established institutional infrastructure is assumed to respond automatically to climate change by implementing adaptation measures.

The benefits of lower heating costs have been translated into reduced costs for consumers. On the other hand extra cost can be expected due to more expensive insurance and larger dependence on commercial outdoor recreation (instead of free access facilities). On the basis of these inputs a modest net loss in purchasing power (tens of millions per year at the aggregate level) results. The domestic production effect of that loss in purchasing power has been assessed by means of linked consumption expenditure – input-output models.

4.2. Overview of results

The overall result for Finland indicates a very modest benefit (Table 4). Yet, this ignores effects that have thus far not been quantitatively assessed: for transport infrastructure, the bank and insurance sector, other industrial and services sectors, and foreign trade. For the financial sector and occasional other services and industries there could be gains thanks to extra demand for services induced by the perception of increased risks of climate change. This requires however timely and adequate adaptations in the business strategies of the companies involved. Obviously an inadequate assessment of the risks involved could also result in losses for the bank and insurance sector. For the others, notably transport infrastructure, losses are expected to prevail. In as far as there will be new business opportunities they imply a substitution within the transport sector (i.e. a zero sum game), whereas damage to transport infrastructure and equipment can be expected.

All in all, it is less likely that any of these sectors not yet quantitatively assessed would experience truly substantial impacts. On the basis of the current experiences and occasional case wise figures that are available it seems possible that sectoral costs rise from a magnitude of an *average* of millions per year to tenths of millions per year. When trends would indicate that average costs may rise even higher it gets ever more likely that more preventive measures are taken in order to moderate the overall cost effect. Having that said the local or temporal significance of the cost rise should neither be underrated. Bear in mind that an average figure is a construct. In reality there will be years with high damage costs often concentrated in particular areas and/or sectors. Even though such events – in retrospect – at most cause only a small dent into the national economic growth curve, they can upset the local economy for a longer time and thus work out inequitable for those affected. Last but not least it should be stressed that it is *unlikely* that large and lasting economic costs would occur, but it is *not impossible either* that climate change would test the economic resilience more than we tend to imagine now. The important issue of (economic) resilience is taken up in the next section.

Table 4 Overview of impacts per sector for the Global markets scenario (A1)

	Changes in net value added (mln €).		
Sectors (scenario A1)	**2020**	**2050**	**2080**
Agriculture	60	100	120
Forestry	75	150	250
Energy	-37	-73	-141
Tourism (hotels, leisure facilities, etc.)	107	107	107
Hydrology	-22	-32	-50
Transport	–?	–?	–?
Real estate	–?	–?	–?
Banking & insurance	–/+?	–/+?	–/+?
Other services	–/+?	–/+?	–/+?
Imports	–/+?	–/+?	–/+?
Exports	–?	–?	–?
Consumption induced production	-60	-80	-55
TOTAL	135	172	231
% of GDP	0.06 %	0.04 %	0.02 %
TOTAL excl. tourism	22	65	124
% of GDP	0.01 %	0.02 %	0.01 %

Assumptions: *Agriculture:* see text in section 4, Table A1 in Appendix 1; *Forestry:* cost structure remains the same, unit-prices constant throughout 21st century; see also Table A2 in Appendix 1; *Energy:* volume of dwellings and other heated real estate grows with 18% up to 2030, real prices of energy part of the delivery prices constant; cost structure constant; change in heating demand based on change in degree days; correction for extra cooling demand by lowering heating cost reduction by 10%; the extra production from hydro (without adding turbine capacity) amounts to 0.5 TWh in 2020, 1.3 TWh in 2050 for A1/B1 and 1.7TWh for A2, 2.1 TWh in 2100 for A1/B1 and 2.8 TWH for A2. The extra network maintenance cost amount to an order of magnitude of 1 million euro per year; *Tourism:* the number of foreign tourists grows by 14% from 2000 to 2030, the number of visiting days per foreign tourist and the real expenditures per tourist are constant; *Hydrology:* see text section 4; *Consumption-production effect*: balance of less energy cost and extra cost of insurance and outdoor leisure for households and its induced effects on domestic production (on balance the extra cost vary between 20 and 30 euro per year per household).

Kuoppamäki (1997) reports, on balance, an improvement of GDP in 2050 attributable to changing climate by about 1%. The results reported above point at much smaller overall net benefits (if any). In qualitative terms there are similar messages, i.e. benefits for the forest sector, for agriculture and from energy saving.

Obviously when comparing the currently estimated effects with total GDP, one can only conclude that at a national level the effects seem to be very modest and not essentially different from zero. Of course some effects may concentrate in certain types of areas and sectors, therefore effects could be more significant at a local level. Furthermore, as mentioned before, the outcomes are based on gradual scenarios. The next section will discuss the economic significance of extreme events and of annual variation in effects.

Note that the total effects indicated in Table 4 *only very partially* include induced effects on the economy. Furthermore, active adaptation policy will probably need to go beyond a focus on climate change effects as such, since interaction effects with other policies, such as for agriculture, forestry, mitigation, spatial planning, etc. clearly have a significant influence on the eventual economic effects.

4.3. Volatility of results and resilience of the system

The small effects shown in the previous section may suggest that there is not so much to worry about after all. However, this result may be deceptive. The minute overall impact results from the summation of several larger pluses and minuses. More importantly, the effects of climate changes will in most cases not develop gradually, but instead show up with large variations in intensity, even though in the long run a trend will probably be seen as well. Furthermore, climate change could well involve changes in variability of daily weather, for example affecting minimum and maximum temperatures as well as amounts of daily and annual precipitation. So the positive and negative effects summarised in Table 4 (and Tables A1 and A2 in the Annex) are in fact (crude) mid-point estimates of large distributions in certain years.

Climate change will expose the world to more extreme weather both in terms of frequency and ferocity. The implication of this is that all countries are tested on their *socio-economic resilience*. The testing of the resilience is probably more important than the cost of adaptation as such, when assessed on the basis of averaged impacts. This will be especially the case in OECD countries where the average volume of costs and benefits is rather modest.

Another problem with comparing costs and benefits occurring over a very long time span (i.e. 100 years or more) is the treatment of discounting. Conventional discounting will make most events beyond 2050 irrelevant (see Figure 1 – SUM disc). On the other hand not discounting would be not realistic either, as it denies the opportunity cost of capital. Hence some sort of weighting is needed (Weitzman 1997; Agnani et al. 2005; Sumaila and Walters 2005), which ensures that the more distant future still really counts. The method adopted in this study (see below) is a very crude way to account for the fact that in very long term assessments the impacts affect people who cannot have taken part in decision making nowadays, whereas these upcoming generations are also affected by climate change beyond the time horizon of the current generations. A more accurate way would be to use survival functions to account for cohorts of the total future population that are not yet born and the fading away of current ones. There is a growing amount of evidence from behavioural economics (e.g. Frederick et al, 2004) that long term discount rates could be downward sloping in a welfare economics context (as distinct from the opportunity cost of capital alone), such as when appraising socio-economic impacts of climate change.

In the examples presented hereafter, the weighted discounting is carried out as follows:

for $T < T*$

$$i_T = i_0 \quad (1)$$

else

$$i_T = \frac{T_t - T_0}{A} i_0 \quad (2)$$

where T is a certain (future) year, $T*$ a threshold year (here 10 years after T_0), i_T the discount rate in year T, i_0 the discount rate in the base year T_0, while A represents life expectancy at birth. In this case A is set at 80 (years).

Subsequently this interpretation of the discount rate is applied in the calculation of annual discount factors. To weigh in the effect of year T, it is multiplied by the discount factor. The discount factor f for year T is defined as:

$$f_T = \Pi_t \left[\frac{1}{1 + i_T} \right]^T \quad (3)$$

The monetary value of the climate change impacts on sector s in year T, V_{sT}, is multiplied by the discount factor to obtain a weighted discounted value for the impacts on sector s in year T.

SUM disc_corr in Figure 1 is the annual sum of DV_{sT} over all sectors. The consequence of this treatment is that, as time goes by (and new cohorts of people enter society), the level of the discount rate goes down, and consequently the annual discount factor diminishes less quickly and beyond the year T_t it remains stable. In the applications below i_0 = 5%, T_t = 2090, $T*$ = 2010, and A = 70. Under these assumptions the discount factor levels off in 2080 at about 0.09, meaning that all effects after 2080 keep weighing in at 9% of their value. In the conventional treatment the discount factor would be reduced to 2% after 80 years and 0.8% after 100 years.

Figure 1 shows the annual sum of the realisations of the sector effects shown in table 4 (except the consumption-production effect). The higher rising (beige) graph concerns the undiscounted series (SUM). A random generator has produced fractions between 0 and 1, which are subsequently multiplied by 1.5. The costs per period are weighted for the build-up of cost over time and then multiplied by the elevated random factor. The series SUM disc represents the discounted sums of the sector effects, when the discount rate is not corrected as explained above, but set at 5% (a common value for public infrastructure assessments). The series SUM disc_corr shows the sums when applying the above explained weighing of the discount rate. Also with the corrected discount rate the significance of effects diminishes after 2050, but slower and only to a certain extent. Apparently effects in the year 2095 are still significant enough to be notable with this weighed system.

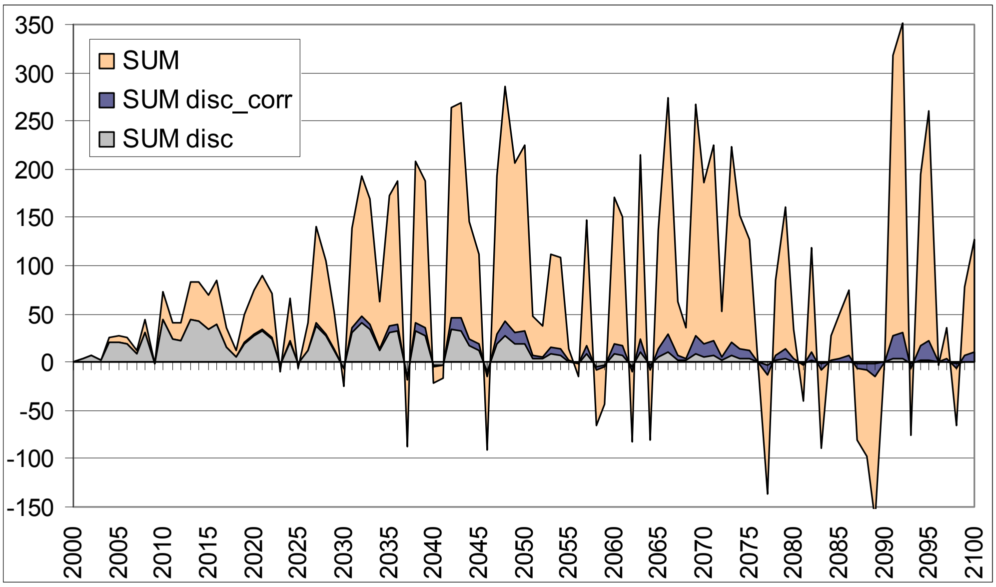

Figure 1 Undiscounted and discounted annual first order costs(-) and benefits(+) (sums over sectors in million €)

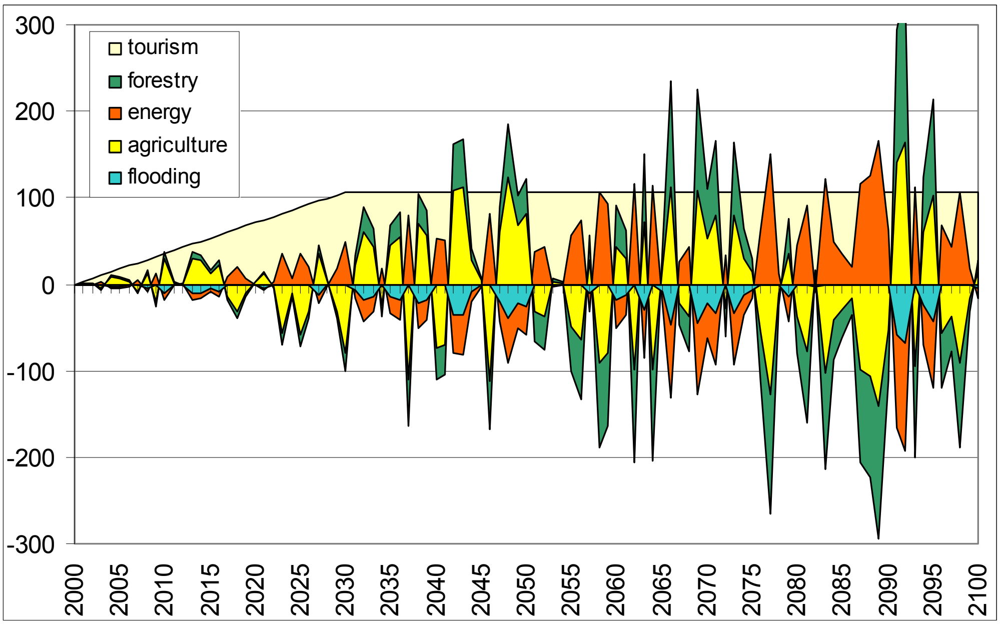

Figure 2 Undiscounted annual first order costs(-) and benefits(+) per sector (million €)

In Figure 2 the contributions of the various sectors are shown (undiscounted). Compared to Figure 1, this provides the additional insights that some sectors may experience effects of several percentage points in one year. The question is then what would happen when such events happen to occur in consecutive years. One could also wonder what would happen with the impact in one year if a more extreme amount of rainfall, strong gusts or extreme duration of high temperatures is *repeated within the same year*. It could mean that the impacts shown in Figure 2 increase by a factor 5 or more.

The above line of argument can also be extended to extremely dramatic events such as a rapid rise of sea level due to the disintegration of the West Antarctic and/or Greenland Ice Sheets (e.g. Oppenheimer and Alley, 2005), or the disruption of the thermohaline circulation (THC) in the north Atlantic leading to abrupt cooling over North-western Europe (e.g. Ramstorf, 2002, Keller et al. 2004; Bryden et al, 2005). The problem is that there is not much analogous material that can be applied as a foundation for simulating responses of economic systems to such drastic shocks. The best material can be found in historic time series of GDP and subsequently relate the growth path and its disruptions with events in history. This has been done for Finland, and Figures 3, 4 and 5 show, respectively:

- observations for the entire 20th century and a simulation of the A1 economic growth rates for the 21st century;
- a focus on the years 1900-1960, and notably the shock around the years 1913-1921;
- a focus on the years 1935-2000, and notably the shock around the years 1990-1995

From these figures it can be inferred that annual fallback seldom exceeds 10% of GDP (though it did in 1918/1919), and a period of shrinkage mostly does not exceed 5 years, while it is usually followed by years with very high growth rates. On the other hand, long term growth rates are also shown in Figures 4 and 5, superimposed in such a way that the respective crises are assumed not to have happened. This is done to illustrate that dramatic events can presage some kind of continuous loss (i.e. later arrival at a certain level of wealth). These graphs are helpful illustrations, but the shocks are all of an anthropogenic nature. A radical change in climate may demand other kinds of adaptation and may offer less room for quick recuperation after a first phase of resettling. Nevertheless, learning effects will help to attenuate the effects, just as happened during and after the wars in the past.

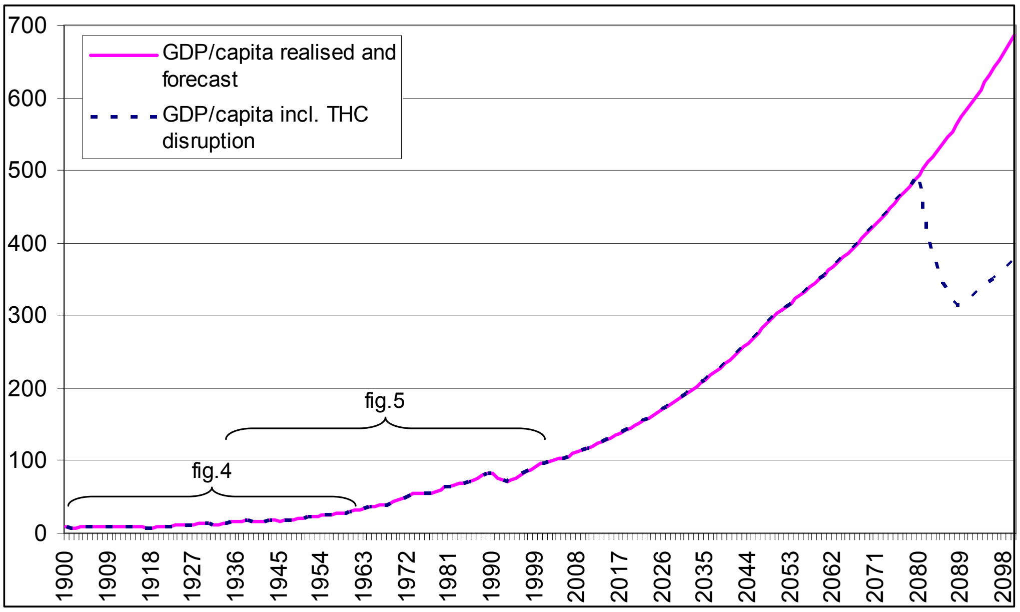

Figure 3 Observed growth of Finnish GDP in the 20th century, simulated growth of the A1 scenario for the 21st century and a sudden disruption of growth in 2080 (index 2003 = 100)

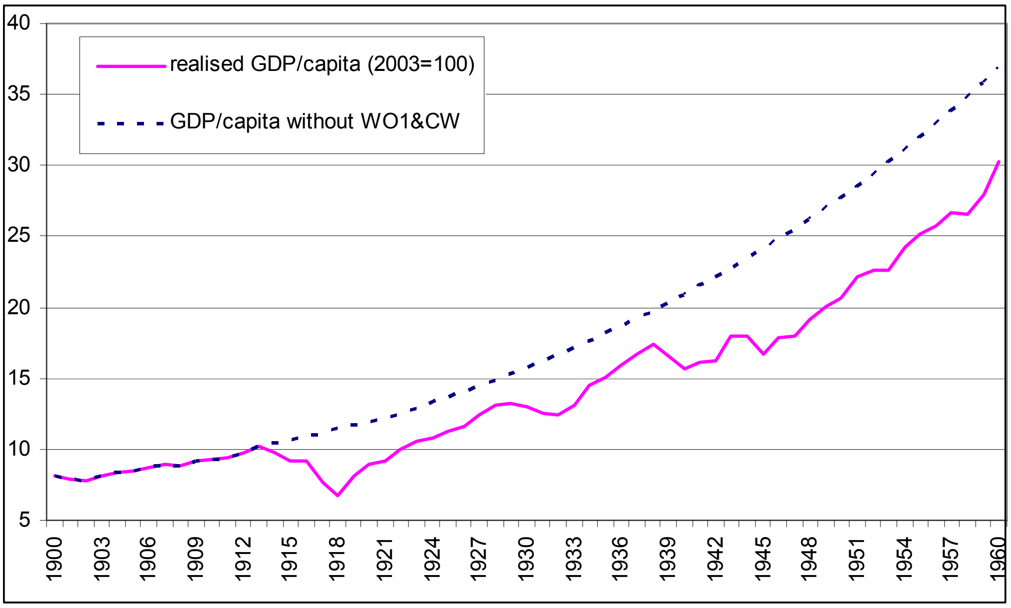

Figure 4 Observed growth of Finnish GDP from 1900 to 1960 and hypothetical growth in the absence of World war I and the Finnish Civil war (index 2003 = 100)

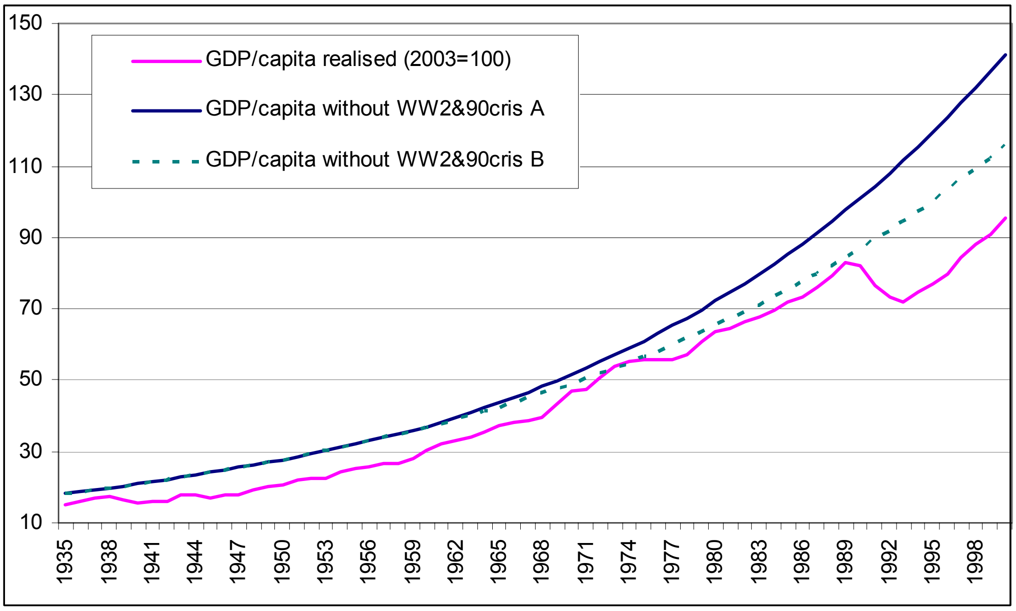

Figure 5 Observed growth of Finnish GDP from 1935 to 2000 and hypothetical growth in the absence of the crisis of 1990-1994 (index 2003 = 100)

Let us assume that we have to account for the possibility of the disruption of the THC after 2050 and that this probability is appreciably higher in the Retrenchment scenario (A2) than in the others (A1T and B1). Furthermore, after a first dramatic effect, learning takes care that the negative effects diminish in subsequent years and after 7 years a positive trend is picking up again, but no speedy recovery phase occurs afterwards. The discounted effects of a disruption of the THC in 2080 multiplied by the probability rating of the event in the different scenarios (0.05 for A1 and B1; 0.3 for A2) are added to the standard time series of the sum of direct and induced effects (sectors + the consumption-production effect). Figures 6 and 7 show the results for the integrated time series, while applying a weighted discount rate.

The impacts in the years 2080-2087 obviously dwarf all other effects. The results underscore the significance of integrating extreme events in the gradual assessments. It also shows the difference of the A1T and B1 scenarios in comparison to the A2 scenario, and emphasises the relevance of jointly considering mitigation and adaptation options. Since we cannot simply prefer an A1T or B1 world and ignore A2, the only option is to promote actions that further the realisation of an A1T or B1 world. This implies on the one hand promotion of world wide mitigation efforts and on the other hand the promotion of the other features of these scenarios, e.g. regarding technology transfer, market access, transparency, environmental quality, enablement of improved equity, etc.

The exercise with the integration of extreme events also suggests that during initial stages of long term climate strategy development, the concept of Tolerable Windows/Safe Landing (e.g. Toth 2005) may be more useful than a quest for optimal pathways, which would be the typical default economic assessment approach. The Tolerable Windows approach means that on the basis of expected developments of impacts under alternative emission scenarios is specified what degree of change (in key indicators at a certain geographical scale level) represents a 'tolerable window'. Subsequently, it can be assessed in a kind of reverse mode what kind of alternative pathways would lead the development of global greenhouse gas emissions to levels that constrain climate changes within tolerable limits that avoid unacceptable levels of impact (i.e. the 'tolerable window'). It should be realised that the assessment of what is 'tolerable' could also include social and economic considerations. Only after the outlines and conditions of sets of feasible pathways are sufficiently specified (and agreed upon) the notion of optimal pathways as contained in usual economic assessment approaches becomes meaningful. Subsequently the strategy can be further assessed and refined in terms of looking for maximum welfare (or well being) pathways, but also in that so to say 'refinement stage' resilience will remain an important feature, necessitating an overhaul of the currently used assessment approaches.

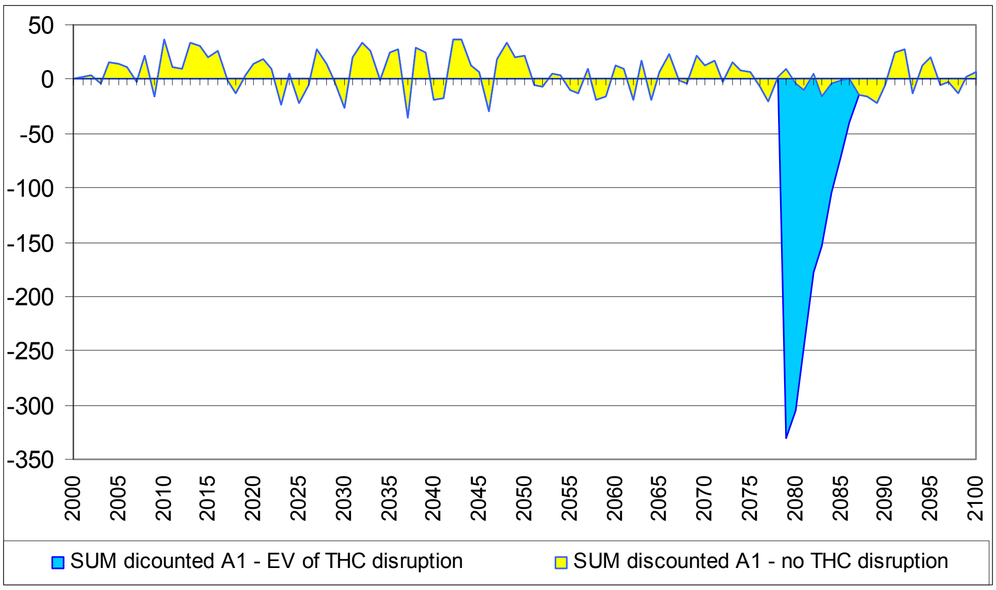

Figure 6 Weighed discounted annual direct and induced effects in the A1 scenario, respectively without disruption of the THC and including the expected value (EV) of the effects of disruption of the THC (in million €)

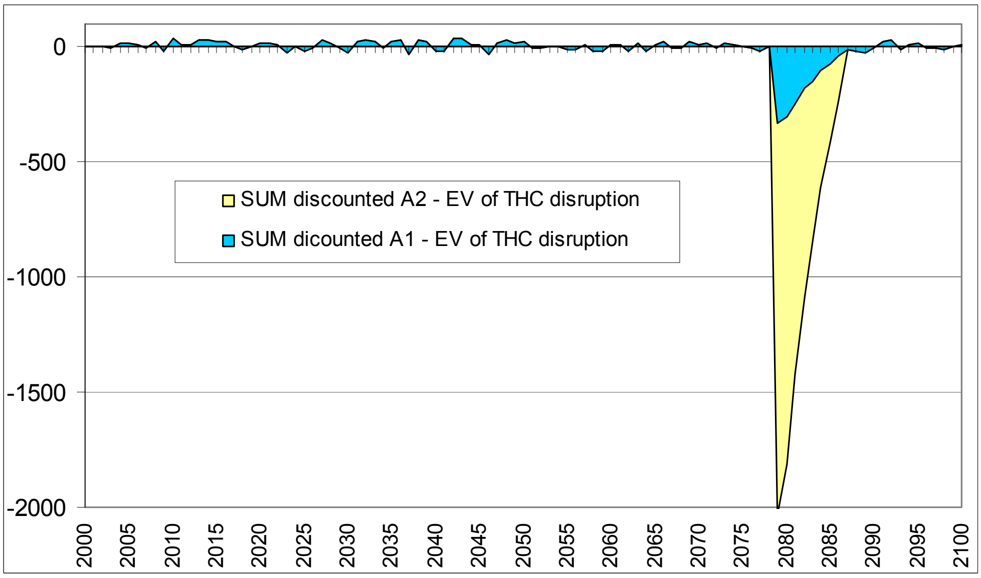

Figure 7 Weighed discounted annual direct and induced effects in the A1 and A2 scenarios, including the expected value (EV) of the effects of disruption of the THC (in million €)

5. Conclusions

Any conclusion regarding the economic effects of climate change should be interpreted with caution, realising that uncertainties and lack of knowledge about various effects, notably at national and local levels, are still prominent. From a domestic economic viewpoint, the impacts of climate change on Finland are probably rather modest and in aggregate could even be slightly positive on average for the 21st century, provided that climate change does not cause abrupt, non-linear events such as disruption of the Atlantic thermohaline circulation (THC, popularly referred to as the Gulf Stream). The order of magnitude of the aggregate effects, however incomplete these are at this stage, hovers in the area between 0 and a few hundred million euro, or to put it differently the effects amount to less than a 0.1% change in GDP.

The extent to which benefits can actually be exploited and costs attenuated depends in many cases also on public and private policies outside the realm of climate policy. Examples are agricultural policy, forest policy, and urban and national spatial planning policy.

Sectors in Finland that could gain from climate change are the forest sector and agriculture. In all likelihood, reductions in demand for heating outweigh the increases in the demand for cooling, and consequently energy end-users will benefit from this but energy companies will experience some loss of sales. Furthermore, the potential for the use of hydro electricity in existing facilities will grow to some extent. Commercial tourist and outdoor leisure services could also benefit from some growth in foreign visitors as well as from Finns who may have to rely more on commercial outdoor leisure services. However, the increase of domestic demand, in fact, constitutes a cost to consumers.

For other sectors there do not exist reasonably reliable overall assessments of the economic impacts, but some indications of the order of magnitude of part of the costs are available. Given this partial tentative impression of costs it is likely that, as regards the construction and maintenance (and repair) of buildings and transport infrastructure, extra costs will occur, albeit mostly at very manageable levels, i.e. in the earlier decades of the 21st century about 10~20 million per year, with some growth over the following decades.

Climate change induced ups or downs in foreign trade are probably an important source for economic impacts for Finland. This could mean negative effects in some periods and positive effects in others. Also the kind of socio-economic and climate conditions anticipated for the future affect assumptions about developments in foreign trade. In the Global Markets (with technology emphasis; A1T) and the Sustainability (B1) scenarios adopted in FINADAPT, the impacts of climate change on foreign trade might be more favourable than in the Retrenchment scenario (A2), not the least because the changes in climate are supposed to be more drastic in the latter scenario.

Volatility in the effects of climate change over time is probably much more important than the calculated (theoretical) average gradual effects. An unfortunate sequence of negative climate change impacts within a short time span could test the resilience of various sectors or even of the socio-economic system at large, if not nationally then at least locally.

Recent literature stresses that continuation of the current pace of growth in global GHG emissions seems to increase the – as such supposedly still small – probability of the occurrence of abrupt, non-linear events, so-called singular events, in the medium to long term (i.e. at least 30 years and probably much further away). One of these, notably a sudden cessation of the THC, were it to occur, could be expected to cause major economic damage to Finland (among other countries). Observing that (1) increased occurrence of extreme weather events is regarded probable, even though the extent of the change is as yet hard to estimate and (2) so-called singular events are considered plausible, if unlikely, it seems worthwhile to attempt to integrate impact assessments of such events with assessments of gradual changes.

If indeed we have to take extreme events more seriously into account and in conjunction with the gradual changes, it also means that it gets even more important to design *integrated* climate change strategies (i.e. jointly assessing mitigation and adaptation policy options) which self-evidently should have a sufficiently long time perspective.

Considering the various integrative and cross-cutting issues with respect to climate change, such as nature, human health, economics, and governance, it was felt that space and spatial dynamics should also be acknowledged as an integrative entity not only at the local (urban) level but also at a national scale. Climate change will affect land use and land values in many ways.

On the basis of the work presented above, the following recommendations can be made for economic research in conjunction with climate change:

- ensure that impact assessment of all sectors proceeds sufficiently and in such a way that within a few years reasonably adequate data on economic effects can be provided;
- step up research efforts with respect to the volatility of economic climate change effects and the related resilience of sectors and the economy as a whole;
- investigate the possibilities of the financial and insurance sector with respect to the enhancement of risk management of all (relevant) sectors, households and local public authorities included;
- step up research efforts with respect to an economically sound elaboration of the concept of Tolerable Window/safe Landing, not the least through international co-

operation; ensure that this is *not* done in isolation from principal developments in economic methods;

- step up research efforts with respect to the interaction effects of different policy areas and the resulting economic impacts of climate change;
- devote at least some efforts to the economic implications of land use changes, as spatial dynamics, notably at a higher (national) aggregation level, is currently virtually a '*tabula rasa*' in Finland;
- ensure good co-ordination between the various economic research efforts and policy making as well as between all climate change research efforts aimed at support of strategic policy design.

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Appendix 1

Table A1 Summary of changes in agriculture (period 2000-2030).

Type of Effect	Impact source	Change in % (compared to baseline)
prod/ha for cereals	CC	20 %
tot_prod of cereals	CC	20 %
prod/ha for oil seeds	CC	20 %
tot_prod of oil seeds	MIAD	0 %
prod/ha fodder grass (pasture)	CC	20 %
tot_prod fodder grass (pasture)	MIAD	-10 %
milk production	CC+SP	+3 %
milk production value	SP+MIAD	-17 %
beef production	SP	-18 %
beef production value	SP	-18 %
pork production	CC+SP	40 % *at most*
pork production value	CC+MIAD	40 % *at most*
poultry production	CC??	8 %
poultry production value	MIAD	-3 %
agrarian income (net VA)	CC+MIAD+SP	19 % *at most*
exports	CC+MIAD	
imports	CC+MIAD	
fallow land	CC+MIAD+SP	150 % (100.000 ha)
biofuel cropping	SP+MP+CC	up??

CC = climate change effect; MIAD = market induced effect; SP = Sector policy; AP = Adaptation Policy; MP = Mitigation Policy

An important reason for net benefits for the agricultural sector comes from an expansion in pork production enabled by more domestic fodder (cereals). The net product price received by the farmers remains the same, but the price paid by pig farms goes down due to lower logistic cost. Yet, without changes in regulations the expansion would imply a larger volume of subsidies. It is however likely that subsidy rates would decrease in case farm incomes in the involved sub-sectors have increased. Therefore, the qualifier *'at most'* has been added to the Table.

Table A2 Production effects in forestry.

				2050-2100	
Type of Effect	**Impact source**	**2000-2030**	**2030-2050**	**A1**	**A2**
wood harvest/ha	CC	3 %	6 %	10 %	
enhanced wood harvest/ha	CC+MIAD(+SP+MP)	6 %	12 %	21 %	
total wood production	CC+MIAD(+SP+MP)	3 %	6 %	10 %	
total production value	CC+MIAD(+SP+MP)	3 %	6 %	10 %	12 %
net value added	CC+MIAD(+SP+MP)	3 %	6 %	10 %	12 %

CC = climate change effect; MIAD = market induced effect; SP = Sector policy; AP = Adaptation Policy; MP = Mitigation Policy

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Abstract	This report discusses the findings of a quick scan type of study of the social-economic effects of climate change for Finland during the 21st century. From a Finnish domestic economic viewpoint the impacts of climate change on Finland are probably rather modest and in aggregate could even be slightly positive on average for the 21st century, provided that climate change does not cause extreme events such as disruption of the Gulf Stream. The order of magnitude of the aggregate effects, however incomplete these are at this stage, amount to less than 0.1% change in GDP. The increase in annual variations of climate change effects and consequent risks putting the resilience of the economy and key infrastructure to test seem to be of more concern than the above mentioned average impacts. The extent to which benefits can be actually exploited and costs attenuated depends in many cases also on public and private policies outside the realm of climate policy. Examples are policies for agriculture, forestry, and urban and national spatial planning. The report proposes several social-economic research themes to be taken up in order to be better prepared for more thorough support of future strategies dealing with climate change.	
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Julkaisun osat/ muut saman projektin tuottamat julkaisut		
Tiivistelmä	Tässä raportissa esitetään tulokset alustavasta selvityksestä ilmastomuutoksen kansantaloudellisista vaikutuksista kuluvan vuosisadan loppuun mennessä. Kotimaisesta näkökulmasta ilmastomuutoksen vaikutukset lienevät melko pienet. Äärimmäiset ilmiöt, kuten Golfvirran pysähtyminen poislukien, kuluvan vuosisadan aikana ilmastonmuutoksen kansantaloudelliset vaikutukset ovat lievästi positiivisia. Yhteenlaskettujen taloudellisien vaikutuksien suuruusluokka on noin 0,1 % BKT:sta. Tämä yhteenlaskettu summa ei informaatio- ja aineistopuutteiden takia sisällä vaikutuksia kaikkien sektoreiden osalta. Ilmastomuutoksen seurauksena vuosittainen vaihtelu sääoloissa ja poikkeuksellisten sääilmiöiden esiintymisessä kasvaa merkittävästi, jonka seurauksena myös merkittävät riskit kansantalouden häiriöille ja infrastruktuurille kasvavat. Vuosittainen vaihtelu voi olla kansantaloudellisesti merkittävämpi riski edellä mainittuihin keskimääräisiin vaikutuksiin verrattuna. Myös ilmastopolitiikan ulkopuoliset ohjauskeinot, erityisesti maatalouspolitiikassa, metsäpolitiikassa ja maakäyttöpolitiikassa, vaikuttavat hyötyjen hyväksikäyttöön ja kustannusten välttämiseen. Raportissa suositellaan joitakin taloudellisen tutkimuksen teemoja, joihin tulisi panostaa, jotta voitaisiin antaa perusteellisempaa informaatiota sekä julkisen sektorin että yhtiöiden ilmastostrategioita varten.	
Asiasanat	taloudelliset vaikutukset, riskit, pitkäjänteinen arviointi, sietokyky, äärimmäiset ilmiöt	
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Tässä raportissa esitetään tulokset alustavasta selvityksestä ilmastomuutoksen kansantaloudellisista vaikutuksista kuluvan vuosisadan loppuun mennessä. Kotimaisesta näkökulmasta ilmastomuutoksen vaikutukset lienevät melko pienet. Äärimmäiset ilmiöt, kuten Golfvirran pysähtyminen pois lukien, kuluvan vuosisadan aikana ilmastonmuutoksen kansantaloudelliset vaikutukset ovat lievästi positiivisia. Ilmastomuutoksen seurauksena vuosittainen vaihtelu sääoloissa ja poikkeuksellisten sääilmiöiden esiintymisessä kasvaa merkittävästi, jonka seurauksena myös merkittävät riskit kansantalouden häiriöille ja infrastruktuurille kasvavat. Vuosittainen vaihtelu voi olla kansantaloudellisesti merkittävämpi riski keskimääräisiin vaikutuksiin verrattuna. Myös ilmastopolitiikan ulkopuoliset ohjauskeinot, erityisesti maatalouspolitiikassa, metsäpolitiikassa ja maakäyttöpolitiikassa, vaikuttavat hyötyjen hyväksikäyttöön ja kustannusten välttämiseen. Raportissa suositellaan joitakin taloudellisen tutkimuksen teemoja, joihin tulisi panostaa, jotta voitaisiin antaa perusteellisempaa informaatiota sekä julkisen sektorin että yhtiöiden ilmastostrategioita varten.

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