Spotlighting Impacts Functions in Integrated Assessment Models

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Research Report Prepared for the Stern Review on the Economics of Climate Change

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EXECUTIVE SUMMARY

This project reviews how the integrated assessment models DICE/RICE, MERGE, PAGE, and FUND simulate climate impacts under different socioeconomic scenarios, and compares this with the results of a parallel study, *Understanding the Regional Impacts of Climate Change.* These models are commonly used in studies to determine the social cost of carbon, and in cost-benefit analyses to determine "optimal" climate change policy.

RICE and FUND simulate regionally specific impacts in a number of sectors (either in the aggregate or sector-specific), whilst PAGE, DICE and MERGE simulate aggregate global market and non-market damages, as well as damage due to rapid or catastrophic climate change. Only FUND shows how damages expressed as %loss of GDP for a given temperature rise vary with socioeconomic scenario[1]. The versions of DICE/RICE, MERGE and FUND studied for this report are deterministic models. Only the PAGE model is probabilistic in nature[2].

Non-market damages are normally estimated through a willingness-to-pay approach. All damages in the DICE/RICE, MERGE, PAGE and FUND models are output from the models in terms of % loss of global or regional GDP or $$. No physical metrics are used. Only FUND includes sector-specific equations based on simple physical processes, but it also does not produce outputs in physical metrics[3]. Adaptation is usually modelled implicitly through the calibration procedure, such that the models reflect the assumptions of the underlying literature. Only PAGE can explicitly simulate adaptation.

The study found that all the models are based on literature from 2000 and earlier. Since this time, some predictions of climate impacts have become more pessimistic, for example predictions of the potential for rapid or catastrophic climate change. The implications of these predictions has, however, recently been studied using PAGE[4].

Most of the models are calibrated using studies of the USA which are then scaled for application to other world regions. Thus the models' representation of impacts in non-US regions is questionable. Specifically, market and non-market damages in DICE/RICE and MERGE are calibrated using an impacts study for the USA only, which is then scaled to represent impacts in other regions[5]. PAGE in its default mode

[1] Note that although PAGE and DICE/RICE simulate identical impacts as %GDP for identical temperatures but different socioeconomic scenarios, that the social costs of carbon will differ between socioeconomic scenarios since these are also influenced by discounting and equity weighting factors

[2] It is of course, possible to carry out uncertainty analysis on the three deterministic models, but this is beyond the scope of this study.

[3] Examples of physical metrics are: numbers of people at risk from hunger, disease, coastal flooding, or crop production changes, or ecosystem areas or species lost.

[4] This work is reported in a parallel study which forms part of the Stern Review

[5] That study found a 0.25% GDP loss for doubled CO_2 in the USA, and a willingness to pay for non-market damages of 2% of GDP for a 2.5C temperature rise.

is calibrated to estimates quoted in IPCC (2001) but many of these are also based on an extrapolation of studies of the USA. Only FUND uses regionally and sector-specific calibration points at CO2 doubling. However, in some sectors the estimates also originate in one country, or may be dominated by estimates from one region - for example in the energy sector, (the sector which accounts for most of the economic damage in FUND) estimates for the UK are scaled across the world.

Models have various ways of simulating damage due to rapid or catastrophic climate change, but all are necessarily simplistic. The impact of climate-change induced catastrophic change such as breakdown of ocean currents, melting ice sheets or release of methane from permafrost is represented as a calibrated power function in DICE/RICE, and through a probabilistic method in PAGE. It is not included in the FUND model. Since this time, impact estimates have been revised upwards for discontinuities, which are now considered more likely at lower temperatures. In PAGE it is easy for the user to change the representation of catastrophic change, whilst in other models small or larger alterations would need to be made to the model code. Hence the results from these models will not yet reflect these latest estimates of the likelihood of melting ice sheets, changing ocean currents or release of methane from permafrost. In PAGE default-mode probabilistic analysis shows that damage due to discontinuities is of a similar magnitude to damages from market and non-market impacts, whilst in DICE/RICE impacts due to catastrophic change actually dominate the estimates of damages.

In all models the discount rate has a very strong influence on any assessment of social cost of carbon, over and above any variations in climate impacts themselves, because at a discount rate of 5%, impacts >50 years in the future are much smaller than they would be with lower discount rates. Since this is the period when climate damages accrue strongly, a high discount rate will inevitably result in lower values of the social cost of carbon.

The representation of the carbon cycle in models will also very strongly affect assessments of the social cost of carbon, since this will determine the ratio between carbon emitted and carbon remaining in the atmosphere, i.e. the relationship between emissions and concentrations of greenhouse gases in the atmosphere. The same is also true of climate sensitivity.

Model outputs are also affected by shape of damage function, which is at best theoretical in both global and regionally specific models, and is often based on an arbitrary choice of function. Specifically, market damages are quadratic in DICE/RICE and MERGE, between linear and cubic in a probabilistic fashion in PAGE, and take a variety of theoretical forms in FUND. Only FUND's damage functions take into account the rate of temperature change as well as its magnitude, and this only for the agricultural and ecosystem sectors.

Owing to the uncertainties in functional form and calibration points of models, users may want to perform uncertainty analyses. Whilst this is possible with all models, it often requires changes to the model code. Only PAGE allows a user-friendly probabilistic analysis. Thus PAGE has been used to explore the full range of optimistic and pessimistic views concerning climate impacts.

A comparison of the outputs of RICE and FUND with those of the parallel project *Understanding Regional Impacts of Climate Change* finds that the RICE and FUND models present a more optimistic picture of climate impacts (and in some cases a much more optimistic one) than the literature-based impacts study. This is because the literature upon which the models are based is very different. However, the RICE, MERGE and FUND models all use a limited set of literature which does not span the full range of potential negative climate impact outcomes found in the literature, and thus the models tend towards an optimistic picture of how climate damages accrue with impacts[6]. Examples may be found in the agriculture and ecosystems sectors:

- For agriculture the regionally specific integrated assessment models use literature which assumes strong adaptation (RICE, FUND) and/or strong CO2 fertilisation (FUND) and hence smaller impacts that the overall combined literature would suggest.

- For ecosystems, the use of a WTP approach and a zero lifetime for impacts (FUND) in the models does not reflect the true value of ecosystems in, for example, preserving watersheds, combating soil erosion, buffering sea level rise, pollinating crops, providing new medicines, etc. It also does not reflect the notion of permanent loss of species, since such damages are regarded as transient.

Some models omit impacts in important sectors or regions, for example FUND omits catastrophic change, and RICE omits impacts in forestry, energy systems, water systems, construction, fisheries, and outdoor recreation in temperate regions. Models do not take account of interactions between sectors, in other words, regional problems which may occur due to the coincidence of climate impacts in different sectors in the same region. Treatment of adaptation in the models is considered inadequate by experts in the field, being generally modelled on large scale and long-term assumptions, not reflecting key aspects of societal development or local factors.

In FUND, most of the climate change damages accrue in the energy sector due to increased need for air conditioning.

Most models do not take into account the influences of extreme weather events which are likely to contribute very strongly to economic impacts; however the top end of the PAGE input ranges do include them as far as the literature allows, albeit that literature on potential changes in the frequency and intensity extreme events is in its infancy.

[6] In some cases this is because the models need estimates of aggregate global damage, and such literature may itself be based on a non-representative or out of date assessment of impacts.

INTRODUCTION

IA models have frequently been used to calculate social costs of carbon and a very wide range of estimates for this quantity exists in the literature. Hence this project details the assumptions and data lying behind the assessment of climate change damage in four well known IA models: RICE/DICE, MERGE, PAGE and FUND. Graphics showing how monetized and non-monetized damages vary with temperature in the various models are also provided. The project also assesses how functions vary with socioeconomic scenario and how they handle adaptation. Finally, a comparison is made with the outputs of the parallel report *Understanding the Regional Impacts of Climate Change.*

1. DICE/RICE

Treatment of Climate Damages in DICE/RICE

The Dynamic Integrated Climate and Economy (DICE) model is a simple integrated model of the climate and global economy. It is designed to calculate the optimal balance between greenhouse gas abatement and economic damages from climate change, based on a suite of assumptions. It uses an aggregate damage function, consisting of impact estimates for agriculture, other market sectors, coastal vulnerability, health, non-market impacts, human settlements and ecosystems, and catastrophic climate change. The Regional Integrated Climate and Economy (RICE) model is a regionalized version of this model, split into 8 regions: USA, OECD Europe, Other High Income (e.g., Japan, Canada, and Australia), China, Russia and Eastern Europe, Middle Income (e.g., Brazil, South Korea, Argentina, Taiwan, Malaysia, and high-income OPEC countries), Lower-Middle Income (e.g., Mexico, Turkey, Thailand, South Africa, much of South America, and several populous oil exporters such as Iran), and Low Income (South Asia, most of India and Southeast Asia, much of the Asian part of the former Soviet Union, sub-Saharan Africa, and a few countries in Latin America). In RICE, each region is assigned a different climate damage function, based on the same impact categories.

The global (DICE) and regional (RICE) aggregate damage functions are derived from a climate impact analysis most completely described by Nordhaus and Boyer (2000), Chapter 4. The assessment relies on a willingness to pay (WTP) approach to estimating the value of preventing future climate change. These sources describe the derivation of the damage functions, but, unfortunately, not in enough detail to fully separate the contribution of each impact category to the aggregate functions. We outline here the aggregate representation of climate damages in the DICE and RICE models as a function of temperature increase, and, as much as possible, the breakdown of these aggregate functions into impact indices relating damages and temperature for each impact category and each region.

Aggregate Damage Functions

All DICE/RICE aggregate damage functions assume a quadratic relationship between temperature increase since 1900 and economic damages, of the form:

$$D(t) = \alpha_1 T(t) + \alpha_2 T(t)^2$$

where D(t) is climate damages measured in % loss of GDP for the globe or region, T(t) is global mean temperature increase above preindustrial levels in ºC, and α_1 and α_2 are constants specific to each function. Table 1.1 gives the values for these constants for the global function and each regional function.

Table 1.1: Coefficients for Aggregate Damage Functions

Function:	α_1	α_2	% Loss GDP for 2ºC increase
Global[a]	-0.0045	0.0035	0.5
United States[b]	-0.0026	0.0017	0.16
Europe[b]	-0.001	0.0049	1.76
Other High Income[b]	-0.007	0.003	-0.2
China[b]	-0.0041	0.002	-0.02
Russia and Eastern Europe[b]	-0.0076	0.0025	-0.52
Middle Income[b]	0.0039	0.0013	1.3
Lower-Middle Income[b]	0.0022	0.0026	1.48
Low Income[b]	0.01	0.0027	3.08

[a]DICE-99 Excel Spreadsheet version
[b]RICE-99 Excel Spreadsheet version

Figure 1.1 shows the relationship between global aggregate damages and temperature increase for DICE-99 and RICE-99. The DICE-99 output matches that of the DICE model running with its optimal carbon tax and emissions control rates set to match the projections of these variables in the optimal run of RICE-99. The RICE-99 outputs may therefore be directly compared with the DICE-99 outputs. RICE-99 has only regional damage functions, not aggregate damage functions, and thus global aggregate output depends on how those regional estimates of damages are aggregated. Results are shown for two different weighting schemes used by Nordhaus, global output weights and population weights, which are given numerically in Table 1.2.

Figure 1.1

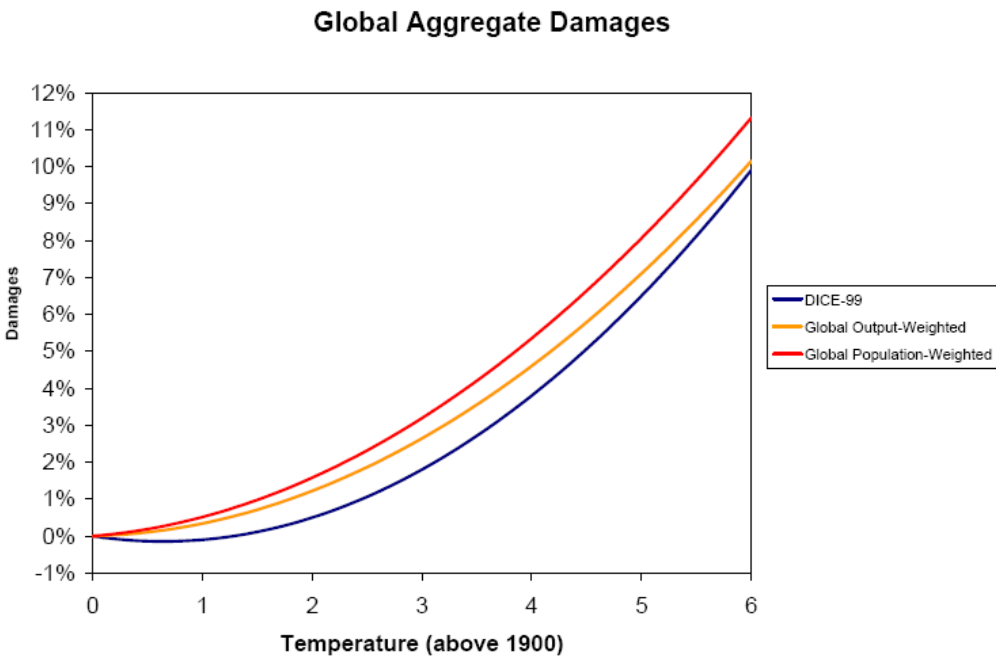
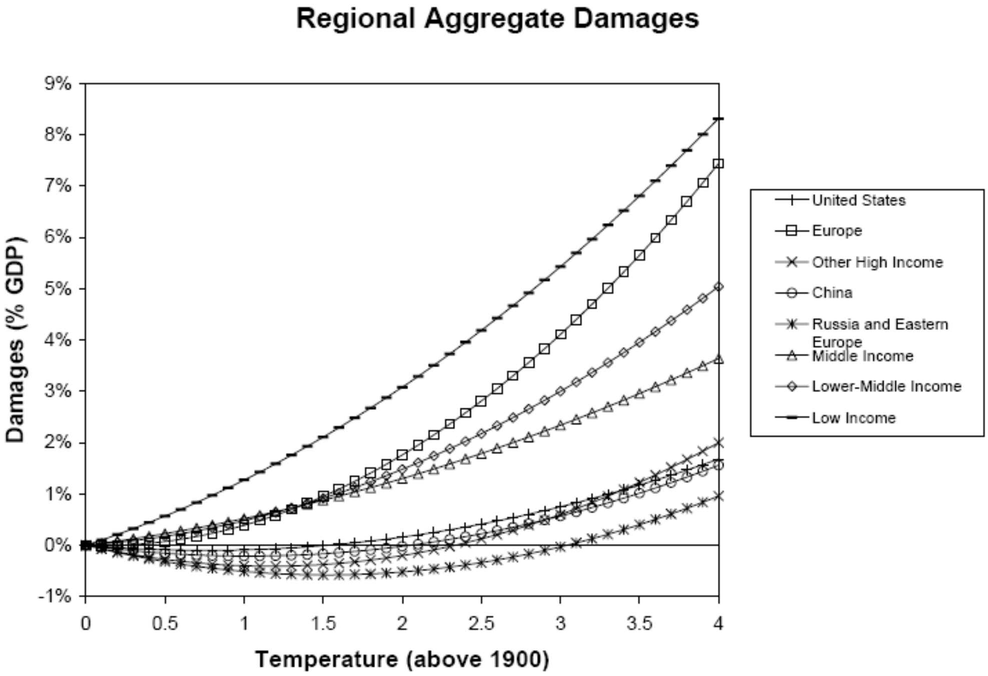


Figure 1.2 shows the corresponding regional aggregate damages for RICE-99.

Figure 1.2



Impact Sector Breakdown

Table 1.2 shows the distribution of impacts across sectors assumed in DICE/RICE.

Table 1.2 Impact of 2.5 degree warming above 1900 on different sectors (source Table 10, Nordhaus 1992): (units: % loss of regional total GDP from damages in each sector; except for TOTAL which shows % loss of regional GDP in all sectors combined. A negative number implies a benefit).

Region	**TOTAL**	**Agri-culture**	**Other Vulnerable Market**	**Coastal**	**Health**	**Non-Market Time Use**	**Catas-trophic**	**Settle-ments**
USA	0.45	0.06	0	0.11	0.02	-0.28	0.44	0.1
China	0.22	-0.37	0.13	0.07	0.09	-0.26	0.52	0.05
Japan	0.5	-0.46	0	0.56	0.02	-0.31	0.45	0.25
EU	2.83	0.49	0	0.6	0.02	-0.43	1.91	0.25
Russia	-0.65	-0.69	-0.37	0.09	0.02	-0.75	0.99	0.05
India	4.93	1.08	0.4	0.09	0.69	0.3	2.27	0.1
Other high income	-0.39	-0.95	-0.31	0.16	0.02	-0.35	0.94	0.1
High-income OPEC	1.95	0	0.91	0.06	0.23	0.24	0.46	0.05
Eastern Europe	0.71	0.46	0	0.01	0.02	-0.36	0.47	0.1
Middle income	2.44	1.13	0.41	0.04	0.32	-0.04	0.47	0.1
Lower-middle income	1.81	0.04	0.29	0.09	0.32	-0.04	1.01	0.1
Africa	3.91	0.05	0.09	0.02	3	0.25	0.39	0.1
Low income	2.64	0.04	0.46	0.09	0.66	0.2	1.09	0.1
Global								
Output-weighted	1.5	0.13	0.05	0.32	0.1	-0.29	0.17	1.02
Population-weighted	2.19	0.17	0.23	0.12	0.56	-0.03	0.1	1.05

Impact Indices and Damage Function Calibration

In the impact assessment by Nordhaus and Boyer, the 8 RICE regions are divided into 13 sub-regions: USA, China, Japan, Western Europe, Russia, India, Other High Income, High-Income OPEC, Eastern Europe, Middle Income, Lower-Middle Income, Africa, and Low Income. This assessment constructed functional relationships between economic damages (% loss GDP) and regional or global temperature for each impact category and sub-region. These damage functions are based on sectoral impact assessments in the literature, or the expert judgment of the authors. Adaptation is considered implicitly in the derivation of these sectoral damage functions.

All damages in the DICE/RICE models are expressed in terms of % loss of global or regional GDP. To make this conversion, the authors define a "future impact index" for each sector i and each region j, using a baseline year of 1995, of the form:

$\theta_{i,j}(T, y_j) = Q_{i,j}(T) \times [y_j(t)/y_j(1995)]^{\eta i}$

where $\theta_{i,j}(T, y_j)$ is the "impact index" for a global mean temperature increase of T and a per capita income of y_j, expressed as current (1995) WTP to avoid a temperature increase of T ($Q_{i,j}(T)$), multiplied by an income adjustment. The income adjustment is the ratio of future per capita GDP in year t, $y_j(t)$, to present (1995) per capita GDP, raised to the power η_i, the income elasticity of the impact index. The authors benchmark these indices for a 2.5ºC warming, constructing estimates for $Q_{i,j}(2.5)$. To calculate $\theta_{i,j}(2.5, y_j)$, the authors use a "base run" of RICE-99 to determine that a 2.5ºC temperature increase occurs around 2100, and report that "a run" of RICE-98 is used to generate values for $y_j(2100)$ (Nordhaus and Boyer, 2000).

Finally, to convert these impact indices into the damage functions used in the models, the authors calculate $\theta_{i,j}(2.5, y_j(2100))$ and $\theta_{i,j}(6, y_j(2100))$, sum across sectors to get regional aggregate estimates, and then define quadratic damages functions of the form given above that intersect these aggregate damage estimates for 2.5ºC and 6ºC temperature increase and zero damages for 0ºC warming. Where the RICE-99 regions include multiple sub-regions, they are weighted by GDP. The authors provide some details about the calculation of impact indices for 2.5ºC, but with the exception of catastrophic climate change, they provide no information about the calculation of impact indices for 6ºC. An overview of this information follows.

Agriculture

For each region j, the WTP function for agriculture is of the form:

$Q_{ag,j}(T) = \{\alpha_{ag,0} + \alpha_{ag,1}(T + T^0_j) + \alpha_{ag,2}(T + T^0_j)^2\} - \{\alpha_{ag,0} + \alpha_{ag,1}(T^0_j) + \alpha_{ag,2}(T^0_j)^2\} + \varepsilon_{ag,j}$

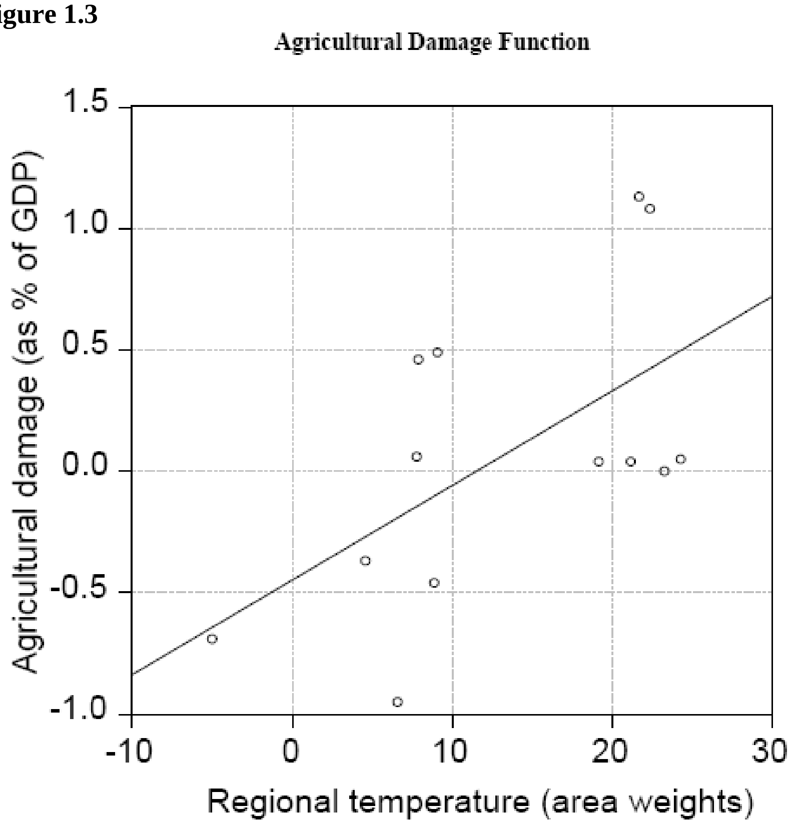
where $Q_{ag,j}(T)$ is the damage to the agricultural sector as a fraction of GDP, $\alpha_{ag,i}$ are coefficients, T^0_j is the sub-regional mean temperature without climate change, T is the global mean temperature increase above preindustrial levels, and $\varepsilon_{ag,j}$ is the error in the estimate. The income elasticity is set to -0.1.

These authors combine sub-regional agricultural impact estimates in most cases from Darwin et al. (1995) but also from Dinar et al. (1998) with estimates of sub-regional temperature to produce a relationship between agricultural damage and climate displayed in Figure 1.3. The regional temperature at which impacts shift from benefits to losses is 11.5ºC.

Specifically, Nordhaus makes particular use of Darwin et al. (1995) Appendix Table B6, which reports changes in GDP by region as a result of climate impacts upon agriculture for various climate scenarios. This table lists the outputs of 4 GCMs considering the cases where land use is restricted to cultivation on existing land and where land use is unrestricted. Nordhaus has selected the second most unfavourable GCM for the case where land use is unrestricted.

These damage estimates reflect the adaptation incorporated in the Darwin et al. (1995) study, which in its summary, states, "Farmer adaptations are the main mechanisms for keeping up world food production under global climate change." This includes farmers selecting the most profitable mix of inputs and outputs on existing cropland, adjustments in domestic markets and international trade, and increases in the amount of land under cultivation. Incorporating all of these adaptations leads to a slight increase (0.2-1.2%) in world cereals production under the climate change scenarios Darwin et al. consider. It should be noted that CO_2 fertilization is excluded in this study. Thus, Nordhaus uses damage estimates that allow transition of land between cropland, pasture and other uses, but which assume no CO_2 fertilization.

Figure 1.3



Other Market Sectors

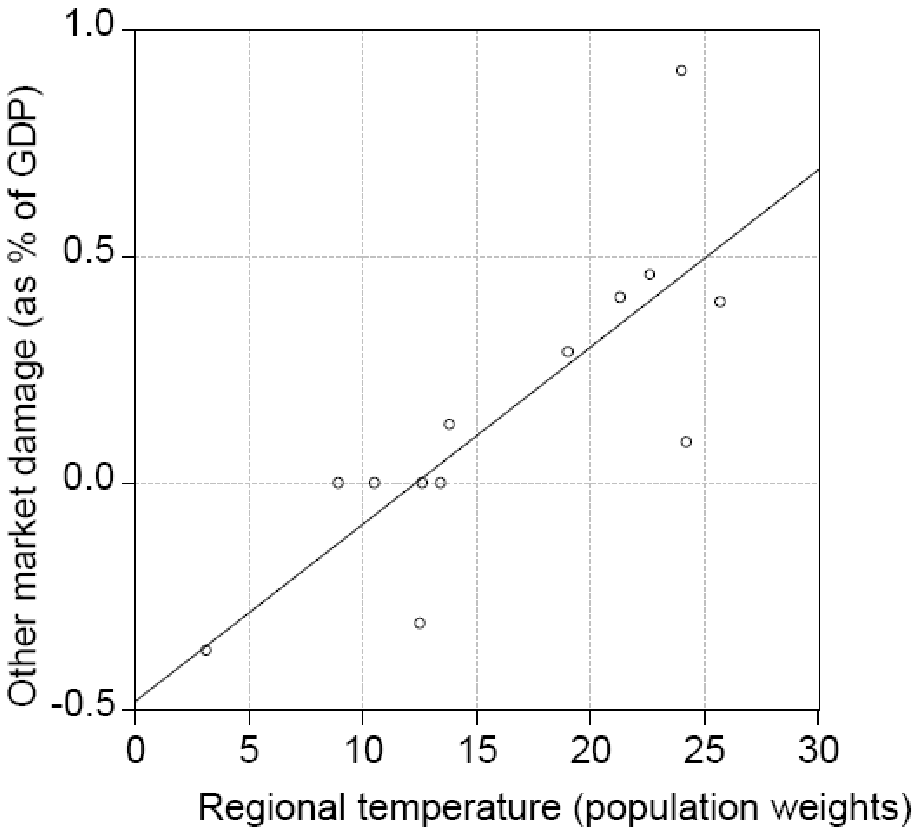
The authors consider forestry, energy systems, water systems, construction, fisheries, and outdoor recreation as sectors moderately vulnerable to climate change. However, citing estimates by Cline (1992), Nordhaus (1991), and Mendelsohn and Neumann (1999) of small losses, zero impacts, and small benefits in these sectors for the US, the authors state a lack of impact in this category for temperate climates. They also state an estimate of a decline of 5% in energy expenditures in cold climates, and an increase of 8% in tropical and semi-tropical climates for a 2.5ºC warming. The income elasticity is set to 0.2.

Although details are not given, the authors produce sub-regional estimates for damages in this category linked to sub-regional temperature as in the agricultural sector (Figure 1.3). These are used to derive WTP functions of the same form as for agriculture. Here, the temperature at which impacts shift from benefits to losses is 12.3ºC.

The authors' assessment of zero damages in the forestry, energy systems, water systems, construction, fisheries, and outdoor recreation sectors in temperate climates implies costless adaptation in these sectors to climate change. The nonzero estimates for other climates are due to benefits and costs in the energy sector, specifically increased cooling needs or decreased heating needs.

Figure 1.4

Damage Function for Other Market Damages



Coastal Vulnerability

For each sub-region j, the WTP function for coastal vulnerability is:

$Q_{coastal,j}(T) = \alpha_{coastal,j}(T/2.5)^{1.5}$

where $\alpha_{coastal,j}$ are constants, and T is global mean temperature increase above preindustrial. The authors cite the work of Yohe and Schlesinger (1998) on impacts from sea-level rise and a consideration of 1987-1995 storm damages from the Statistical Abstract (1997), page 240, based on which they estimate 0.1% of income as a reasonable WTP for preventing a 2.5ºC warming for the US. For other sub-regions, they scale this estimate based on the ratio of "coastal area" (within 10 km of the coast) to total land area, divided by the same ratio for the US. The income elasticity is set to 0.2.

Since the coastal vulnerability estimates are not directly based on one specific study, it is difficult to fully assess what forms of adaptation are implicit. Estimates made by Yohe and Schlesinger (1998) are prominently mentioned, and they calculate "the economic damage that might be attributed to future sea-level rise in the absence of any decision to protect threatened property in terms of the value of that property at the (future) time of inundation, taking into account any adaptation that might have occurred naturally and efficiently prior to flooding and abandonment." They designate adaptation as "any sort of cost-reducing activity undertaken in response to the threat of future (or immediate) inundation. Some adaptation occurs 'naturally' as, for example, markets' incorporating the threat. Other adaptation requires specific action by specific individuals – such as deciding to protect a particular piece of property." Protection is explained as involving "building dikes, building seawalls, nourishing beaches, raising houses – any activity that prevents (or reduces the likelihood of) damage from rising seas." The authors do note that human resettlement and its associated costs are incorporated in the human settlements and ecosystems sector.

Health

For each sub-region j, the WTP function for climate impacts on health is:

$Q_{health,j}(T) = \alpha_{health,j}(T_j)^{0.2243}$

where $\alpha_{health,j}$ are constants, and T_j is the sub-regional mean temperature increase. The authors base their impact estimates on work by Murray and Lopez (1996). The impacts for each sub-region are determined based on the results for the region from Murray and Lopez that it most overlaps. The income elasticity is not reported.

Adaptation is taken into account through the use of the data of Murray and Lopez (1996), which represents baseline improvements in health care, such as antimicrobials and vaccines, by using time as a proxy, based on the rate of improvement over the 20th century. The authors specifically reduce the estimated damages for Africa from 4.6% to 3.0% GDP loss for a 2.5ºC warming to account for expected additional improvements in public health in the region that reduce the incidence of climate-related diseases.

Non-Market Impacts

The authors' non-market impacts sector focuses on climate-related time use such as outdoor recreation. Details are not provided, but the authors state that they represent impacts using the same methodology as in the agricultural sector. Citing a study by Nordhaus (1998) of the value of climate-related time use in the US, the authors estimate a benefit of 0.3% GDP for a 2.5ºC warming and a quadratic relationship between sub-regional mean temperature and time use impacts. These estimates are based on increased outdoor activity, and therefore assume that people will take advantage of warmer weather and engage in more outdoor activities. The estimate is extended to other countries using this quadratic relationship and an adjustment for differences in per capita GDP and average hourly earnings. The authors set the income elasticity to 0.

Human Settlements and Ecosystems

The authors use an impact index function similar to that for coastal impacts, based on global temperature changes (the formula is not given). The authors cite unpublished estimates (of their own) of the capital value of climate-sensitive human settlements and natural ecosystems in each sub-region, and estimate that each sub-region has an annual WTP of 1% of the capital value of the vulnerable system, for a 2.5ºC increase. The income elasticity is set to 0.1. The authors acknowledge the difficulty of adaptation for coastal cities, islands, and natural ecosystems, but give no specific guidance on how this was incorporated into their "rough estimates."

Catastrophic Climate Change

The authors consider abrupt climate changes such as rapid sea-level rise from ice sheet collapse, shifting monsoons, and changing ocean currents as potentially catastrophic impacts of climate change. The authors assume a linear damage function up to 3ºC, and an unspecified power function for temperatures above 3ºC. To calibrate this damage function, they base estimates of the probability of catastrophic change on the expert survey by Nordhaus (1994), which reported results for scenarios of 3ºC warming by 2090 and 6ºC warming by 2175. Citing growing concerns over abrupt changes such as shutdown of the thermohaline circulation since the survey was completed, they estimate the probability of catastrophic change for 2.5ºC as double the probability estimate for 3ºC warming (0.012), and the probability for 6ºC as double the estimate for 6ºC (0.068). The authors also assume sub-regions such as India and OECD Europe have a higher vulnerability than others. To calculate WTP, the authors assume a rate of relative risk aversion of 4, and a loss of 30% of global GDP for a catastrophic event, distributed between sub-regions based on their (author-defined) relative vulnerability. Given these assumptions and the probabilities of occurrence, the authors calculate WTP for each sub-region to avoid both temperature levels. The income elasticity is set to 0.1. The difficulty of adapting to such impacts is a central criterion for inclusion in this sector.

Comparison with the "Understanding Regional Impacts of Climate Change" Project

In order to compare directly the results from RICE simulations with those of the Understanding Regional Impacts of Climate Change Project (URICC), the RICE model was run for the 4 SRES scenarios A1F1, B1, A2 and B2. These calculations were initiated using radiative forcing time series from 1905 to the present day provided by the Hadley Centre, matching the scenarios shown in Figure 6 of Johns *et al.* 2003 which are also those underlying the primary impacts studies (Parry *et al.* 2001) reported in URICC. The accumulation of damage with respect to temperature for each SRES scenario (Figure 1.5, shown for completeness) lies on a curve identical to that shown in Figure 1.1 (DICE99 curve). The accumulation of damage with respect to time in each SRES scenario therefore reflects only the temperature changes in the respective SRES scenarios (Figure 1.5) since damage in RICE does not depend on socioeconomic factors or on the rate of temperature change. Figures 1.6a-c shows the evolution of damage with time in the SRES scenarios using Nordhaus's three weighting schemes. There is most damage under the A1F1 scenario and least under B1, but the differences are entirely due to the influence of temperature (Note that other literature utilizing the DICE/RICE model is based on different climate scenarios and, for example, simulate a different temperatures for 1995).

Figure 1.5. RICE damage function derived from SRES scenario runs

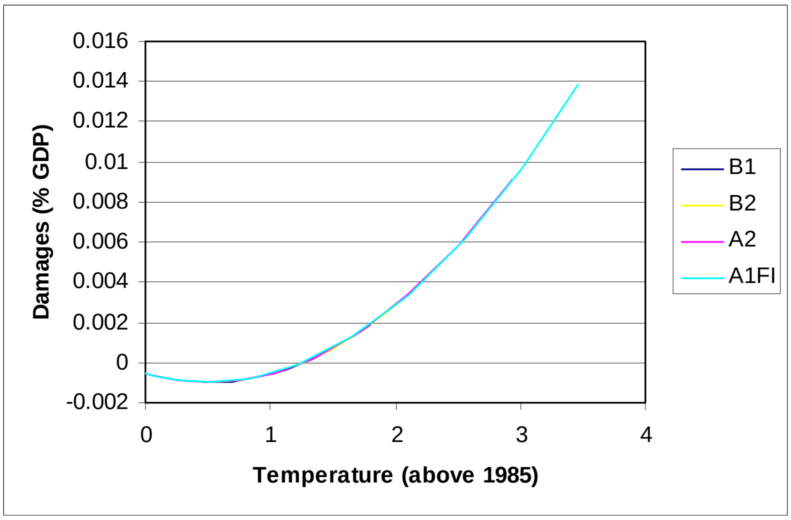


Figure 1.6a.

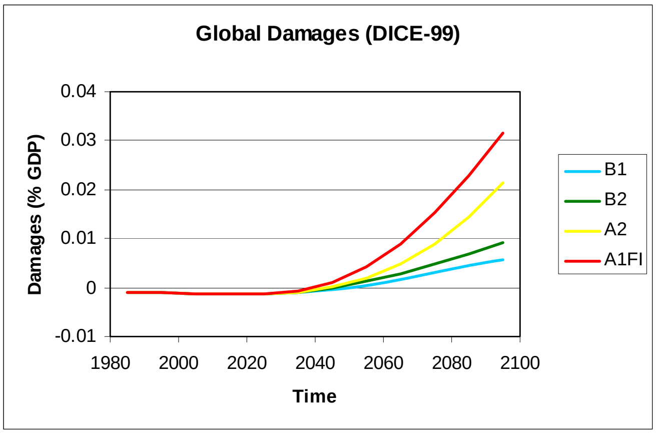


Figure 1.6b

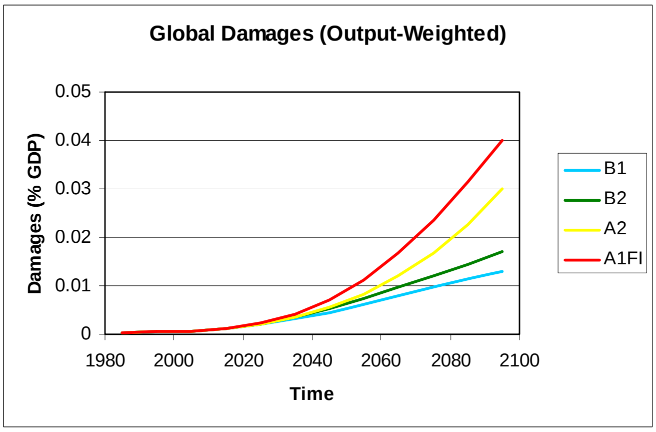
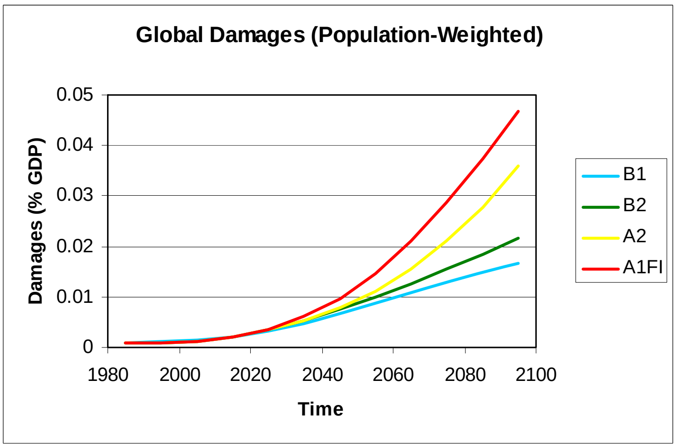


Figure 1.6c



The distribution of impacts across regions evolves with temperature as shown in Figure 1.2. Damages accrue most rapidly with temperature in low income countries, and also in Europe and China. In middle income countries damages increase more slowly. In contrast in the USA, other high income countries, Russia, E Europe and lower-middle income countries, there are small benefits until temperatures reach 2.5 to 3 degrees above 1900, or 2 to 2.5 degrees above 1990, after which point damages do accrue. Once temperature rise exceeds 5C above 1900 regional aggregate damages are a higher fraction of the economy in Europe than in any other region.

The monetization process makes direct comparisons of outputs from RICE with the URICC project impossible, but it is clear that a monetized approach gives a very different picture of the distribution of impacts than does the URICC project which uses physical metrics.

A key point is that the RICE model is showing benefits up till a temperature rise of 2 to 2.5 degrees C above 1990 in many regions, whilst the URICC project finds potentially high impacts in many world regions for these temperature rises. URICC's main study finds the possibility of benefits only in Australasia, Europe and N America in the agriculture sector when the full CO2 fertilisation of crops is assumed.

Table 1.2 above shows that for a temperature rise of 2.5C above 1900 (2C above 1990) the distribution of impacts across sectors is highly non-uniform with effects in the agriculture and non-market-time-use sectors and consideration of the potential impact of catastrophic change dominating the overall picture. Regionally, damage to agriculture coastal settlements and catastrophic climate impacts are most important in the EU, offset somewhat by benefits from non-market time use; in the US, these benefits offset the low damage estimates in all sectors beyond the consideration of catastrophic change; damage by catastrophic change, in agriculture and health are particularly strong in India; in Africa, catastrophic change is the strongest driver of damage. The lack of influence of other market sectors in RICE is due to the treatment of these sectors referred to above under "Other Market Sectors".

Hence, whilst DICE/RICE is progressive in its recognition of the importance of catastrophic change, the literature upon which its assessments of other market sectors is based is rather limited and dates back to the 1990s. The authors themselves point out the lack of treatment of impacts on "other market sectors" in temperate climates (this chapter has already highlighted the implication of costless adaptation in the forestry, energy systems, water systems, construction, fisheries, and outdoor recreation sectors in temperate climates). This chapter has already detailed the treatment of agriculture in DICE/RICE, and how this is based on a study which, whilst it does not include CO2 fertilisation, assumes unrestricted cultivation on new land and farmer adaptations (see above). For this reason, the impacts on agriculture appear much smaller than those found for the URICC project, the main study of which assumes no cultivation on new land and a specified set of farmer adaptations. Hence overall, the treatment of impacts in

RICE is completely different from that of the URICC project and estimated impacts from RICE are much lower in all sectors and regions.

Nordhaus (2006) pioneers a new method of damage estimation based not on the DICE model but on an entirely new, statistical method of estimating the relationship between economic and geographic conditions, including latitude, elevation, climate, distance from the coast, and climate. The climatic data used includes annual mean temperature and precipitation and the model as a whole has a resolution of 1 degree of latitude and 1 degree of longitude. The resultant aggregate estimates of global output lost due to a 2.5C warming are dependent on the method of aggregation and vary between -0.72% (area weighted aggregation) -0.93% (output weighted) and -1.73% (population weighted). If potential changes in precipitation are allowed for the figures increase to -1.05%, -1.41% and -2.95% respectively. Integrated modeling inevitably does not yet represent this work.

2. MERGE

MERGE builds on Nordhaus (1991) in the sense that, like DICE/RICE, it is a simple integrated model of the climate and global economy, and designed to calculate the optimal balance between greenhouse gas abatement and economic damages from climate change, based on a suite of assumptions. It uses two sets of regionalized damage functions, one for market impacts and one for non-market impacts. Unlike DICE/RICE it simulates out to 2200. The utility discount rate in MERGE is chosen so that the net real rates of return on capital (ie interest rates) are identical at 5%/year in all regions, to avoid the model dealing with the rate of change of each market exchange rate with the US dollar. Two discount rates are relevant, R and p:

$$R = p + g \qquad (1)$$

Where R is the net real rate of return on capital, p is the pure rate of time preference and g is the net rate of growth of GDP in 1 year.

MERGE regions are US, other OECD (W Europe, Japan, Canada, Australia & NZ), China, Former Soviet Union, and Rest of World.

This study reports on two model versions : firstly that described by Manne, Mendelsohn & Richels 1995, and secondly the freely downloadable version documented by Manne (2004).

2.1 Manne, Mendelsohn & Richels 1995 MERGE version

Treatment of Market Impacts

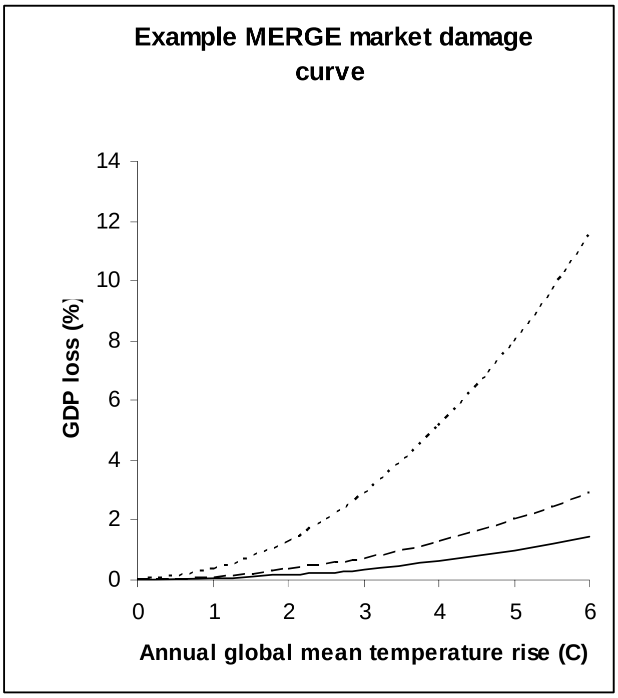
Here it is assumed that damages rise quadratically with T in the equation below $d_{2,r} = 2$ (the value of 2 is said to be taken from Nordhaus, 1992). The quadratic form assumed means that each damage function needs only 1 calibration point. In some applications of the model it is calibrated using Nordhaus (1992) whilst in other applications an uncertainty analysis is carried out on this calibration.

In this version market damages, $D_{t,r}$, for any time period *t* in the region *r,* are defined by the following relationship:

$$D_{t,r} = d_{1,r} * [\Delta AT_{t,r}]^{d2,r} * GDP_{t,r} \qquad (2)$$

where $d_{1,r}$ and $d_{2,r}$ are constants. This can be shown graphically as the solid or dashed curves in Figure 2.1, which illustrates the specific case for calibration such that a 2.5C increase in T above 1990 levels would result in 0.25% loss of GDP in line with Nordhaus (1992) early estimates of damage to the USA for doubled CO2 (solid line) whilst losses were twice as large if the country is a developing one (dashed line).

Figure 2.1



Treatment of non-market damages

Non market damages are modelled with a willingness-to-pay (WTP approach). It is assumed to have an S shaped dependence with GDP based on a WTP formulation calibrated so that it does not exceed 100% of GDP. Consumers in a particular region *place the same value on losses whether they occur inside or outside their region*. The model explores the options of different valuations that society might place on these non-market damages rather than advocating any particular set of numbers.

$$WTP_{t,r} = d_{3,r} * [\Delta AT_{t,r}]^{d4,r} / [\ 1+ (100* \exp(-0.23*GDP_{t,r}\ /POP_{t,r}))\ ] \qquad (3)$$

where $d_{3,r}$ and $d_{4,r}$ are constants.

Figure 2.2 shows the willingness to pay to avoid non-market damages associated with a 2.5C change in temperature, with $d_{3,r}$ set to 0.0032 and $d_{4,r}$ set to 2. This means that when per capita income approaches $40,000 US 1990, consumers are willing to pay 2% of GDP to avoid a 2.5C increase in temperature (and 8% to avoid 5C) as shown. In 1995

US expenditure on environmental protection was 2% GDP. Thus the WTP in a developed country, i.e. the non-market damages as modelled in MERGE, may be very much larger than the market impacts (Table 2.1)

Figure 2.2 (taken from Manne, Mendelsohn & Richels 1995).

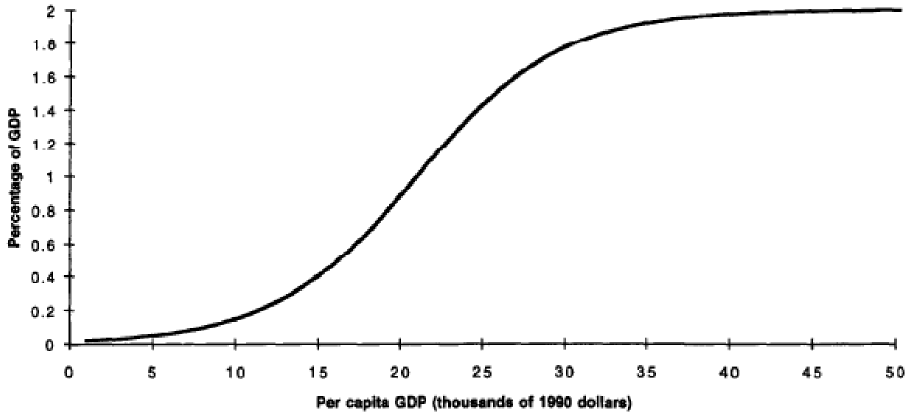


Table 2.1 Damages in the MERGE model calibrated according to the method explained in Manne, Mendelsohn & Richels, 1995.

Increase in global average temperature from 1990	Market damage (% loss GDP, developed)	Market damage (% loss GDP, developing)	Non-market damage (% loss GDP, for developed country with $40,000 per capita income)
0	0.00	0.00	0.00
0.5	0.01	0.02	0.08
1	0.04	0.08	0.32
1.5	0.09	0.18	0.72
2.0	0.16	0.32	1.28
2.5	0.25	0.5	2.0
3.0	0.36	0.72	2.88
3.5	0.49	0.98	3.92
4.0	0.64	1.28	5.12
4.5	0.81	1.62	6.48
5.0	1.0	2.0	8.0

2.2 MERGE freely downloadable version (Manne, 2004)

Treatment of market-damages

Manne (2004) explains that in this version market damages are proportional to T rise ie $d_{2,r}$ is assumed to be 1. The calibration point is the same as in the original version.

The following "market damage multipliers" are used to determine the regional distribution of market impacts (Table 2.2)

Table 2.2 Market damage multipliers for GDP loss at a reference temperature in MERGE (Manne 2004)

Region	Multiplier
USA	0.0025
W Europe	0.0025
Japan	0.0025
Canada/New Zealand	0.0025
Eastern Europe/FSU	0.0025
China	0.005
India	0.005
OPEC	0.005
Rest of World	0.005

Treatment of non-market damages

Manne (2004) explains that the freely downloadable version of the model uses the same calibration point of a 2% loss in GDP for a 2.5C temperature rise in a developed country, but a different formulation of WTP than the earlier version.

In this version, instead of equation (3), two new parameters *hsx* and *catt* are used to define the WTP. An economic loss function (ELF) is calculated which represents the amount of consumption that society is willing to invest in avoiding non-market damages of climate change. In developed countries:

$$ELF(x) = [1 - (x/catt)^2]^{hsx} \qquad (4)$$

where *hsx* =1 in developed countries. ELF is the remaining consumption such that ELF(2.5)=0.98.

Where *x* is the increase in temperature rise since 2000, *catt* is a catastrophic temperature chosen such that the entire regional product is wiped out at this level, and hsx modifies the quadratic loss function so as to allow for a hockey-stick shape.

For consistency with a willingness to pay of 2% of GDP, such that ELF(2.5) = 0.98, a catt value of 17.7C is implied.

In low income countries *hsx* << 1 and is chosen such that for a per capita income of $25,000 a region would be willing to spend 1% of its GDP so as to avoid a global temperature rise of 2.5C. If per capita income reached $50,000 or above, a value of 2% GDP is considered appropriate.

Figure 2.3 shows the resultant ELFs for the USA and India.

Manne (2004) emphasizes that the values of *catt* and *hsx* are highly speculative, and that with different numerical values one can attain different estimates of the WTP to avoid non-market damages. The general principle that WTP is higher in high income countries however, seems defensible whilst a specific calculation is questionable.

In both versions when damages across regions are combined the resultant economic welfare figures are combined by calculating their discounted logarithms and using Negishi weights which are an instrument to account for disparities in economic development (Nordhaus and Yang, 1996).

Figure 2.3 Economic Loss Functions for the USA and India

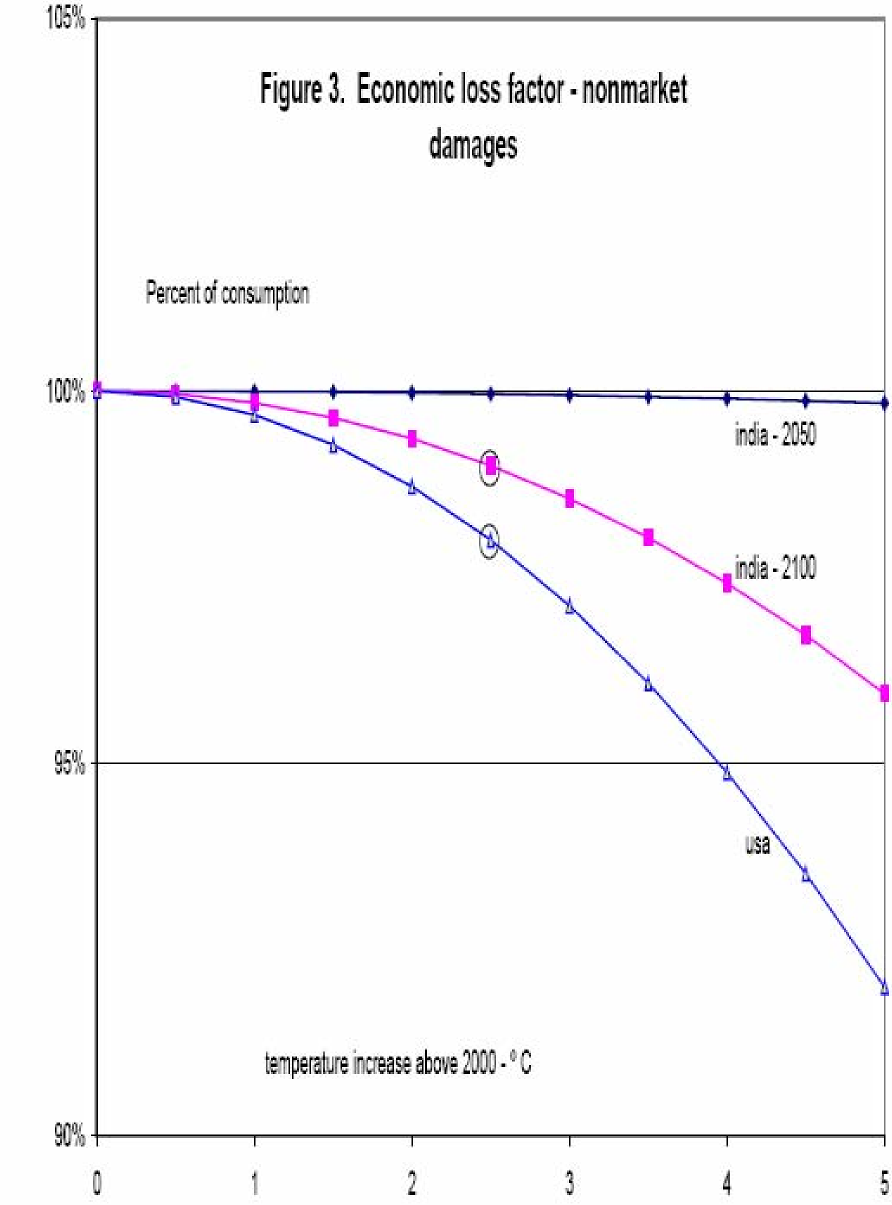


Figure 3. Economic loss factor - nonmarket damages
Percent of consumption
105%
100%
95%
90%
india - 2050
india - 2100
usa
temperature increase above 2000 - ° C
0
1
2
3
4
5

Table 2.3 Damages in the MERGE model calibrated according to the method explained in Manne, 2004.

Increase in global average temperature from 1990	Market damage (% loss GDP, developed)	Market damage (% loss GDP, developing)	Non-market damage (% loss GDP, for developed country)
0	0.00	0.00	0.00
0.5	0.01	0.02	0.08
1	0.04	0.08	0.32
1.5	0.09	0.18	0.72
2.0	0.16	0.32	1.28
2.5	0.25	0.5	1.99
3.0	0.36	0.72	2.87
3.5	0.49	0.98	3.91
4.0	0.64	1.28	5.11
4.5	0.81	1.62	6.46
5.0	1.0	2.0	7.98
6.0			11.49
7.0			15.64
10.0			31.92
17.0			92.25
17.7			100.00

Outputs

Tables 2.1 and 2.3 show global damages simulated in the two versions of the MERGE model described here, and the proportions from market and non-market impacts. It has already been observed that non-market impacts may be larger than market impacts.

When the model is used for cost-benefit analysis, in the 1995 version the default assumptions show that for stabilisation at 415 ppmv CO2 the costs outweight benefits by 8:1 with the 5% discount rate applied. If consumers were willing to pay 17% GDP to avoid non-market damages the model shows benefits equalling costs. If more optimistic assumptions are made about costs or the discount rate is lowered to 2% then the break even WTP falls to to 2.5%.

Such results show the importance of the discount rate: if one adopts a real annual discount rate of 5% of more the present value is virtually negligible for impacts that lie at least 50 years into the future, so within a cost-benefit framework, even if one allows a gradual rise in the relative value of environmental goods it becomes exceedingly difficult to justify any near term mitigation action.

Manne & Stephan (2005) make the interesting observation that their derivation of optimal emission reduction (which they call the Pareto-efficient stock of atmospheric carbon) is independent of the initial distribution of emissions rights (i.e. different ideas about initial allocation of permits for emissions trading) when market damages are considered in

MERGE. However when non-market damages are considered, if there is an income effect on the willingness to pay to avoid non-market damages, the different values that different regions place on avoiding damage can interact with the initial distribution of emission rights, so that different optima would be arrived at for different initial distributions. It is explained that in the Pareto-optimal case, nonmarket damages enter the Negishi welfare definition, and market damages represent one of the competing claims on the allocation of total production resources. In all other cases, non-market and market damages are excluded from the determination of the equilibrium, but are determined in a post-optimization step. In this way, a representation of the possibility for non-cooperation or of non-optimal international control agreements is allowed for.

3. PAGE

PAGE, Policy Analysis of the Greenhouse Effect, uses relatively simple equations to simulate the effects of different policies for mitigation of and adaptation to climate change. The main outputs are equity-weighted impacts, calculated as $million, which can then be divided by regional or global GDP outside the model if desired. These calculations approximate the results of more complex simulations through calibration of key model parameters to the outputs in the literature. Most parameter values are taken from the IPCC Third Assessment Report. PAGE is set up in a probabilistic spreadsheet format which enables the user to carry out extensive sensitivity analysis of outputs such as the social cost of carbon to the input assumptions. The model simulates (i) emissions of the primary greenhouse gases (ii) the resultant increase in radiative forcing (iii) cooling from sulphate aerosols (iv) regional temperature changes (v) damage caused by warming to market and non-market sectors, taking account of non-linearity (vi) the potential for a discontinuity in the climate damages caused by catastrophic rapid change (vii) regional economic growth, allowing impacts to be evaluated in terms of an annual % loss of GDP in each region (viii) the potential for adaptation to climate change. Detailed model equations may be found in Hope (2006). Regional temperature rise is calculated by a very simple formulation of radiative forcing, sulphate aerosol forcing and carbon cycle feedback which has uncertain parameters that are varied strongly in the model to allow for uncertainties. To derive social costs of carbon from the model the user must compare two very similar policies or emissions scenarios in which the second has 1 billion tons less of C than the first. The spreadsheet model then automatically computes the differences in damages for the two policies to generate the marginal benefits of reduced carbon emissions.

Damage functions in Page

Market and non-market impacts in each region are not calculated physically but in terms of GDP losses, and are an uncertain power function of temperature rise. The uncertain functional form is then calibrated with a benchmark estimate of impacts from the literature when mean temperature rises by 2.5C over pre-industrial. Each regional impact is then multiplied by a weighting factor. Impact parameters in PAGE 2002, the most recent version of PAGE, are given in Table 3.1a below.

The following sectors only are considered in PAGE:
Sector 1: Economic
Sector 2: Non-economic
Sector 3: Discontinuity impacts

More specifically, the impact functions (for sectors 1 and 2 in all regions) take the form of a polynomial

$$I(r) = A(r)T^{n(r)}$$

where n is an uncertain variable whose minimum, most likely and maximum values are taken as 1, 1.3 and 3 respectively, and r is an index specifying region. Plambeck and Hope (1997) explain (section 2.6) that the mean value taken from the expert survey of Fankhauser (1994), who in turn takes it from Cline (1992), which is a study based on estimates of climate impacts in the USA for CO2 doubling and recommends that further studies should include detail of other countries. Cline derived the exponent's value of 1.3 from estimates of the annual damage from warming to the US 1990 economy. Aggregate damage was estimated at $335.7 billion for a 10C warming, compared to 61.6 billion for 2.5C warming (above 1900). Cline recommended that future studies should take into account explicit studies of the situation in other countries. The range of 1 to 3 for the exponent is taken from Peck & Teisberg (1992) in their simulation of damage in the CETA integrated model. Cline is now of the opinion that the exponent 1.3 needs to be revised upwards (pers. comm.)

The sum of economic and non-economic impacts is modeled to lie between a 2% reduction in GDP and a 0.1% increase in GDP for a 2.5C temperature rise, consistent with IPCC TAR Table 19.4, page 940 figures for world impacts, reproduced below as Table 3.1b.

Discontinuity impacts represent damages due to rapid climate change events such as collapse of the THC, or other very large earth system changes. These have been estimated to be an order of magnitude greater than the impacts from continuous change, an estimation broadly consistent with IPCC TAR WGII p947. The chance of a large-scale discontinuity is estimated to be zero until temperatures reach between 2 and 8C (most likely 5C) above pre-industrial (hence 1.5 to 7.5, mean 4.5, above 1990 temperatures since PAGE models a 0.5C difference between pre-industrial temperatures and those of 2000). Beyond this the risks increase by 1 to 20% (most likely 10%) for each subsequent 1C rise in temperature. Damages from discontinuities comprise about 15% of today's social cost of carbon, a percentage that will rise in the future as we get closer to the time that discontinuities are likely to occur .

Weights are used to monetize the above impacts to allow for comparison and aggregation across economic and non-economic sectors. The weights used are the % of GDP lost for benchmark warming of 2.5C in each impact sector in the focus region (the EU); multiplicative weights are used to express the % of GDP lost for benchmark warming of 2.5C in other regions. They are chosen to be consistent with IPCC TAR WGII, page 940 and involved a large amount of expert judgement to encompass the various studies covered by IPCC (see Tables 3.1a, 3.1b).

PAGE considers 8 world regions: European Union, Latin America, Eastern Europe & former Soviet Union; USA; China & CP Asia; India & SE Asia; Africa & Middle East; and Other OECD (which includes Canada, Japan and Australia).

Table 3.1a. Impact parameters in PAGE 2002, version 1.4

PAGE 2002 Impact Parameter	Mean	Min	Mode	Max	Metric (where relevant)
Impact function exponent	1.77	1	1.3	3	
Economic impact	0.5	-0.1	0.6	1	%GDP loss for 2.5 degC
Non-econ impact	0.73	0	0.7	1.5	%GDP loss for 2.5 degC
Loss if discontinuity occurs	11.67	5	10	20	%GDP
Eastern Europe and former Soviet Union weights factor	-0.35	-1	-0.25	0.2	
USA weights factor	0.25	0	0.25	0.5	
China and E Asia weights factor	0.2	0	0.1	0.5	
India and S Asia weights factor	2.5	1.5	2	4	
Africa weights factor	1.83	1	1.5	3	
Latin America weights factor	1.83	1	1.5	3	
Other OECD weights factor Canada Aus Japan NZ	0.25	0	0.25	0.5	

Table 3.1b *(taken from Table 19.4 IPCC TAR):* Indicative world impacts, by region (% of current GDP). Estimates are incomplete, and confidence in individual numbers is very low. There is a considerable range of uncertainty around estimates. Tol's (1999) estimated standard deviations are lower bounds to real uncertainty. Figures are expressed as impacts on a society with today's economic structure, population, laws, etc. Mendelsohn et al. (2000) estimates denote impact on a future economy. Positive numbers denote benefits; negative numbers denote costs (Pearce et al., 1996; Tol, 1999a; Mendelsohn et al., 2000; Nordhaus & Boyer, 2000).

	IPCC SAR	**Mendelsohn et al.**		**Nordhaus and Boyer**	**Tol**
	2.5°C Warming	1.5°C Warming	2.5°C Warming	2.5°C Warming	1°C Warming[a]
North America					3.4 (1.2)
United States			0.3	-0.5	
OECD Europe					3.7 (2.2)
- EU				-2.8	
OECD Pacific					1.0 (1.1)
- Japan			-0.1	-0.5	
E. Europe/FSU					2.0 (3.8)
- Eastern Europe				-0.7	
- Russia			11.1	0.7	
Middle East				-2.0[b]	1.1 (2.2)
Latin America					-0.1 (0.6)
- Brazil			-1.4		
S & SE Asia					-1.7 (1.1)
- India			-2.0	-4.9	
China			1.8	-0.2	2.1 (5.0)[c]
Africa				-3.9	-4.1 (2.2)
Developed countries	-1.0 to -1.5	0.12	0.03		
Developing countries	-2.0 to -9.0	0.05	-0.17		
World					
- Output weighted	-1.5 to -2.0	0.09	0.1	-1.5	2.3 (1.0)
- Population weighted				-1.9	
- At world average prices					-2.7 (0.8)
- Equity weighted					0.2 (1.3)

[a] Figures in brackets denote standard deviations.
[b] High-income countries in Organization of Petroleum Exporting countries (OPEC).
[c] China, Laos, North Korea, Vietnam

Treatment of Adaptation

Impacts are modelled to occur for each of the three sectors (market, non-market and discontinuity) and regions, above some time-dependant profile of tolerable region-specific and sector-specific temperature rise. In the absence of adaptation the tolerable temperature rise is assumed to be zero at all times in the market and non-market sectors.

The user can "buy" different amounts of adaptation in different sectors and regions in different time periods. Figure 3.1 shows a conceptual PAGE damage function (curve Actual). The user can influence (a) the tolerable level of temperature rise (b) the tolerable rate of temperature rise or (c) the reduction in damage if the temperature does rise beyond what is tolerable. The model can thus be tuned for different assumptions about the dates and amount of adaptation in each year, region and sector. Thus adaptation is modeled both to affect the date/temperature changes at which an onset of impacts begins, and also to reduce the severity of impacts once they begin.

Figure 3.1 shows how (a) and (b) are modeled within PAGE. The figure shows temperature-time space, and the red line shows the actual temperature rise from an emissions scenario. The blue curve shows the situation if the user of the model purchases adaptation of types (a) and (b). In the example shown adaptation is purchased increasingly between 2000 and 2020, which is sufficient to stave off climate impacts in this particular sector and region until 2050, after which impacts begin to accrue. Figure 3.2 shows how the user can simulate the purchase of adaptation to reduce the impacts which still eventually accrue after adaptation of types (a) and (b) has been purchased. In the example shown the additional purchase reduces impacts by a percentage that increases linearly between 2010 and 2040. There are, however, limits to adaptation and hence not more than 60% of the impacts can be avoided, in this example.

In version 1.4 of PAGE2002, adaptation is a policy which may be selected, so there is no probabilistic treatment. The user may purchase different amounts of adaptation in different regions, but there is a default set of parameters which were derived from CRU/ERL (1992), and in PAGE the assessment therein of adaptive capacity in the EU was extrapolated to the OECD and used as the default case in version 1.4. At this time adaptation was considered economically advantageous and hence this large amount of adaptation was used as a default. In other developing regions adaptive capacity is considered to be smaller. The default set of parameters (Table 3.2) offsets 33% of the climate impacts without adaptation in scenario A2.

Table 3.2: Parameters for the default adaptation case with 25% cut in non-economic impacts. "Slope" and "plateau" may be found in Figure 3.1, "impact" as % reduction in Figure 3.2.

Adaptation	**2001**	**2002**	**2010**	**2020**	**2040**	**2060**	**2080**	**2100**	**2150**	**2200**	
EU Economic slope	1	1	1	1	1	1	1	1	1	1	°C/dec
EE Economic slope	1	1	1	1	1	1	1	1	1	1	°C/dec
US Economic slope	1	1	1	1	1	1	1	1	1	1	°C/dec
CA Economic slope	0	0	0	0	0	0	0	0	0	0	°C/dec
IA Economic slope	0	0	0	0	0	0	0	0	0	0	°C/dec
AF Economic slope	0	0	0	0	0	0	0	0	0	0	°C/dec
LA Economic slope	0	0	0	0	0	0	0	0	0	0	°C/dec
OT Economic slope	1	1	1	1	1	1	1	1	1	1	°C/dec
EU Economic plateau	2	2	2	2	2	2	2	2	2	2	°C
EE Economic plateau	2	2	2	2	2	2	2	2	2	2	°C
US Economic plateau	2	2	2	2	2	2	2	2	2	2	°C
CAEconomic plateau	0	0	0	0	0	0	0	0	0	0	°C
IA Economic plateau	0	0	0	0	0	0	0	0	0	0	°C
AF Economic plateau	0	0	0	0	0	0	0	0	0	0	°C
LA Economic plateau	0	0	0	0	0	0	0	0	0	0	°C
OT Economic plateau	2	2	2	2	2	2	2	2	2	2	°C
EU Economic impact	18	54	90	90	90	90	90	90	90	90	%
EE Economic impact	18	54	90	90	90	90	90	90	90	90	%
US Economic impact	18	54	90	90	90	90	90	90	90	90	%
CA Economic impact	10	30	50	50	50	50	50	50	50	50	%
IA Economic impact	10	30	50	50	50	50	50	50	50	50	%
AF Economic impact	10	30	50	50	50	50	50	50	50	50	%
LA Economic impact	10	30	50	50	50	50	50	50	50	50	%
OT Economic impact	18	54	90	90	90	90	90	90	90	90	%
EU Non-econ slope	0	0	0	0	0	0	0	0	0	0	°C/dec
EE Non-econ slope	0	0	0	0	0	0	0	0	0	0	°C/dec
US Non-econ slope	0	0	0	0	0	0	0	0	0	0	°C/dec
CA Non-econ slope	0	0	0	0	0	0	0	0	0	0	°C/dec
IA Non-econ slope	0	0	0	0	0	0	0	0	0	0	°C/dec
AF Non-econ slope	0	0	0	0	0	0	0	0	0	0	°C/dec
LA Non-econ slope	0	0	0	0	0	0	0	0	0	0	°C/dec
OT Non-econ slope	0	0	0	0	0	0	0	0	0	0	°C/dec
EU Non-econ plateau	0	0	0	0	0	0	0	0	0	0	°C
EE Non-econ plateau	0	0	0	0	0	0	0	0	0	0	°C
US Non-econ plateau	0	0	0	0	0	0	0	0	0	0	°C
CA Non-econ plateau	0	0	0	0	0	0	0	0	0	0	°C
IA Non-econ plateau	0	0	0	0	0	0	0	0	0	0	°C
AF Non-econ plateau	0	0	0	0	0	0	0	0	0	0	°C
LA Non-econ plateau	0	0	0	0	0	0	0	0	0	0	°C
OT Non-econ plateau	0	0	0	0	0	0	0	0	0	0	°C
EU Non-econ impact	25	25	25	25	25	25	25	25	25	25	%
EE Non-econ impact	25	25	25	25	25	25	25	25	25	25	%
US Non-econ impact	25	25	25	25	25	25	25	25	25	25	%
CA Non-econ impact	25	25	25	25	25	25	25	25	25	25	%
IA Non-econ impact	25	25	25	25	25	25	25	25	25	25	%
AF Non-econ impact	25	25	25	25	25	25	25	25	25	25	%
LA Non-econ impact	25	25	25	25	25	25	25	25	25	25	%
OT Non-econ impact	25	25	25	25	25	25	25	25	25	25	%

Treatment of adaptation costs

Adaptation costs do not affect the computed value of the social cost of carbon in PAGE, as a marginal reduction in emissions is assumed not to affect the amount of adaptation performed. The model estimates adaptation costs using a set of uncertain parameters CS(d,0), CP(d,0), and CI(d,0) in sector d and region 0, reflecting the cost per unit increment of the slope, plateau and impact options described above. Costs in other regions are obtained through multiplication by a multiplicative cost factor for each region, CF(r) which is identical for slope, plateau, and impact whether economic or non-economic sectors are considered.

The total adaptive costs AC(i,d,r) for sector d in region r for time period i are then obtained by:
AC(i,d,r) = CS(d,r)*SLOPE(i,d,r) + CP(d,r)*PLAT(i,d,r) + CI(d,r)*IMP(i,d,r)
for i=timesclice or analysis period, d= sector (there are two), r=region (there are 8).

The accumulated adaptive costs AAC(i,d,r) are aggegated using:
AAC(i.d.r)=AC(i,d,r)*(Yhi(i)-Ylo(i))
where Yhi(i) and Tlo(i) are the start and end of each analysis period i.

and then discounted over time using the same discount rate as the model uses for costs. Default adaptation costs (Table 3.3) are calibrated to CRU/ERL (1992).

Table 3.3. Default adaptation cost parameters.

PAGE2002	version	1.4epu								
Adaptive cost parameters	Economic slope	Economic plateau	Economic impacts	Non-econ slope	Non-econ plateau	Non-econ impacts				
	CS_1	CP_1	CI_1	CS_2	CP_2	CI_2				
EU	0.01	13333	173	0.01	0.01	0.01				
EE	0.001	1333	17	0.001	0.001	0.001				
US	0.005	6667	87	0.005	0.005	0.005				
CA	0.0052	6933	90	0.0052	0.0052	0.0052				
IA	0.0052	6933	90	0.0052	0.0052	0.0052				
AF	0.0052	6933	90	0.0052	0.0052	0.0052				
LA	0.0052	6933	90	0.0052	0.0052	0.0052				
OT	0.002	2667	35	0.002	0.002	0.002				
	$million /°C/dec	$million per °C	$million per %	$million /°C/dec	$million per °C	$million per %				
2000	2001	2002	2010	2020	2040	2060	2080	2100	2150	2200
Analysis period	1	1	8	10	20	20	20	20	50	50
Yhi	2002	2006	2015	2030	2050	2070	2090	2125	2175	2200
Ylo	2000	2002	2006	2015	2030	2050	2070	2090	2125	2175
Aggregation period	2	5	9	15	20	20	20	35	50	25

Figure 3.1. How adaptation shapes damage functions in PAGE.

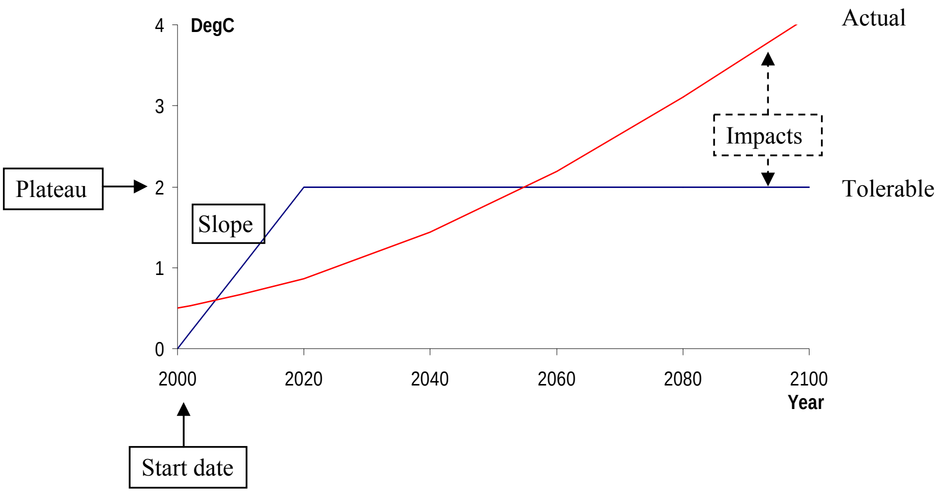
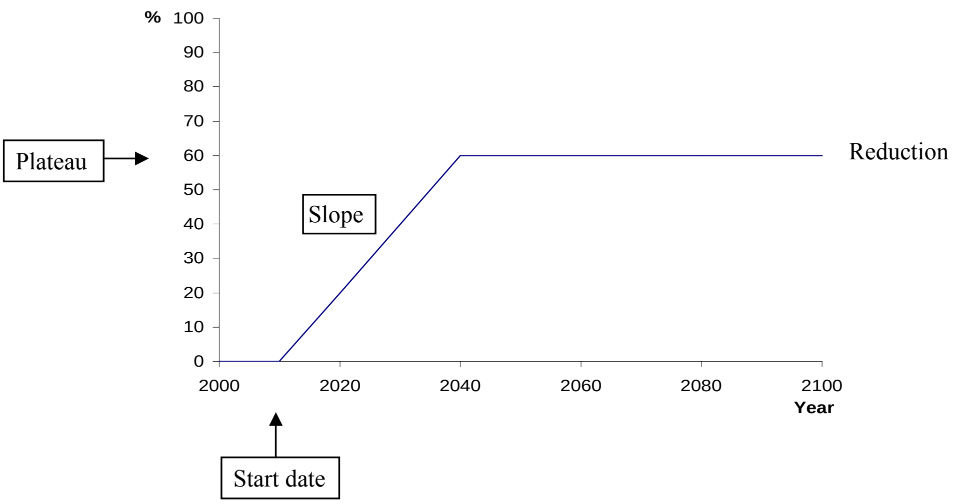


Figure 3.2.



Discount rate

The discount rate in PAGE, which is applied to all financially valued quantities, and is therefore key in influencing how damages are treated in the model is derived from

$$d = p + e * g$$

where p is the pure rate of time preference, e is the negative of the elasticity of marginal utility with respect to income, and g is the per capita GDP growth rate. Thus in the year 2000 the discount rate is close to 4% and by 2100 it is close to 5%, because the population growth rate slows more than the GDP growth rate does. This discount rate formula is applied to all regions, so different regions can have different values of d.

Input parameters used in this study

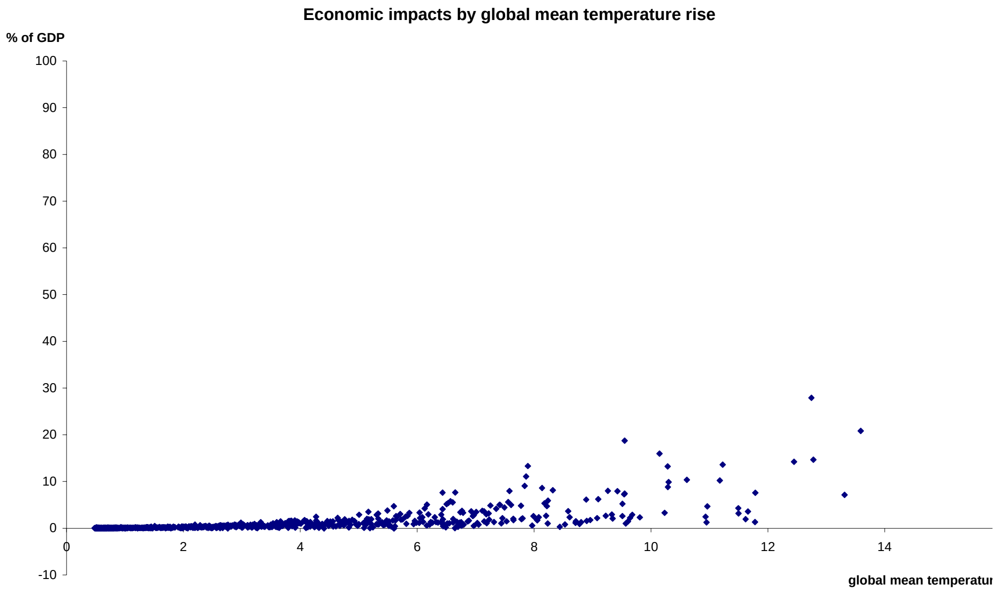
The version of PAGE used in this study is v1.4, which utilizes a probabilistic pure time preference rate and equity weight parameters[7]. The inputs detailed here are those which gave a mean SCC of $43 per tC, and a 5 to 95% range of $7 to $128, including a pure time preference rate in the range of 1% to 3% per year, and an equity weight parameter (the negative of the elasticity of marginal utility with respect to income) in the range of 0.5 to 1.5, as reported in Chris Hope's evidence to the Stern review. Apart from the PTP rate and the equity weight parameters, for both of which triangular probability distribution functions are assumed, the input values are identical to those documented in tables 1 to 6 of Hope, 2006. The GDP growth rates are those of SRES Scenario A2, converted to PPP exchange rates (in Hope, 2006, the GDP growth rates were expressed in market exchange rates). Population and emissions are also input to the model to represent the scenario A2. (There is no economic module: emissions are an input).

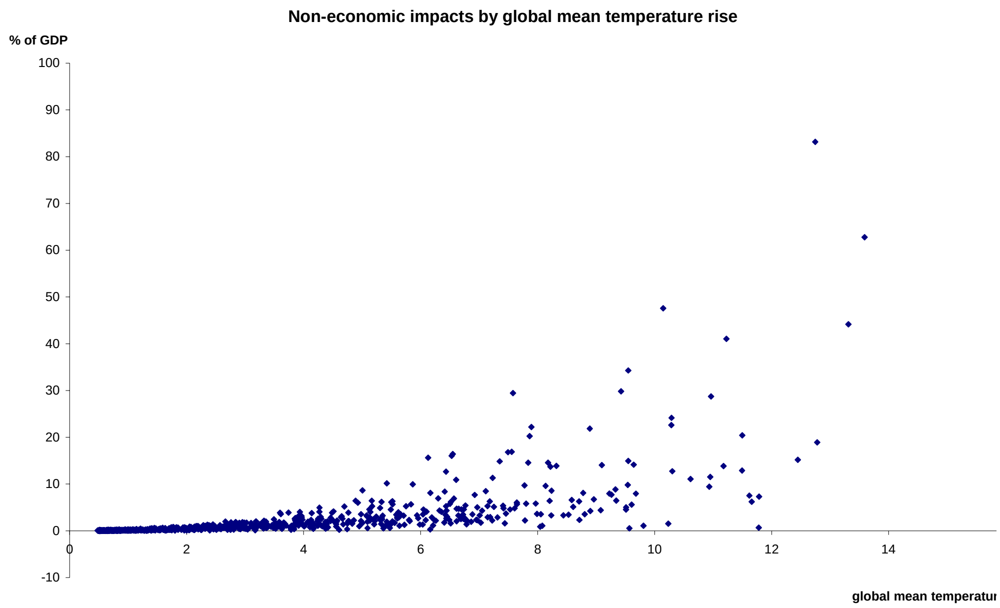
Outputs from PAGE

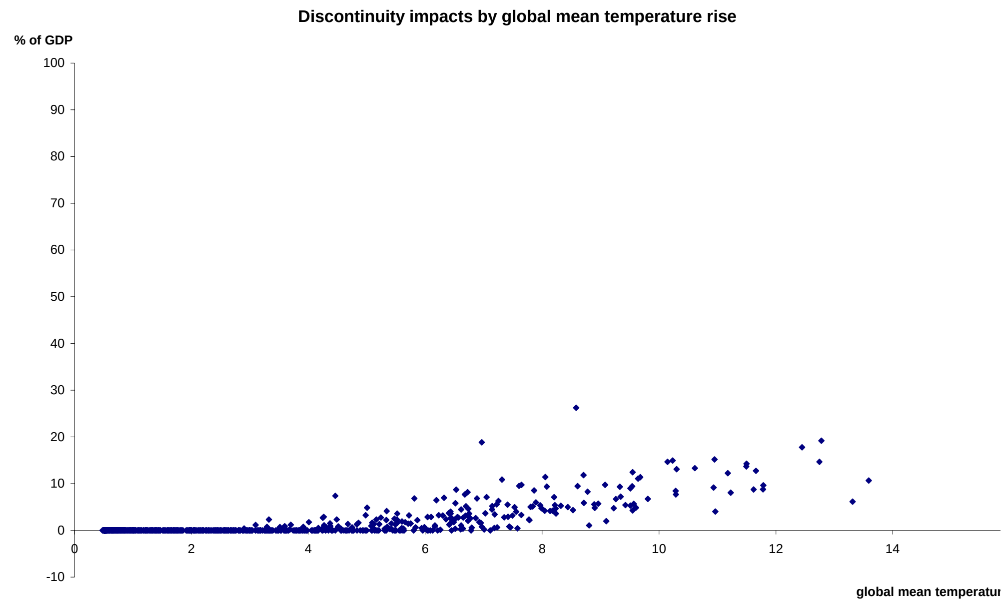
The main outputs are equity-weighted impacts, calculated as $million, which can then be divided by regional or global GDP outside the model. Figure 3.3 shows simulated global damages as a function of temperature increase for the three sectors for the globe as a whole, expressed in terms of both %GDP and in $$million (year 2000).

[7] This model version thus does not match exactly the version used in Hope (2002) where PPP is not used consistently throughout the model. The only other version of PAGE which is used currently is the Green book which has declining discount rates taken from the Treasury Green Book which has single value declining discount rates.

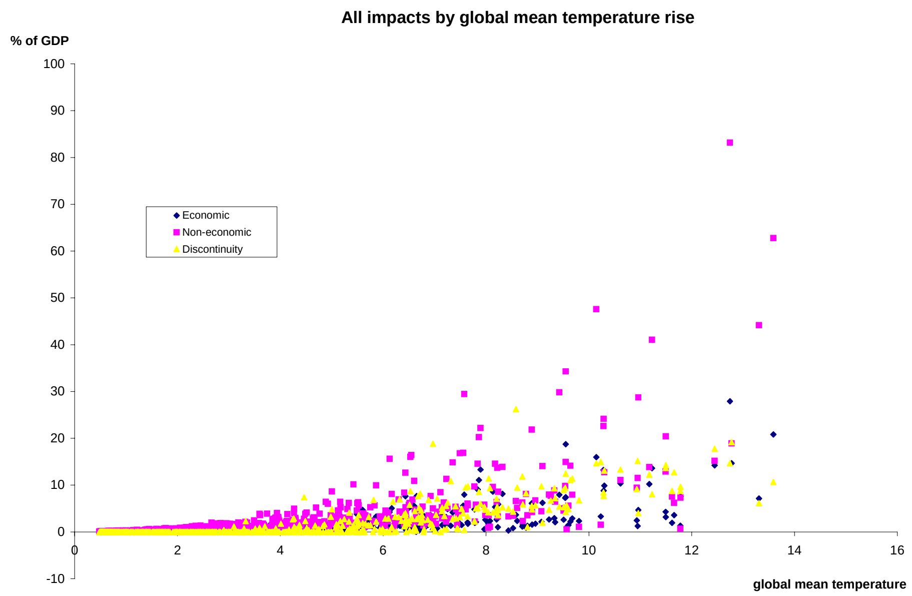
Figure 3.3


Economic impacts by global mean temperature rise
% of GDP
100
90
80
70
60
50
40
30
20
10
0
-10
0
2
4
6
8
10
12
14
global mean temperatur

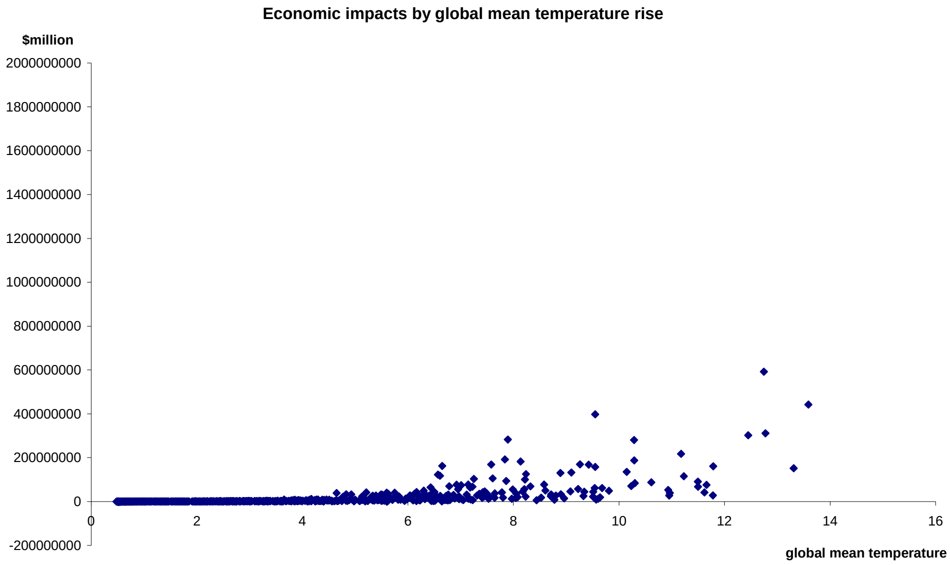

Non-economic impacts by global mean temperature rise
% of GDP
100
90
80
70
60
50
40
30
20
10
0
-10
0
2
4
6
8
10
12
14
global mean temperatur



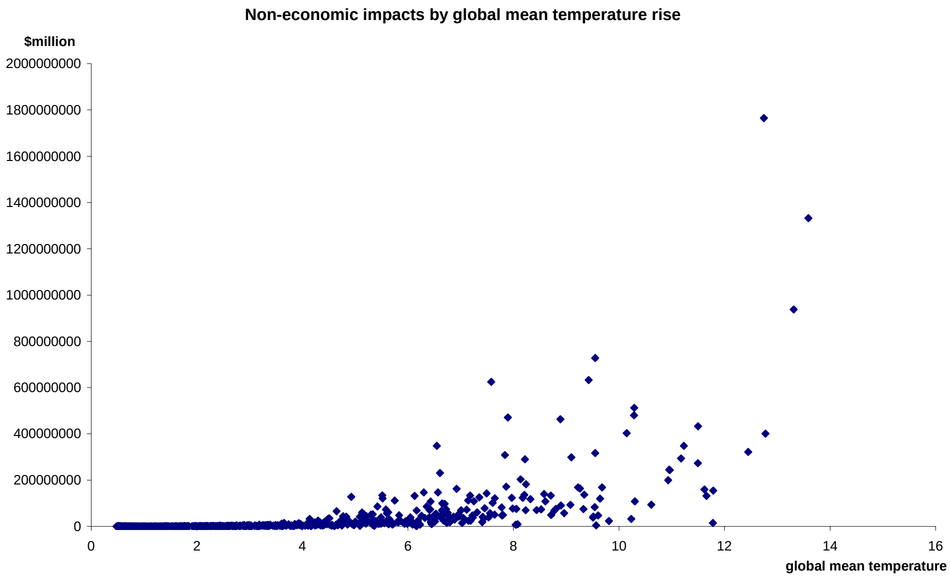
Source: PAGE2002 model runs



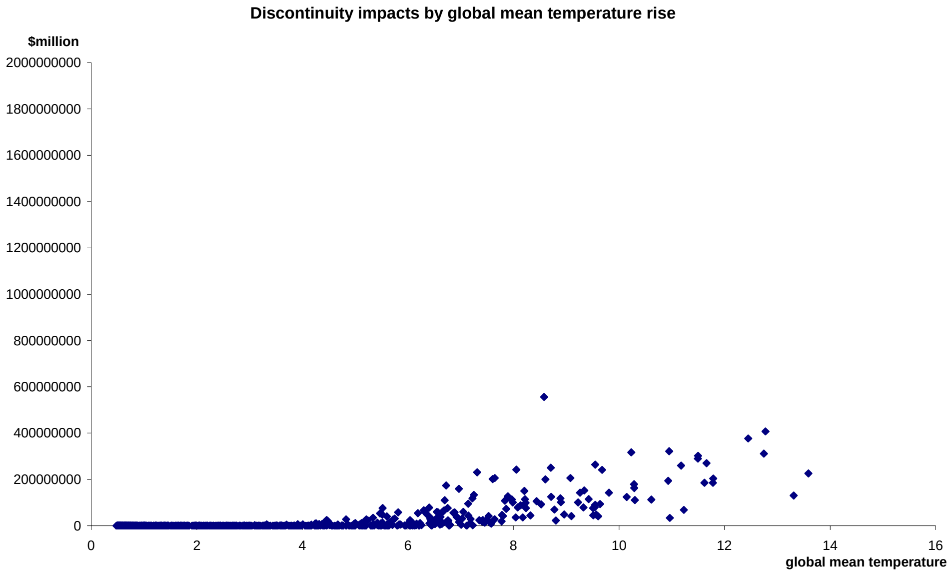
Source: PAGE2002 model runs



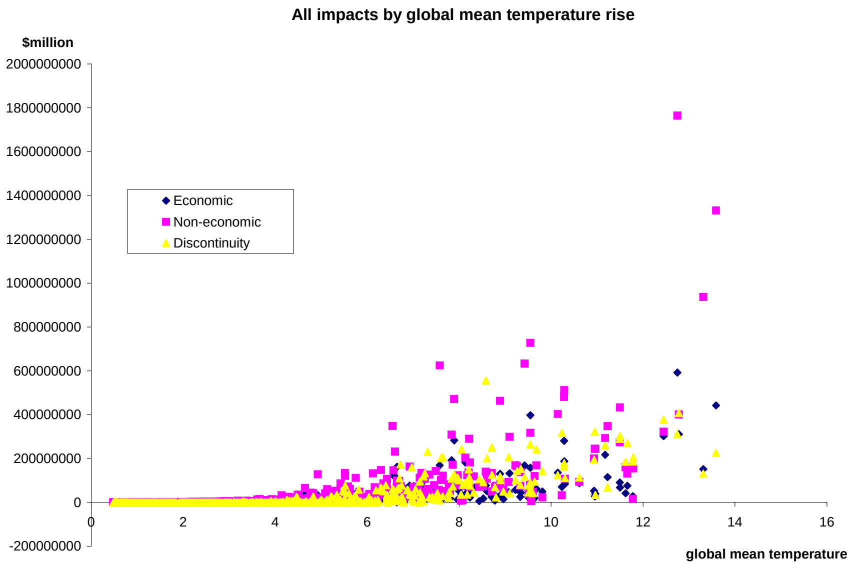
Source: PAGE2002 model runs



Source: PAGE2002 model runs



Source: PAGE2002 model runs



Source: PAGE2002 model runs

Tables A3.1a to A3.8b of Annex 1 show corresponding regional information for different time periods. In each table 'min' is the 5% value and 'max' the 95% value on the output probability distribution.

Since the outputs are equity-weighted, very occasionally (eg the 95% value for total impacts in India in 2150 and 2200), the impacts can come out as more than 100% of GDP; the equity weights in India are still around 3 in 2150 and 2200, so an actual impact of, say, 40% of GDP would be recorded as 120% of GDP after equity weighting.

In one or two cases (eg EU in 2060), both the 5% and 95% values for the discontinuity are 0, but the mean value is not zero ($870million for the EU in 2060). This is because the threshold temperature for a discontinuity to be possible has very occasionally been reached, but only in fewer than 5% of the runs.

The 5% and mean values are negative (ie benefits) in the EE region for all three of the impact categories. This is a consequence of only having a single weights factor for each region, which is applied to all three of the impacts. For EE, this factor has a negative mean value.

The top of the y axis for each of the graphs is $2000 trillion. Global GDP is under $50 trillion in 2000, but under scenario A2 rises to $340 trillion by 2100, and over $2100 trillion by 2200 (in $US 2000).

Temperature is an output of the PAGE2002 model, and is probabilistic like all other outputs. Therefore it is noted in the tables as a probability distribution for each year in each region. In the graphs, output from 100 runs of the model was post-processed to match up 1000 values for each of the three impacts with 1000 values for the temperatures (100 values for each of 10 analysis years).

4. FUND

THE CLIMATE FRAMEWORK FOR UNCERTAINTY, NEGOTIATION AND DISTRIBUTION, TECHNICAL DESCRIPTION, VERSION 2.9

Resolution

FUND2.9 is defined for 16 regions, specified in Table A4.1 of the Annex 2. The model runs from 1950 to 2300 in time-steps of a year.

Population and income

Population and per capita income follow exogenous scenarios. There are five standard scenarios (FUND, A1B, A2, B1 and B2), specified in Tables A4.2a-e and A4.3a-e.

Emission, abatement and costs

Carbon dioxide (CO_2)

Carbon dioxide emissions are calculated on the basis of the Kaya identity:

(CO2.1) $$M_{r,t} = \frac{M_{r,t}}{E_{r,t}} \frac{E_{r,t}}{Y_{r,t}} \frac{Y_{r,t}}{P_{r,t}} P_{r,t} =: \psi_{r,t}\varphi_{r,t}Y_{r,t}$$

where M denotes emissions, E denote energy use, Y denotes GPD and P denotes population; t is the index for time, r for region. The carbon intensity of energy use, and the energy intensity of production follow from:

(CO2.2) $$\psi_{r,t} = g^{\psi}_{r,t-1}\psi_{r,t-1} - \alpha\tau^{\psi}_{r,t-1}$$

and

(CO2.3) $$\varphi_{r,t} = g^{\varphi}_{r,t-1}\varphi_{r,t-1} - \alpha\tau^{\varphi}_{r,t-1}$$

where τ is policy intervention and α is a parameter. The exogenous growth rates g are referred to as the Autonomous Energy Efficiency Improvement (AEEI) and the Autonomous Carbon Efficiency Improvement (ACEI); see Tables A4.4a-e and A4.5a-e for each scenario. Policy also affects emissions via

(CO2.1’) $$M_{r,t} = \left(\psi_{r,t} - \chi^{\psi}_{r,t}\right)\left(\varphi_{r,t} - \chi^{\varphi}_{r,t}\right)Y_{r,t}$$

(CO2.4) $$\chi^{\psi}_{r,t} = \kappa_{\psi}\chi_{r,t-1} + (1-\alpha)\tau^{\psi}_{r,t-1}$$

and

(CO2.5) $$\chi^{\varphi}_{r,t} = \kappa_{\varphi}\chi_{r,t-1} + (1-\alpha)\tau^{\varphi}_{r,t-1}$$

Thus, the parameter $0<\alpha<1$ governs which part of emission reduction is *permanent* (reducing carbon and energy intensities at all future times) and which part of emission reduction is *temporary* (reducing current energy consumptions and carbon emissions), fading at a rate of

$0<\kappa<1$. In the base case, α=0.5, $\kappa_\psi=\kappa_\varphi$=0.9. Alternatively, one may interpret the difference between permanent and temporary emission reduction as affecting commercial technologies and capital stocks, respectively. The emission reduction module is a reduced form way of modelling that part of the emission reduction fades away after the policy intervention is reversed, but that another part remains through technological lock-in. Learning effects are described below.

The costs of emission reduction C are given by

(CO2.6) $$\frac{C_{r,t}}{Y_{r,t}} = \frac{\beta_{r,t}\tau_{r,t}^2}{H_{r,t}H_t^g}$$

H denotes the stock of knowledge. Equation (CO2.6) gives the costs of emission reduction in a particular year for emission reduction in that year. In combination with Equations (CO2.2)-(CO2.5), emission reduction is cheaper if smeared out over a longer time period. The parameter β follows from

(CO2.7) $$\beta_{r,t} = 1.57 - 0.17\sqrt{\frac{M_{r,t}}{Y_{r,t}} - \min_s \frac{M_{s,t}}{Y_{s,t}}}$$

That is, emission reduction is relatively expensive for the region that has the lowest emission intensity. The calibration is such that a 10% emission reduction cut in 2003 would cost 1.57% (1.38%) of GDP of the least (most) carbon-intensive region, and a 80% (85%) emission reduction would completely ruin its economy; later emission reductions are cheaper by Equations (CO2.6) and (CO2.7). Emission reduction is relatively cheap for regions with high emission intensities. The thought is that emission reduction is cheap in countries that use a lot of energy and rely heavily on fossil fuels, while other countries use less energy and less fossil fuels and are therefore closer to the technological frontier of emission abatement. For relatively small emission reduction, the costs in *FUND* correspond closely to those reported by other top-down models, but for higher emission reduction, *FUND* finds higher costs, because *FUND* does not include backstop technologies, that is, a carbon-free energy supply that is available in unlimited quantities at fixed average costs.

The regional and global knowledge stocks follow from

(CO2.8) $$H_{r,t} = H_{r,t-1}\sqrt{1+\gamma_R\tau_{r,t-1}}$$

and

(CO2.9) $$H_t^G = H_{t-1}^G\sqrt{1+\gamma_G\tau_{r,t}}$$

Knowledge accumulates with emission abatement. More knowledge implies lower emission reduction costs. Equations (CO2.6) and (CO2.8) together constitute learning by doing. The parameters γ determines which part of the knowledge is kept within the region, and which part spills over to other regions as well. In the base case, γ_R=0.9 and γ_G=0.1. Note that, although there is learning by doing – Equations (CO2.8) and (CO2.9) – technology diffusion – Equation (CO2.7) – as well as permanent effects of emission reduction on the growth path of the economy – Equations (CO2.2) and (CO2.3) – the model does assume that policy interventions are always costly, and that larger interventions are more costly.

Emissions from land use change and deforestation are exogenous, and cannot be mitigated. Numbers are found in Tables A4.6a-e.

Methane (CH_4)

Methane emissions are exogenous, specified in Table A4.7a. Note that there is no distinction between scenarios. Parameters for the emission reduction of methane are given in Table A4.7b.

Nitrous oxide (N_2O)

Nitrous oxide emissions are exogenous, specified in Table A4.8. Note that there is no distinction between scenarios. Parameters for the emission reduction of methane are given in Table A4.8b.

Sulfurhexafluoride (SF_6)

SF_6 emissions are linear in GDP and GDP per capita. Table A4.9 gives the parameters. The numbers for 1990 and 1995 are estimated from IEA data.

Sulphur dioxide (SO_2)

Sulphur dioxide emissions follow grow with population (elasticity 0.33), fall with per capita income (elasticity 0.45), and fall with the sum of energy efficiency improvements and decarbonisation (elasticity 1.02). The parameters are estimated on the IMAGE scenarios.

Atmosphere and climate

Concentrations

Methane, nitrous oxide and sulphur hexafluoride are taken up in the atmosphere, and then geometrically depleted:

(C.1) $$C_t = C_{t-1} + \alpha E_t - \beta\left(C_{t-1} - C_{pre}\right)$$

where C denotes concentration, E emissions, t year, and *pre* pre-industrial. Table A4.10 displays the parameters α and β for all gases.

The atmospheric concentration of carbon dioxide follows from a five-box model:

(C.2a) $$Box_{i,t} = \rho_i Box_{i,t} + 0.000471 \alpha_i E_t$$

with

(C.2b) $$C_t = \sum_{i=1}^{5} \alpha_i Box_{i,t}$$

where α_i denotes the fraction of emissions E (in million metric tonnes of carbon) that is allocated to *Box i* (0.13, 0.20, 0.32, 0.25 and 0.10, respectively) and ρ the decay-rate of the boxes (ρ = exp(-1/lifetime), with life-times infinity, 363, 74, 17 and 2 years, respectively). The model is due to Maier-Reimer and Hasselmann (1987), its parameters are due to Hammitt *et al.* (1992). Thus, 13% of total emissions remains forever in the atmosphere, while 10% is—on average—removed in two years. Carbon dioxide concentrations are measured in parts per million by volume.

For sulphur, emissions are used rather than concentrations.

Radiative forcing

Radiative forcing is specified as follows:

$$RF_t = 6.3\ln\left(\frac{CO_2}{275}\right) + 0.036\sqrt{CH_4 - 790} + 0.14\sqrt{N_2O - 285} -$$

(C.3) $$2\cdot 0.47\ln\left(1 + 2.01\cdot 10^{-5} CH_4^{0.75} N_2O^{0.75} + 5.31\cdot 10^{-15} CH_4^{2.52} N_2O^{1.52}\right) +$$

$$0.00052(SF_6 - 0.04) - 0.03\frac{SO_2}{14.6} - 0.08\frac{\ln\left(1 + S/34.4\right)}{\ln\left(1 + 14.6/34.4\right)}$$

Temperature and sea level rise

The global mean temperature *T* is governed by a geometric build-up to its equilibrium (determined by radiative forcing *RF*), with a half-time of 50 years. In the base case, global mean temperature *T* rises in equilibrium by 2.5°C for a doubling of carbon dioxide equivalents, so:

(C.4) $$T_t = \left(1 - \frac{1}{50}\right) T_{t-1} + \frac{1}{50}\frac{2.5}{6.3\ln(2)} RF_t$$

Global mean sea level is also geometric, with its equilibrium level determined by the temperature and a life-time of 50 years. Temperature and sea level are calibrated to the best guess temperature and sea level for the IS92a scenario of Kattenberg *et al.* (1996).

Impacts

There follows a detailed description of how FUND simulates climate damages in key sectors, specifying the mathematical form assumed in each sector, and the parameters used to calibrate these. The accompanying Table 4.1 summarises the sources of some of these key parameters.

Agriculture

For the impact of the rate of climate change on agriculture, the assumed model is:

(A.1) $$A_{t,r}^r = \alpha_r \left(\frac{\Delta T_t}{0.04}\right)^\beta + \rho A_{t-1,r}^r$$

a^r denotes the change in agricultural production due the rate of climate change (see Table A4.11); *t* denotes time; *r* denotes region; ΔT denotes the change in the global mean temperature; α is a parameter, denoting the benchmark change in agricultural production (cf. Table 1); β = 2.0 (1.5-2.5) is a parameter, denoting the non-linearity of the reaction to temperature; ρ=10 (5-15) is a parameter, denoting the speed of adaptation.

The model for the impact due to the level of climate change is:

(A.2) $A^{l}_{t,r} = \frac{-2A^{B}_{r}T^{opt}_{r}}{1-2T^{opt}_{r}}T_{t} + \frac{A^{B}_{r}}{1-2T^{opt}_{r}}T^{2}_{t}$

A^l denotes the change in agricultural production due to the level of climate change; *t* denotes time; *r* denotes region; *T* denotes the change in global mean temperature relative to 1990; A^B is a parameter, denoting the benchmark change in agricultural production (cf. Table A4.11); T^{opt} is a parameter, denoting the optimal temperature (cf. Table A4.11). It is derived from Darwin *et al* 1995, Reilly *et al* 1994, and Rosenzweig and Parry (1994) by regressing the change in agricultural production after adaptation upon the change in global mean temperature and its square, as described in Tol (2002b).

CO2 fertilisation has a positive, but saturating effect on agriculture, specified by

(A.3) $A^{f}_{t,r} = \gamma_{r} \ln\left(\frac{CO_{2,t}}{275}\right)$

A^f denotes the change in agricultural production due to the CO2 fertilisation; *t* denotes time; *r* denotes region; *T* denotes the atmospheric concentration of carbon dioxide; 275 ppm is the pre-industrial concentration; γ is a parameter, see Table A4.11.

The share of agricultural production in total income falls with per capita income. The elasticity across the nine regions is -0.31. So,

(A.4) $\frac{GAP_{t,r}}{Y_{t,r}} = \frac{GAP_{1990,r}}{Y_{1990,r}}\left(\frac{y_{1990,r}}{y_{t,r}}\right)^{\varepsilon}$

GAP denotes gross agricultural product; *Y* denotes gross domestic product; *y* denotes gross domestic product per capita; *t* denotes times; *r* denotes regions; ε = 0.31 (0.15-0.45) is a parameter.

Forestry

The model is:

(F.1) $F_{t,r} = \alpha_{r}\left(\frac{y_{t,r}}{y_{1990,r}}\right)^{\varepsilon}\left(0.5T^{\beta}_{t} + 0.5\gamma \ln\left(\frac{CO_{2,t}}{275}\right)\right)$

where *F* denotes the change in forestry consumer and producer surplus (as a share of total income); *t* denotes time; *r* denotes region; *y* denotes per capita income; *T* denotes the global mean temperature; α is a parameter; see Table A4.12; ε = 0.31 (0.11-0.51) is a parameter; β = 1 (0.5-1.5) is a parameter; γ = 0.44 (0.29-0.87) is a parameter; γ is such that a doubling of the atmospheric concentration of carbon dioxide would lead to a change of forest value of 15%.

Water resources

Earlier versions of *FUND* incorrectly assumed that water technologies are constant. *FUND*'s impact estimates are based on Downing *et al.* (1995, 1996), and they also assume that there is no technological change in water. In reality, however, there are considerable improvements, both for water supply (e.g., desalinisation) and water demand (e.g., drip irrigation). In the revised impacts module, we assume that water technology progress by 0.5% a year, with a standard deviation of 0.5%. This manifests itself in that the sensitivity of the water sector to climate change falls by 0.5% a year.

The impact of climate change on water resources follows:

$$(\text{W.1})\, W_{r,t} = \alpha_r (1-\tau)^{t-1990} \left(\frac{Y_{r,t}}{Y_{r,1990}} \right)^{\beta} T_t^{\gamma}$$

where *W* denotes the change in water resources, expressed in billion dollars; *t* denotes time; *r* denotes region; *Y* denotes income; *T* denotes the global mean temperature; α is a parameter, the benchmark estimate; see Table A4.12; β = 0.85 (0.70 - 1.00) is a parameter; γ = 1 (0.5-1.5) is a parameter; τ = 0.005 (0.000-0.010) is a parameter.

Energy consumption

FUND's impact estimates for energy consumption are based on Downing *et al.* (1995, 1996). As Downing *et al.* do not provide details on the functional form, earlier versions of FUND assume that the demand for heating decreases linearly with temperature, while the demand for cooling increases linearly. There is obviously a limit to the savings on heating, whereas the additional demand for cooling may actually rise faster than linearly. Therefore, cooling energy demand is assumed to rise with temperature to the power 1.5, and heating energy demand is assumed to fall with the square root of temperature.

Downing *et al.* is itself based on a UK model relating energy used for heating or cooling to degree days, per capita income, and energy efficiency. Downing *et al.* derived the economic impacts from energy price scenarios and extrapolated these to the rest of the world.

For space heating, the model is:

$$(\text{E.1})\;\; SH_{t,r} = a_r T_t^{\beta} \left(\frac{y_{t,r}}{y_{t,1990}} \right)^{\varepsilon} \left(\frac{P_{t,r}}{P_{t,1990}} \right) \prod_{s=1990}^{t} AEEI_{s,r}$$

SH denotes the amount of money spent less on space heating; *t* denotes time; *r* denotes region; *T* denotes the change in the global mean temperature relative to 1990; *y* denotes per capita income; *P* denotes population size; α is a parameter; cf. Table A4.12; β is a parameter; β = 1 (0.5-1.5); ε is a parameter; ε = 0.8 (0.6-1.0); *AEEI* is a parameter (Tables A4.4a-e); it is about 1% per year in 1990, converging to 0.2% in 2200; its standard deviation is set at a quarter of the mean.

For space cooling, the model is:

$$(\text{E.2})\;\; SC_{t,r} = a_r T_t^{\beta} \left(\frac{y_{t,r}}{y_{t,1990}} \right)^{\varepsilon} \left(\frac{P_{t,r}}{P_{t,1990}} \right) \prod_{s=1990}^{t} AEEI_{s,r}$$

SC denotes the amount of money spent additionally on space cooling; *t* denotes time; *r* denotes region; *T* denotes the change in the global mean temperature relative to 1990; *y* denotes per capita income; *P* denotes population size; α is a parameter; cf. Table A4.12; β is a parameter; β = 1 (0.5-1.5); ε is a parameter; ε = 0.8 (0.6-1.0); *AEEI* is a parameter (Tables A4.4a-e).

Sea level rise

Dry- and wetlands become inundated by rising waters, and are lost unless protected. Costs, then, are the costs of the degree of protection selected, plus the value of lost drylands and wetlands. Protection of the drylands also results in additional losses to wetlands. Figure A4.1 illustrates these relationships. The total land lost to sea level rise is provided by wetlands lost, dryland not protected, and additional wetlands lost due to protection efforts for drylands.

As populated drylands are lost, the people living there must emigrate, incurring costs to them, plus costs to the region to which the displaced people immigrate.

Table A4.13 shows the accumulated loss of drylands and wetlands for a one metre rise in sea level. Land loss is assumed to be a linear function of sea level rise. The value of dryland is assumed to be linear in income density ($/km^2), with an average value of $4 million per square kilometre for the OECD. Wetland value follows: is assumed to be logistic in per capita income, with an:

(SLR.1) $$V_{t,r} = \alpha \frac{y_{t,r}/30{,}000}{1 + y_{t,r}/30{,}000} \max\left(2{,}1 - \sigma + \sigma \frac{L_{\max,r}}{L_{\max,r} - L_{t,r}}\right)$$

where V is wetland value; y is per capita income; L is the wetland lost to date; $L_{\max}$ is a parameter, given the maximum amount of wetland that can be lost to sea level rise; α is a parameter such that the average value for the OECD is $5 million per square kilometre; and σ=0.05 is a parameter.

If dryland gets lost, the people living there are forced to move. The number of forced migrants follows from the amount of land lost and the average population density in the region. The value of this is set at three times the regional per capita income per migrant. In the receiving country, costs equal 40% of per capita income per migrant. The costs of emigration for the first year of emigration are set to an arbitrary 0.3 times the per capita income but these costs continue over time, declining at a rate of 7% annually. Immigration costs are set to 40% of the income per capita in the region and decline by 33% annually.

Immigration due to sea level rise is estimated by applying the immigration ratios from Table A4.14 of the Annex. The majority of the people stay within their regions but some inter-regional migration is estimated with the trend being emigration to developed economies. Table A4.14 displays the estimates of migration from one region to another, a small fraction of the total number of people estimated to be displaced. Inter-regional emigration estimates follow from multiplying the number of people who emigrate when one person is displaced by SLR (a fraction) times the average population density times the regional dryland loss.

Table A4.13 displays the annual costs of fully protecting all coasts against a one metre sea level rise in a hundred years time. If sea level would rise slower, annual costs are assumed to be proportionally lower.

The level of protection, that is, the share of the coastline protected, depends on the annualized capital costs of shoreline protection, and is based on a cost-benefit analysis:

(SLR.2) $$L = \min\left\{0{,}1 - \frac{1}{2}\left(\frac{PC + WL}{DL}\right)\right\}$$

L is the fraction of the coastline to be protected and is selected so that (1 minus the fraction) is proportional to (protection costs plus the value of secondary loss of adjacent wetlands) divided by (the value of the dryland potentially lost with half the dryland protected where this proportion is one) after Fankhauser (1994b). If a piece of dryland is protected fully, no dryland services will be forgone but the costs of protection will be high and the adjacent wetland may be inundated. This means that FUND is selecting an adaptive policy which in turn determines the impacts of sea level rise in the output.

PC is the net present value of the protection if the whole coast is protected.

Table A4.13 reports average costs per year over the next century. *PC* is calculated assuming annual costs to be constant. This is based on the following. Firstly, the coastal protection decision makers anticipate a linear sea level rise. Secondly, coastal protection entails large infrastructural works which last for decades. Thirdly, the considered costs are direct investments only, and technologies for coastal protection are mature. Throughout the analysis, a pure rate of time preference, ρ, of 1% per year is used. The actual discount rate lies thus 1% above the growth rate of the economy, *g*. The net present costs of protection *PC* thus equal

$$\text{(SLR.3)}\quad PC = \sum_{t=1}^{\infty}\left(\frac{1}{1+\rho+g}\right)^{t} PC_a = \frac{1+\rho+g}{\rho+g} PC_a$$

where PC_a is the average annual costs of protection.

WL is the net present value of the wetlands lost due to full coastal protection. Land values are assumed constant, reflecting how much current decision makers care about the non-marketed services and goods that get lost. The amount of wetland lost is assumed to increase linearly over time. The net present costs of wetland loss *WL* follow from

$$\text{(SLR.4)}\quad WL = \sum_{t=0}^{\infty} t\left(\frac{1}{1+\rho+g}\right)^{t} WL_0 = \frac{1+\rho+g}{(\rho+g)^2} WL_0$$

where WL_0 denotes the value of wetland loss in the first year.

DL denotes the net present value of the dryland lost if no protection takes place. Land values are assumed to rise at the same pace as the economy grows. The amount of dryland lost is assumed to increase linearly over time. The net present costs of dryland loss *DL* are

$$\text{(SLR.5)}\quad DL = \sum_{t=0}^{\infty} t\left(\frac{1}{1+\rho+g}\right)^{t} DL_0 = \frac{(1+g)(1+\rho+g)}{\rho^2} DL_0$$

where DL_0 is the value of dryland loss in the first year.

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Ecosystems

Tol (1999) assesses the impact of climate change on ecosystems, biodiversity, species, landscape *etcetera* based on the "warm-glow" effect. Essentially, the value people are assumed to place on such impacts are independent of any real change in ecosystems *etcetera*. This values is specified as

$$\text{(E.1)} \quad \frac{E_{t,r}}{Y_{t,r}} = \alpha P_{t,r} \frac{y_{t,r}/y_b}{1 + y_{t,r}/y_b} \frac{\Delta T_{t,r}/\tau}{1 + \Delta T_{t,r}/\tau} \left(1 - \sigma + \sigma \frac{B_0}{B_t}\right)$$

where E denotes the value of the loss of ecosystems; t denotes time; r denotes region; Y denotes GDP; y denotes per capita income; P denotes population size; ΔT denotes the change in regional temperature; B is the number of species; α is a parameter such that E equals \$50 per person if per capita income equals the OECD average in 1990; y_b = \$30,000 is a parameter; τ=0.025 is a parameter; σ=0.05 is a parameter; and B_0=14,000,000 is a parameter.

The number of species follows

$$\text{(E.2)} \quad B_t = B_{t-1}\left(1 - \rho - \gamma \Delta T_{t-1}^2\right)$$

where ρ = 0.003 is a parameter; and γ = 0.625 is a parameter.

Human health: Diarrhoea

The number of additional diarrhoea deaths D^d is given by

$$\text{(HD)} \quad D_{r,t}^d = \mu_r^d P_{r,t} \left(\frac{y_{r,t}}{y_{r,0}}\right)^{\varepsilon} \left(T_{r,t}^{\eta} - T_{r,0}^{\eta}\right)$$

where P denotes population, y per capita income, and T regional temperature; μ is the mortality in 1995, ε=-1.58 (0.23) and η=1.14 (with a standard deviation of 0.51) are parameters; r indexes region, and t time. Equation (HD) was estimated based on the WHO Global Burden of Diseases data.[8] Diarrhoea morbidity has the same equation as mortality, but with ε=-0.42 (0.12) and η=0.70 (0.26). Table A4.15 gives impact estimates, ignoring economic and population growth.

Human health: Vector-borne diseases

The model for vector-borne diseases is:

$$\text{(HV)} \quad m_{r,t,d} = m_{r,1990,d} \alpha_{r,d} \left(T_t - T_{1990}\right)^{\beta} \left(\frac{y_{t,r}}{y_{1990,r}}\right)^{\gamma}$$

m denotes mortality (see Table A4.16); t denotes time; r denotes regions; d denotes disease; α is a parameter, the benchmark impact of climate change on vector-borne diseases; see Table A4.16; y denotes per capita income; T denotes the change in the global mean temperature relative to 1990; β=1 (0.5) and γ=-2.65 (0.69) are parameters.

[8] http://www.who.int/health_topics/global_burden_of_disease/en/

Mortality is valued at 200 times the per capita income, with a standard deviation of 100.

Morbidity is proportional to mortality, using the factor specified in Table A4.21. Morbidity is valued at 80% of per capita income per year of illness, with a standard deviation of 1.

Cardiovascular and respiratory mortality

Cardiovascular and respiratory disorders are worsened by both extreme cold and extreme hot weather. Martens (1998) assesses the increase in mortality for 17 countries. Tol (1999) extrapolates these findings to all other countries, based on formulae of the shape:

(HC.1) $$\Delta M_d = \alpha_d + \beta_d T_B$$

where ΔM denotes the change in mortality due to a one degree global warming; T_B is the current temperature in the country; and α and β are parameters, given in Table A4.17. Equation (HC.1) is specified for populations above and below 65 years of age for cardiovascular disorders. Cardiovascular mortality is affected by both heat and cold. In the case of heat, T_B denotes the average temperature of the warmest month. In the case of cold, T_B denotes the average temperature of the coldest month. Respiratory mortality is not age-specific.

Equation (HC.1) is readily extrapolated. If warming exceeds one degree, the baseline temperature T_B changes. If this change is proportional to the change in the global mean temperature, the equation becomes quadratic. Summing country-specific quadratic functions results in quadratic functions for the regions:

(HC.2) $$\Delta M_{r,d} = \alpha_{r,d} T + \beta_{r,d} T^2$$

where T denotes the change in global mean temperature; α and β are parameters, specified in Tables A4.18-A4.20.

One problem with (HC.2) is that it is a non-linear extrapolation based on a data-set that is limited to 17 countries and, more importantly, a single climate change scenario. A global warming of 1°C leads to changes in cardiovascular and respiratory mortality in the order of magnitude of 1% of baseline mortality due to such disorders. Per cause, the total change in mortality is restricted to a maximum of 5% of baseline mortality. (This restriction is binding.) Baseline cardiovascular and respiratory mortality derives from the share of the population above 65 in the total population.

If the fraction of people over 65 increases by 1%, cardiovascular mortality increases by 0.0259% (0.0096%). For respiratory mortality, the change is 0.0016% (0.0005%). These parameters are estimated from the variation in population above 65 and cardiovascular and respiratory mortality over the nine regions in 1990.

Mortality as in equations (HC.1) and (HC.2) is expressed as a fraction of population size. Cardiovascular mortality, however, is separately specified for younger and older people. In 1990, the per capita income elasticity of the share of the population over 65 is 0.25 (0.08).

Heat-related mortality is assumed to be limited to urban populations. Urbanisation is a function of per capita income and population density:

(HC.3) $$U_t = \frac{\alpha\sqrt{y_t} + \beta\sqrt{PD_t}}{1 + \alpha\sqrt{y_t} + \beta\sqrt{PD_t}}$$

where U is the fraction of people living in cities, y is per capita income, PD is population density and t is time; α and β are parameters, estimated from national data for the year 1995; α=0.031 (0.002) and β=-0.011 (0.005); R^2=0.66.

Mortality is valued at 200 times the per capita income, with a standard deviation of 100.

Morbidity is proportional to mortality, using the factor specified in Table A4.21. Morbidity is valued at 80% of per capita income per year of illness, with a standard deviation of 1.

Table 4.1 Sources of parameters used in FUND.

Sector	Formula and its source	Parameter	Value	Description in words	Source parameter	Where within source	Key assumptions
Agri-culture	Rate of change (A.1)	α_r	Table A columns 2 and 3 give regional breakdown	Rate of change of ag. prod. due to rate of cc	Based on assumptions about how the results underlying Darwin et al (1995), Reilly et al (1994), Rosenzweig and Parry (1994) would change with and without adaptation (Tol 2002b)		The effects of adaptation: these are not in the underlying literature, which itself includes adaptation assumptions
		β	An estimate (no reference) and is not regionally specific	Non-linearity of reaction to temperature			
		ρ	1/p =10 (range 5 – 15) Also estimated, and not regionally specific	Speed of adaptation			
	Level of climate change (A.2)	A_r^B	Table A cols 4 and 5 give regional breakdown	Benchmark change in agricultural production	Regression analysis of Darwin et al (1995), Reilly et al (1994), Rosenzweig and Parry (1994)		Quadratic equation assumed to which literature fitted;
		T^{opt}	Table A gives regional breakdown	Optimal temperature	Tol 2002a, b		
	Carbon	γ	Table A gives	Carbon	Tol 2002a, b		

	dioxide fertilization (A.3)		regional breakdown	dioxide fertilization factor			
	Agricultural production (A.4)	$GAP_{1990,r}$ $Y_{1990,r}$		Gross ag. prod. and GDP in 1990			
		ε	0.31 (0.15-0.45)	Elasticity			
Forestry	Forestry consumer and producer surplus (F1)	α_r	Table EFW cols 2 and 3	Benchmark estimate			
		β					
		γ	0.44 (0.29-0.87)		Set so that a doubling of [CO2] leads to a change in forest value of 15%		
Water	Change in water resources (W.1)	α_r	Table EFW cols	Benchmark estimate	Downing 1995, 1996,		assume water tech progress by 0.5%/year (s.d. 0.5%) hencese5ns of water to cc falls by 0.5%/year (previous vs assumed no tech change)
		β	0.85 (0.11-0.51)				
		γ	1.0 (0.5-1.5)				
		τ	0.005 (0.000-0.010)				
Energy	Space heating/cooling (E.1 and E.2)	α_r	Table EFW cols 6-9	Benchmark estimates	Downing et al. 1995, 1996		
		β	1 (0.5-1.5)				
		ε	0.8(0.6-1.0)				
		$AEEI_{s,r}$	Table AEEI.FUND Tables AEE1.A1B, AEEI.A2, AEEI.B1 AEEI.B2	Autonomous energy efficiency improvement in years s and region r			

Sea Level Rise	Dryland value proportional to GDP per square kilometre		$4 million/km2 in 1990 (average across globe)	Dryland value	Fankauser (1994)		
	Wetland value (SLR.1)	α	Calibrated such that average OECD wetland value is $2 million /km2 in 1990 with logistic relation to per capita income	Wetland value	Source of OECD $2 m/sq km in 1990 is Fankhauser 1994c		
		σ	0.05				
		$Y_{t,r}$	Available from SRES?				
		$L_{max,r}$	Database of wetland area in each country?	Maximum amount of wetland that can be lost to sea level rise	Source is Hoozemans et al (1993)		
	Share of coastline protected (SLR.2) Cost-benefit calculation following Fankhauser 1994c		Cost-benefit in each region separately		Costs from Tol 1999 (same as Tol 2002a which follows partly from Bijlsma et al 1996, Hoozemans et al. 1993 and Fankhauser 1994c)		Wetland and dryland loss are assumed to be linear with sea level rise in absence of protection
	NPV of protection cost (SLR.3)	PC_a	Calculated within model for each year or 1990 value taken from current data?	Average annual protection costs	Unit dike costs from Hoozemans et al. 1993		Costs are linear with dike height
		ρ	1%/year	Pure rate of time preference			
		g	Different in regions or not? And by SRES?	Growth rate of economy			
	NPV wetland and dryland loss (SLR.4 and 5)	WL_0 and DL_0		Value of wetland lost in first year	Derived from losses for 1m sea level rise reported in Hoozemand et al (1993)		
Ecosys	Value of lost	α	Calibrated such that		Tol 1999,		

Comment [rjn1]: Fankhauser, S. (1994), 'Protection vs. Retreat -- The Economic Costs of Sea Level Rise', *Environment and Planning A*, **27**, 299-319.

tem	ecosystem (E1)		value E is $50/per person if pc income = OCED 1990 mean.		2002a.		
		σ	0.05				
		τ	0.025				
		Y_b	$30,000				
	Number of species (E2)	ρ	0.003				
		γ	0.625				
Human health	Diarrhoea mortality/m orbidity (H1)	ε	-1.5/-0.42 (s.d. 0.23,0.12)		WHO burden disease data (ref 3 [1] http://www.who.int/health_topics/global_burden_of_disease/en/)		
		η	1.14/0.7 (s.d.0.51,0.26)		As above		
	Vector borne disease mortality/m orbidity(HV)	$\alpha_{r,d}$	How derived? From bnchmrks?				
		β	1 (s.d. 0.5)				
		γ	-2.65 (s.d. 0.65)				
	Valuation of life		200 times per capita income (s.d. 100)	v.o.s.l.			
	Valuation of morbidity		80% of p.c. income annually (s.d. 1)				
	Cardiovascu lar mortality (HC.1)	α		Table HC1	Tol 1999		
		β		Table HC1			
	Cardiovascu lar mortality regional (HC.2)	α_r		Tables HC2-4	17 country data-set and 1 climate scenario		Cannot exceed 5% baseline mortality derived from popn>65
		β_r		Tables HC2-4			
	Heat-related mortality (HC.3)	U(t)		Fraction living in cities.			Assumes limited to urban pops
		PD(t)		Table **			
		α	0.031 (s.d. 0.002)		Estimated from national data from 1995		
		β	-0.011 s.d. 0.005)				

Damage Functions Extracted From FUND

The FUND spreadsheet model described above was used to simulate the 4 SRES scenarios, A1, A2, B1 and B2. For each SRES scenario a graph was produced showing how global impacts accrue with temperature. Damages in the FUND model are provided as outputs in monetized form only for the years 2000-2100, so graphs may show damages in US$ or in %GDP (Figures A4.2a-A4.3b). These graphs were disaggregated (using FUND) to show how damage accrues globally and in each of the main sectors FUND includes (agriculture & forestry, sea level rise, ecosystems, water, energy and health) (Figures A4.2a,b) and in each of the regions considered in the parallel study "Understanding the Regional Impacts of Climate Change" (Figures A4.3a,b). Further disaggregation showing the impacts in each sector and region is shown in Figures A4.4a to A4.9b. Note that these graphs show impacts of climate change, so a positive value on the "damage" axis implies a benefit, and a negative value on the "damage" axis implies a disbenefit.

A global damage function extracted from the FUND model
Globally the FUND results show an initial small benefit to GDP from climate change, up to a temperature increase of approximately 0.5C above 1990 for all SRES scenarios, after which damages steadily accrue, reaching to between 1.2 and 2.7% global GDP for a 3 degree rise in temperature (Figure A4.2a, b), between 0.5-1.0% for a 2 degree rise above 1990, and 0-0.5% for a 2 degree rise above pre-industrial. These FUND damage estimates are broadly similar to those of DICE, although for the A1 scenario there are no damages for a temperature rise of 1.5C above 1990; whilst DICE shows that damages begin to accrue globally for a 1C rise above 1990.

Distribution of monetised impacts across sectors
Figure A4.2a shows that the energy sector almost totally dominates the calculation of impacts of climate change on global GDP out to 2100, and is responsible for most of the negative impacts, with the water sector playing a lesser role. This results from the assumed high growth rates of per capita income, the assumed high income elasticity of cooling energy, and the high temperatures in Africa, where in FUND air conditioning is simulated to be common by 2100.

In contrast, in FUND health shows a net benefit for all SRES scenarios until 2100, with the benefit slowly tailing off. Agriculture shows a small benefit to global GDP, again positive for all SRES scenarios out to 2100, slowly tailing off, and ecosystems a small disbenefit to global GDP for all SRES scenarios out to 2100.

The parallel project "Understanding the Regional Impacts of Climate Change" (URICC project, Warren *et al.* 2006) which describes climate impacts in each sector in different metrics, finds that ecosystems are the sector which experiences a very, if not the most, dramatic damage due to climate change. The difference between the impression given by this project and that of FUND is largely because the valuation process produces a different distribution of impacts than an examination of the distribution of physical changes resulting from climate change.

Distribution of impacts across SRES scenarios

Figures A4.2a-b and A4.3a-b show that for all sectors, the effects of given temperature rise may be very different depending on the socioeconomic scenario. These differences are not apparent in the RICE model because RICE's damage functions depend only on temperature and not upon socioeconomic data or rate of temperature change. The following gives the order of impact magnitude in each sector, starting with the scenario which has the lowest damage or highest benefit:

For a given temperature rise:
All sectors and regions combined: A1<B1<B2<A2
Energy: A1<B1<B2<A2
Health: A1<A2<B2<B1
Water: scenarios very close B2/B1/A1<A2
Agriculture/forestry: A2<B2<A1<B1
Coasts: scenarios very close
Ecosystems: A2<B2<B1<A1

It seems counter-intuitive that the high population scenario A2 shows smaller climate impacts on ecosystems for a given temperature rise than the low population scenario A1, but this is because the rate of change of temperature is faster in the FUND A1 scenario than in the FUND A2 scenario, and the FUND model for ecosystems does not take into account the effects of increased human populations upon land use and other resources.

Distribution of impacts (in terms of losses in regional GDP) across regions

Figures A4.3a-b show that the greatest impacts of climate change in all sectors combined, according to FUND, for a given temperature rise, will be in Africa, with the high population A2 and B2 scenarios having the worst effects at any given temperature. Here FUND and the URICC project are in agreement.

However, West Asia, North America and Europe are all modeled to benefit from climate change until temperature rises reach 3C above 1990 when impacts become negative in N America. South America, South Asia, Central America and Australasia all show negative impacts of climate change out to 2100 for all SRES scenarios. In E Asia the picture is more complex with benefits under scenarios A1 and B2 for smaller temperature increases and disbenefits for scenarios A2 and B1. In contrast, the URICC project finds many disbenefits in these regions between now and 2100.

Distribution of impacts across regions in each sector and comparison with URICC project results

(a) *Water*: In the water sector FUND shows disbenefits in all regions for all SRES scenarios through 2100 except East Asia where there are small benefits. The largest impacts in GDP terms are in Central Asia and N Africa. In the URICC project the largest impacts are in Africa, Asia, Europe and S America. In FUND there are small impacts only in W Africa, S Asia, Europe and S America. The two projects agree that N Africa is a badly affected area.

(b) *Agriculture & Forestry*: benefits occur through 2100 for all SRES scenarios in all regions except Australasia; the greatest benefits in GDP or monetized terms are in E Asia and these peak between 1 and 2C above 1990. The smallest benefits are in S America and C Asia.

In the URICC project there are in contrast strong disbenefits in the agriculture sector in many regions. Specifically, for wheat there are strong disbenefits in Africa and W Asia and smaller dis-benefits in C America, C Asia and E Asia. There are benefits in only Australasia, Europe and N America under the assumption of CO2 fertilisation. For maize URICC finds large disbenefits in North and Southern Africa; next affected are Central Asia, West Africa, South Asia and West Asia with significant losses still occurring under the assumption of CO2 fertilisation. Since maize is the dominant grain crop in most of Southern and West Africa, and there are losses even if CO2 fertilisation does occur, the anticipated yield losses here are a serious problem. Maize is also a dominant grain crop in much of Central America, South and North America. The situation in Southern and West Africa is also of concern, even under conditions of CO2 fertilisation. For rice yields URICC finds disbenefits in North and Southern Africa where reductions of 30-40% in yield could occur for temperature rises of 3-4C in the absence of CO2 fertilisation. The next most affected countries are Central Asia, West Africa and S America. However if CO2 fertilisation does occur, URICC finds global increases in yield of 1-2% occur between temperature rises of 2-3C for many regions, except Africa and Central Asia where losses still occur. At higher temperatures of 3-4C global reductions of around 3% in yield still occur as temperature effects dominate CO2 fertilisation. Rice is the dominant grain crop in S and E Asia, where the 10-20% potential losses in the absence of CO2 fertilisation are significant. It is also a dominant grain crop in much of Central and South America, and West Africa.

Hence the pictures painted for agriculture in URICC and FUND contrast markedly. This is because the underlying literature upon which the two simulations are based is very different: (i) URICC uses the Parry *et al.* results which examine he consequences of CO2 fertilisation being fully realized or not realized at all whilst FUND assumes a single level of quite strong CO2 fertilisation derived from an extrapolation from values given in Darwin *et al* 1995, Reilly *et al* 1994, and Rosenzweig and Parry (1994). (ii) The Parry *et al.* results assume that marginal land only is brought under cultivation, whilst Darwin *et al.* 1995 simulate successful cultivation of new land previously climatically unsuitable for cultivation as the world warms(i.e .a high level of adaptation). Darwin (2004) explored scenarios with and without this process included. (iii) Although Darwin *et al.* 1995 did not include CO2 fertilisation, Tol (2002a) use the outputs of this study through factoring in the effects of CO2 fertilisation in line with the other literature which included it. Similarly FUND is based on a calculation of what the results of the three studies would be both with and without adaptation (Tol 2002a) , and uses for FUND the case where, in the long term, adaptation is included. (iv) In FUND regionally optimal temperatures for agriculture are used, which are derived through regression of the results of the three studies assuming the formula given above. This means that FUND presents a full adaptation, strong CO2 fertilisation analysis of the impacts of climate change upon agriculture, whereas URICC's tables are describing literature which examines a range of outcomes for CO2 fertilisation and only the agricultural potential on existing land. Parry *et al.* do include a significant amount of adaptation on existing land, specifically that "level 0" adaptation is applied at zero cost at the farm level, by shifting planting dates and available crop varieties; "level 1" low cost adaptation is applied at the farm level by methods such as choice of crop, variety, planting date, and irrigation : this is assumed applied 100% in developed countries and 75% in developing countries; and "level 2" adaptation is applied in developed countries, involving some regional or national policy change resulting in major changes in planting dates, availability of new cultivars, extensive expansion of irrigation and increased fertilizer application (Parry 2005). These imply economic adjustments and are applied in developed countries only, based on current GDP. These large differences in model assumptions explain the discrepancy between the respective results.

(c) *Coasts*: Sea level rise causes disbenefits to all regions through 2100 for all SRES scenarios. The largest impacts in GDP terms are in W Africa, then S Asia and Australasia whilst in monetized terms the largest impacts are in the Americas. The URICC project finds the largest impacts in S and E Asia.

(d) *Energy:* In the energy sector the greatest impact (in million $$) is seen in North Africa. In fact the impacts in the energy sector are dominated by changes in developing countries. This follows from assumed high growth rates of per capita income, assumed high income elasticity, and the high temperatures predicted for Africa, implying that air conditioning will be common in Africa well before 2100. This means that the largest contribution to global climate change damages in FUND is the installation of air conditioning in developing countries, particularly Africa.

(e) *Health* In FUND Central and E Asia, North America and Europe show health benefits through 2100 for all SRES scenarios. In all other regions there are health disbenefits through 2100 for all SRES scenarios. The reason for the discrepancy is largely that in the richer parts of the world, cardiovascular and respiratory illness dominate infectious disease, whereas in the developing world the reverse is the case. The greatest benefits in GDP terms in FUND are in Central Asia, whilst the largest damages in GDP terms are in S and W Africa.

URICC also finds particular problems in Africa, but finds it less clear whether there are benefits or disbenefits in N America and Europe, since literature variously suggests that benefits due to reduced cold waves might, or might not, more than offset the disbenefits due to heat waves. The FUND analysis posits that reduced cold stress dominates increased heat stress. Also FUND does not include the large estimates of increased flood deaths predicted by WHO and included in the URICC report. Patz (2005) highlights also that temperate latitudes are particularly vulnerable in human health terms, due to heat stress caused by disproportionate warming compared to tropical regions. FUND also does not include indirect impacts of higher temperatures on health such as exacerbation of episodes of tropospheric ozone pollution or increased sensitivity of tissue to UV light. These differences in the literature underlying FUND compared to URICC account for the differences in the findings.

(f) *Ecosystems* In FUND ecosystems are negatively impacted by climate change through 2100 for all SRES scenarios in all regions. Impacts accrue strongly with both increase in temperature and increase in rate of temperature change, and in GDP terms are fairly evenly distributed across regions. In monetized terms impacts are small in Australasia, Central America, N Africa, Central Asia, W Africa and W Asia. URICC shows strong negative ecosystem impacts around the globe, and in particular that ecosystem impacts are particularly large in the Arctic (which is not modeled explicitly in FUND), Australasia, and in biodiversity hotspots.

Comments on shapes and magnitudes of damage functions in FUND

(a) Health sector: Health impacts in FUND are dominated by cardiovascular and respiratory disease in the rich parts of the world and by infectious disease in the poorer parts. The damage functions for Europe and N America show benefits due to the dominating effect of reduced cold stress over increased heat stress. However, the effect of reduced cold stress saturates whilst heat stress continues to increase, so at some point during the next century there is a turnover point and benefits decrease. Also, in Australasia, there is no cold stress initially so disbenefits due to heat stress occur right away as climate warms. In FUND the health disbenefits in Africa decrease over the coming century with economic growth, and heat stress takes over as the main health problem.

(b) Coastal sector: Sea level rise impacts in FUND are dominated by protection costs. Because dike building has low labour costs, its costs rise much more slowly than the economy grows, and hence annual impacts decrease as temperature increases even though more protection is being constructed. Wetland loss stops increasing after a small amount of temperature rise because there is no wetland left. These factors explain the shapes of the curves in Figures A4.7a,b. In Australasia there are marked "oscillations" in the damage function, reflecting the "myopic" behaviour of decision makers who respond to accelerating sea level rise or economic growth by building more protection, and if economic growth then slows again little additional protection is bought.

There are several different estimates of the costs of sea level rise. For the USA, for instance, costs range from \$7 to \$12 billion a year, compared to \$2 billion, here. Fankhauser's (1995) estimate for the OECD amounts to \$25 billion (for a 50 cm sea level rise) compared to \$7 billion here (for a 100 cm rise). Fankhauser's estimate for the world as a whole of \$47 billion compares to \$13 (\$19 B) billion here. This is largely the result of the optimal protection strategy used here as opposed to the arbitrary protection strategy used in earlier studies. Fankhauser finds that a 1 metre sea level rise would cost the OECD some \$9 billion per year if protection is optimized, compared to \$25 billion , his estimate for a non-optimized strategy for a 50 cm rise. CCRAF, in turn, estimates median (10^{th}- 90^{th}) protection costs of about \$5 B (\$3-7 B). Whilst OECD estimated a value of (1990)\$5 million/km2 for wetlands following Fankhauser (1994b), a recent trade in the US Wetland Banking and Trading System implicitly valued wetlands at (2005)\$365,000 per hectare i.e. \$36,500,000 per km2.

(c)Ecosystem sector: The outputs of FUND show ecosystems suffer increasing damages in all regions as temperature increases, as the URIC literature also shows. However in the B1 scenario (and to a lesser extent the A1 scenario) FUND annual damages decrease above a certain temperature rise, because the ecosystem damage model is strongly influenced by the rate of temperature change. Figure 5.2 shows that the rate of temperature change increases steadily in FUND A2, increases to a plateau (which slowly falls) in FUND B2; reaches a peak in 2040 and falls dramatically in FUND B1, and to a lesser extent in FUND A1 in 2050. Hence annual ecosystem impacts decrease once the rate of temperature change starts to decrease in scenarios FUND B1 and FUND A1.

Losses due to impacts in FUND have an assumed zero lifetime, so that for example permanent changes, such as loss of species, are only valued as losses during the time period during which they disappear. Whilst it is reasonable to assume that some impacts are transient, in that society eventually adapts, a policy maker may feel that permanent change, such as loss of species, loss of land area to the sea, and even arguably loss of human life (which is permanent) has an infinite lifetime. The FUND ecosystem damage model assumes a loss of 31% species associated with a temperature rise of 3C above 1990, compared to Thomas et al (2004) who predict a 35% species loss associated with a temperature rise of only 2C above 1990. The use of a zero lifetime for impacts in FUND implies that ecosystem loss is costed transiently, in other words that extinction damage is not valued beyond the year in which it occurs.

5. COMPARISON BETWEEN FUND AND RICE OUTPUTS

5.1 Simulation of temperature profiles of SRES scenarios

The temperature profiles that FUND simulates for the SRES scenarios are reproduced in Figure 5.1, whilst Figure 5.2 shows how the rate of temperature change varies. Those which RICE simulates are shown in Figure 5.3.

Figure 5.1 Increase in global annual average temperature relative to 1990 in 4 SRES scenarios according to the FUND model

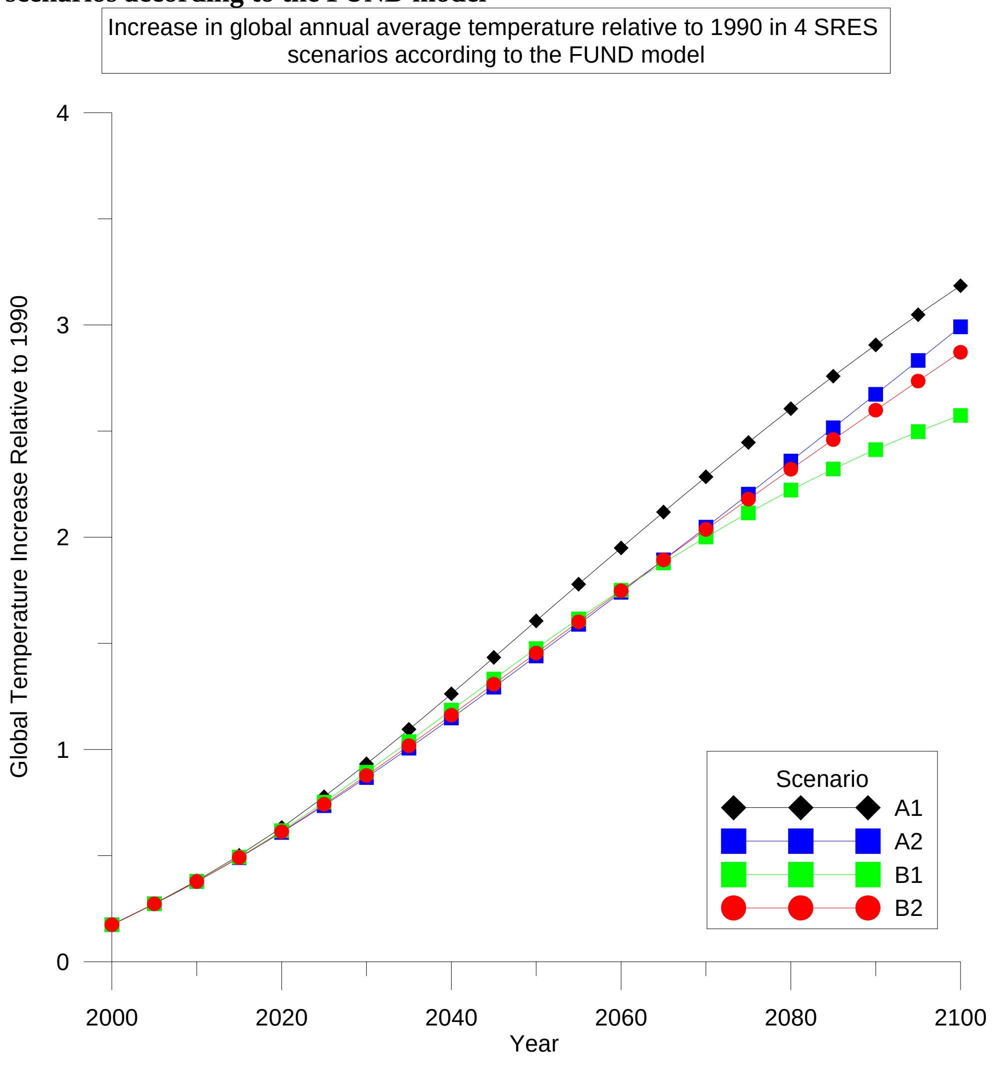
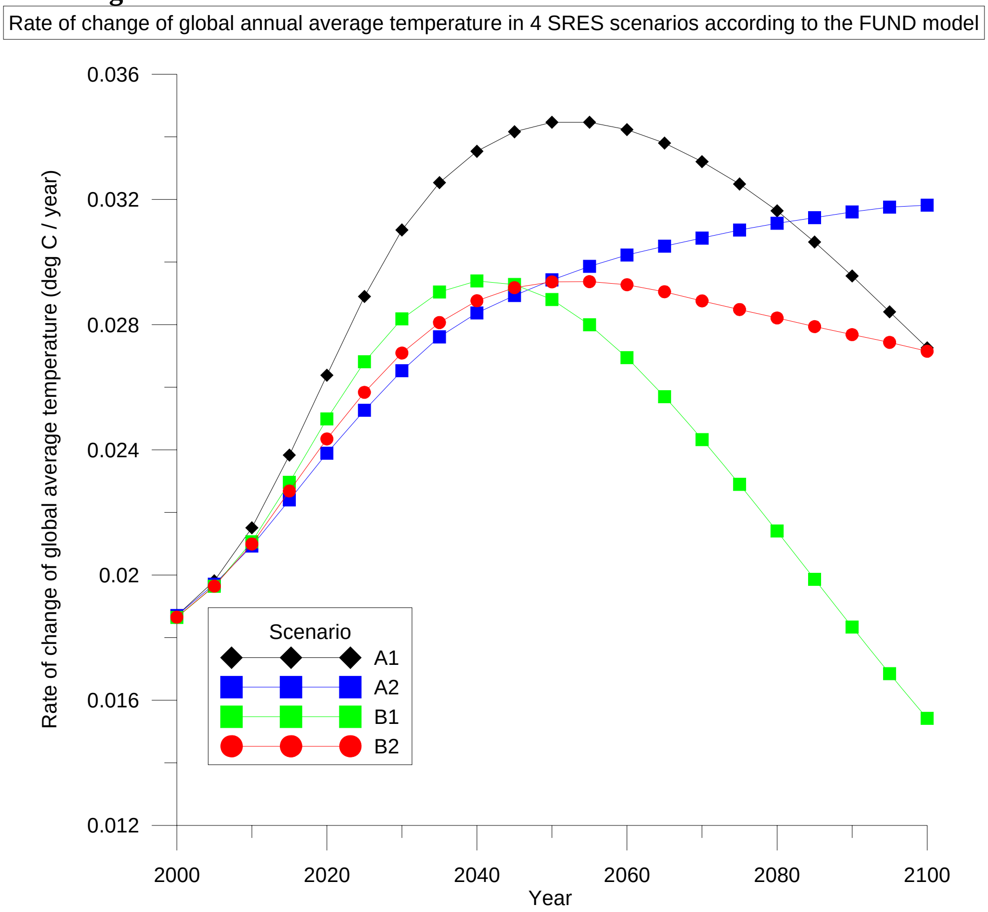


Figure 5.2 Rate of change of global annual average temperature in 4 SRES scenarios according to the FUND model



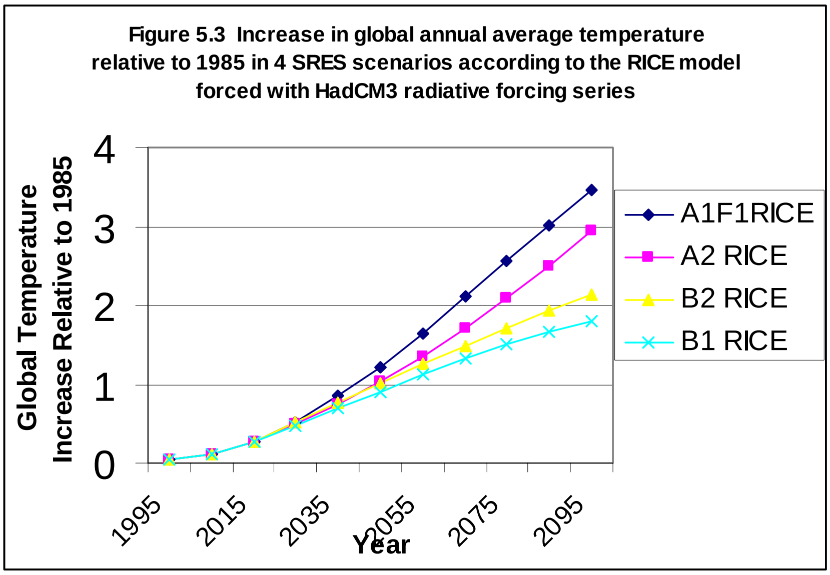
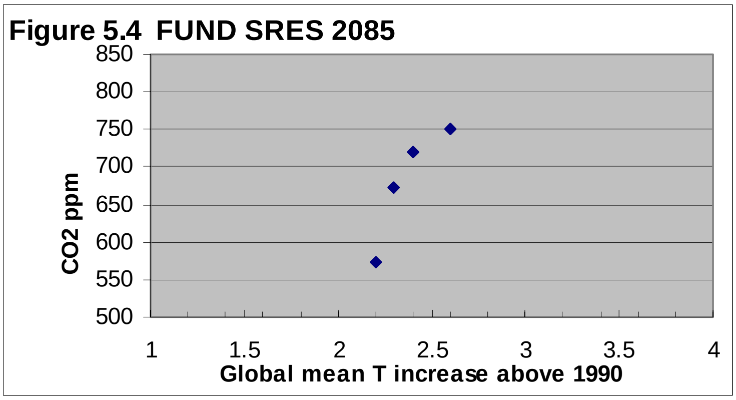
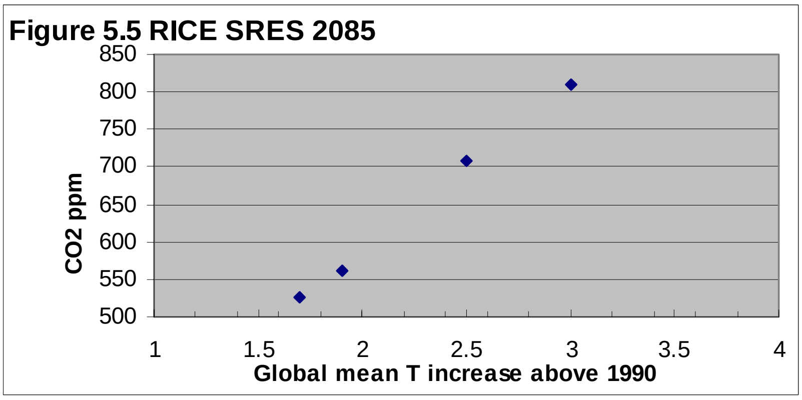
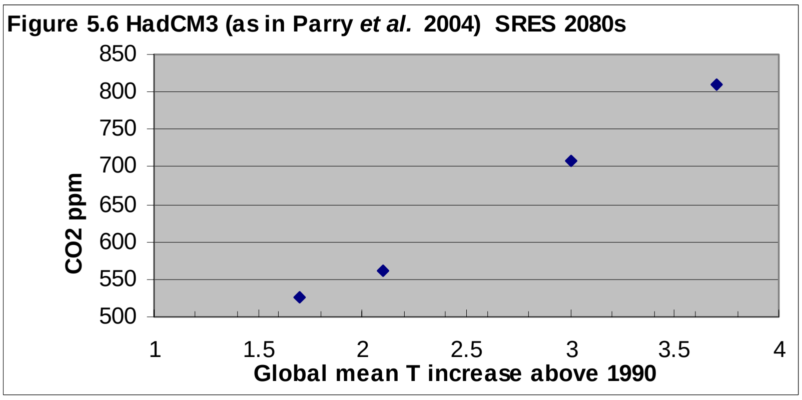


Figure 5.1 shows that the temperature profiles for the 4 SRES scenarios lie very close together in FUND. For example, in 2080 the FUND simulations give annual global mean temperature rises of 2.2C (B1), 2.3C (B2), 2.4C (A2) and 2.6C (A1B) above 1990, whereas Arnell *et al* (2004) for 2080 use 1.7C (B1), 2.1C (B2), 3.0C (A2) and 3.7C (A1F1) above 1990 . The IPCC TAR shows ranges of temperature rise relative to 1990 of 1.4 to 2.5C for B1 and 1.7 to 5.8C for A1 (2.1 to 3.8C for A1B and 3.2 to 5.8C for A1F1) in 2100. Whilst the FUND simulations are not individually outside the IPCC range, the IPCC marker scenarios (as shown in Figure 3.1 of the IPCC 2001 Synthesis Report) show a much greater temperature difference between SRES scenarios than does the FUND simulation. IPCC gives 2100 marker temperature rises relative to 1990 of close to 1.9C (B1) 2.6C (B2) 3.7C (A2) 3C (A1B) and 4.4C (A1F1), and 2080 rises of approximately 1.8C (B1), 2.1C (B2), 2.8C (A2), 2.5C (A1B) and 4.0C (A1F1).

This means that the temperature (and thus impact) outputs of the FUND model, and to a lesser extent the RICE model, are responding less strongly to the choice of SRES scenario than are other models underpinning the IPCC TAR climate simulations. The CO2 concentrations in 2085 in FUND are 720 ppm (A2), 751 ppm (A1B), 573 ppm (B1) and 673 ppm (B2). In the URICC project the scenarios (Arnell *et al.* 2004) from HadCM3 simulations give concentrations in the 2080s of 709 ppm (A2), 810 ppm (A1F1), 527 ppm (B1) and 561 ppm (B2). Thus the range of concentrations which the SRES scenarios spread in 2080 is rather similar between FUND and Arnell *et al.* 2004 (HadCM3), but the temperature range spanned by the 4 scenarios in 2080 is half as great. Figures 5.4-5.6 show the relationships between CO2 concentration and temperature change in FUND, RICE and those used in Arnell *et al.* 2004. The RICE model shows relationships intermediate between the other two studies.







Hence high emission scenarios in FUND may not result in such high temperatures as in other models, and the damage avoided by moving from a high emissions trajectory such as A1 to a lower one similar to B1, will be much smaller than in other models, because the resultant avoided temperature increments will be smaller.   In particular, for these FUND simulations, the A1 scenario always has the highest temperatures, whereas in Arnell *et al.* 2004 and in the IPCC marker scenarios, this is only true up to around 2065, after which greater temperature increases result in the A2 scenario than the A1B scenario. Hence, FUND is likely to simulate the greatest damages for the A1B scenario, and this is likely to contrast with other models which simulate greater temperature rises in the period 2080-2100 for A2 than for A1B. The RICE model temperature simulations are more similar to those used by Arnell *et al.* 2004 (HadCM3) although the high emission scenarios produce a smaller increase in temperature than the HadCM3 scenarios.

5.2 Simulation of climate change damages

Table 5.1 provides a comparison of global damages in %GDP as simulated by FUND and RICE at matching temperatures and matching dates for several SRES scenarios. (Note that A1B was simulated in FUND and A1F1 in RICE, but the other three SRES scenarios match). Unsurpisingly estimates differ significantly, and in spite of RICE's omission of impacts in temperate regions in many sectors, damages are higher in Europe and the USA in RICE than they are in FUND, owing to its prediction of strong benefits in Europe and the USA in the agriculture & forestry, and health sectors.

Table 5.1. Comparison of % GDP losses in selected regions simulated by FUND and RICE for SRES scenarios in 2095

SRES scenario	Year	FUND Global Temperature rise above 1990	RICE Global Temperature rise above 1985	Region	FUND damages	RICE damages
A2	2095	3.3	2.9	Globe	2.18	2.1496
A2	2080	2.9		Globe	1.44	
B2	2095	2.7	2.1	Globe	1.59	0.9295
B2	2075	2.2		Globe	0.98	
B1	2095	2.5	1.8	Globe	1.18	0.5679
B1	2060	1.8		Globe	0.53	
A2	2095	3.3	2.9	USA	0.14	0.9114
A2	2080	2.9		USA	0.21	
B2	2095	2.7	2.1	USA	0.15	0.3523
B2	2075	2.2		USA	0.42	
B1	2095	2.5	1.8	USA	0.003	0.1901
B1	2060	1.8		USA	0.59	
A2	2095	3.3		Europe	0.742	4.707
A2	2080	2.9	2.9	Europe	0.838	
B2	2095	2.7		Europe	0.3	2.5705
B2	2075	2.2	2.1	Europe	0.48	
B1	2095	2.5		Europe	0.19	1.8919
B1	2060	1.8	1.8	Europe	0.63	
A2	2095	3.3	2.9	S Africa/Low Income	7.39	5.9733
A2	2080	2.9		S Africa/Low Income	6.89	
B2	2095	2.7	2.1	S Africa/Low Income	7.47	3.9431
B2	2075	2.2		S Africa/Low Income	6.51	
B1	2095	2.5	1.8	S Africa/Low Income	3.47	3.2262
B1	2060	1.8		S Africa/Low Income	3.68	

6. CRITIQUE OF TREATMENT OF ADAPTATION COSTS IN PAGE AND FUND MODELS

Irene Lorenzoni and W. Neil Adger

Both the PAGE and FUND models conceptualise adaptation as a means of reducing (or avoiding) the impacts of climate change. In both models adaptation costs are calculated based on parameters denoting change, often linked to technological development or innovation. The PAGE model derives adaptation costs mainly a function of protecting against the first 50cm or so of sea level rise (costs would be higher in Europe with its long coastline and low-lying areas).

More accurate estimates of the costs of adaptation should take into account the complexity through which adaptation occurs. From observations of adaptation to climate variability several lessons emerge. Adaptation is context-specific, often does occur as step changes, and most often evolves in anticipation to an event or series of events[9]. The costs of anticipatory adaptation may be lower than those from reactive adaptation (because some of the consequences of climate change impacts will be prevented by anticipating change)[10] (Leary, 1999). For anticipation, however, one should also allow for the costs of misplaced foresight (in other words, getting it wrong). In the latter case, costs may also be incurred in the process towards adaptation (e.g. adjustment costs).

It is unclear whether the PAGE and FUND IA models include considerations about adjustment costs. These are defined as "the extra costs incurred relative to the (counterfactual) case of instantly adapting to changed circumstances" (Kelly *et al*., 2005:469). In other words, these are costs that accrue to agents before they modify their behaviour (i.e. adapt). Some would argue these adjustment costs could be seen as part of the costs of adaptation, rather than as a category per se. In any case, adjustment costs can significantly influence the net costs / benefits of adaptation. Kelly and colleagues' 2005 theoretical and empirical study on adjustment costs - whilst learning about a climate change shock (imperfect information) - estimated adjustment costs at 1.4% of annual profits per acre from climate change to agricultural land in the US mid-west.

Furthermore, the PAGE and FUND models assume that markets are efficient and therefore that adaptation is efficient. This approach, however, does not consider the more complex relationships between socio-economic systems and the way costs and benefits of adaptation are diffused and distributed.

[9] In contrast, the PAGE model assumes that adaptation is possible (to different degrees) in various locations around the world (dictated by different assumptions and 'purchase' of adaptation types) and that this occurs linearly until it reaches some plateau.

[10] Not all adaptation to climate change is planned. Recent studies have indicated that there are only few examples in the UK (e.g. Tompkins *et al*., 2005) and in the EU (EEA, 2006) where adaptation is specifically planned for weather-related events (and climate change). In addition, not all adaptation reduces the negative effect of climate change impacts. Some adaptive responses may become unsuitable over time due to changing circumstances, resulting in maladaptation. Therefore, models may want to consider that adaptation may serve not only as a means to decrease the impacts of climate change or take advantage of its opportunities, but may operate by reducing the ability to address these impacts.

Measuring the impacts of climate change on agriculture has provided most extensive discussions of how much cost reduction can be expected from adaptation by economic agents. Two approaches are the most used:

- a Ricardian approach, whereby farmland values are statistically linked to climatic, soil and economic variables. The fitted relationship is then used to predict changes in value (e.g. rent or price, usually of farmland) as a function of climate change.
- agronomic analysis to predict the impacts of climate change on crop yields and subsequently the economic effects of changes in yields on agriculture. These estimates are often extrapolated to other environments and situations with altered climates.

Mendelsohn's (2000) work, following a Ricardian approach, suggests that -providing there are no externalities or collective action - adaptation will be efficient and therefore reduce the costs of climate change. However, there is much evidence suggesting that efficiency is not always maximised, in every situation and in very case. Hanemann (2000) argues that adaptation cannot always be considered as efficient, simply because externalities and policy changes invariably affect the price of the land and other related assets; in addition, land markets are non existent or operate very differently in other non-market economies (e.g. subsistence farming in developing nations), which can be overcome by considering net farm revenues as a measure of the value of agricultural activities.

It has been argued that the Ricardian approach estimates the full range of adaptation possibilities (e.g. adaptation by farmers, market adaptations reflected in shifts of land use into or out of agriculture), whereas the agronomic approach understates adaptation (overestimating the economic costs and underestimating the benefits of climate change by focussing exclusively on crops). Theoretical economic studies in the literature have often considered that the difference between the former and the latter yields reliable measures of the economic effects of adaptation. Hanemann (2000:576) revisits such claims, pointing out that both approaches disregard their inherent measurement errors (often from empirical observational data). In other words, the difference in estimates between the two, considering such measurement errors, should be more appropriately considered the "difference in adaptation + difference in measurement error". These limitations should be considered in relation to developing a more accurate representation of adaptation in the two models.

Some broader general considerations

Discounting is always a complex and thorny issue. Caution should be exercised on how it is applied in the models. The default case in the PAGE model is that impacts will be reduced in total by 33%, with adaptation, over 200 years (applying the default discount rates). Rates can also be set by the user. However, discounting over 200 years is unrealistic. Changes in socio-economic systems cannot be projected semi-realistically for more than 5 -10 years at a time (e.g., Berkhout and Hertin, 2000). The utility of calculating costs and benefits of adaptation over these timescales may be debatable (this same reasoning can also be applied to calculations relating to mitigation measures also). Therefore it is important to take into account the outputs of various different models which utilise different methodologies and assumptions, and to use outputs of models which explore the implications of various future socioeconomic scenarios and possible decisions about adaptation.

Beyond the metricised approaches to costing of adaptation, wider ranging considerations about adaptation in practice (often not reducible to economic metrics) should be taken into consideration, where feasible, in the construction, interpretation and use of the models. This approach can be limited by the context-specificity of adaptation, an area of research in which reconciling some of the discrepancies between adaptation modelling and findings from the field may prove challenging, lengthy and a source of much debate.

For instance, modelling based on standardised approaches to countries worldwide masks the diversity that exists between countries - as demonstrated in the CRU / ERAL 1992 report and which Nicholls and Klein (2003) seem to suggest in their paper (in EEA 2006:23, Table2). Adaptive capacity may not be highest, under all circumstances, in the EU and OECD. The response to the 2003 heat wave in France lends itself as an interesting case. It has also been shown that the capacity to adapt among resource-dependent societies in Southern Africa is high if based on adaptations to previous changes (Thomas et al., 2005).

Research has also drawn attention to the importance of actors at different levels (institutions, communities, individuals) in promoting / constraining adaptation (e.g. through knowledge transfer, support for measures and practices) (e.g. Tompkins et al., 2005; Thomas et al., 2005). Some acknowledgement of their role would be helpful (see EEA, 2006).

The models clearly do not (and perhaps cannot) make reference to considerations of equity and justice in climate change management. They do not address issues such as responsibility for human-induced climate change; beneficiaries and victims (or winners and losers) from the changes that have, and will take, place; any form of aid or compensation for the damages already incurred. This is where the realms of modelling and policy-making intersect. Costing adaptation provides estimates for guiding policy. This in turn should eventually give due account to the wider underlying circumstances and implications of actions, as these are inevitably entwined with any policy decision on climate change.

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References

Arnell, N.W., Cannell, M.G.R., Hulme, M., Kovats, R.S., Mitchell, J.F.B., Nicholls,
Arnell, N.W., Livermore, M.J.J., Kovats, S., Levy, P.E., Nicholls, R., Parry, M.L., and Gaffin S.R. 2004. Climate and socioeconomic scenarios for global-scale climate change impacts assessments: characterising the SRES storylines. *Global Environmental Change* 14 pp 3-20.

Berkhout, F. and Hertin, J. (2000) Viewpoint: socio-economic scenarios for climate impact assessment, *Global Environmental Change*, 10:165-168.

Bijlsma, L., Ehler, C.N., Klein, R.J.T., Kulshrestha, S.M., McLean, R.F., Mimura, N., Nicholls, R.J., Nurse, L.A., Nieto, P., Stakhiv, E.Z., Turner, R.K., Warrick, R.A. (1996) Coastal zones and small islands. In Watson, R.T., Zinyomera, M.C., Moss, R.H., *Impacts, Adaptations and Mitigation of Climate Change: Scientific Technical Analyses.* Cambridge University Press, Cambridge, pp. 289-324.

Climatic Research Unit and Environmental Resources Limited (CRU / ERL) (1992) *Economic evaluation of impacts and adaptive measures in the European Community. Development of a Framework for the Evaluation of Policy Options to deal with The Greenhouse Effect*. ERL, CRU and EC DG XI.

Cline, W.R. (1992) *The Economics of Global Warming,* Institute for International Economics, Washington D.C.

CRU/ERL (1992) Economic evaluation of impacts and adaptive measures in the European Community, phase 3, final report, CEC, DG XI, Brussels.

Darwin, R, Tsigas, M., Leqandrowski, J., and Raneses, A. (1995) World *Agriculture and Climate Change: Economic Adaptations*. Agricultural economic report number 703, US Dept of Agriculture.

Darwin, R. (2004) Effects of greenhouse gas emissions on world agriculture, food consumption, and economic welfare. *Climatic Change* 66, 191-238.

Dinar, A., R. Mendelsohn, R. Evenson, J. Parikh, A. Sanghi, K., Kumar, J. McKinsey, and S. Lonergan (1998). Measuring the Impact of Climate Change on Indian Agriculture, World Bank Technical Paper No. 402, 1998.

Downing, T.E., Greener, R.A., and Eyre, N. (1995) *The Economic Impacts of Climate Change: Assessment of Fossil Fuel Cycles for ExternE Project.* Oxford and Lonsdale, Environmental Change Unit and Eyre Energy Environment.

Downing, T.E., Eyre, N., Greener, R., and Blackwell, D. (1996) *Projected Costs of Climate Change for Two Reference Scenarios and Fossil Fuel Cycles* Oxford: Environmental Change Unit.

European Environment Agency (EEA) (2006) *Vulnerability and adaptation to climate change in Europe*. EEA Technical Report no. 7/2005, EEA Copenhagen and Office for Official Publication of the European Communities, Luxembourg.

Fankhauser, S. (1994a). The economic costs of global warming damage: a survey. *Global Environmental Change* 4, pp. 301-109.

Fankhauser, S (1994b) Protection versus retreat: The Economic Costs of Sea Level Rise *Environmental and Planning A* 27, 299-319

Fankhauser, S (1995) *Valuing Climate Change: The Economics of the Greenhouse.* London, Earthscan.

Hanemann, W.M. (2000) Adaptation and its measurement; an editorial comment, *Climatic Change*, 45:571-581.

Hammitt, J.K., Lempert, R.J. and Schlesinger, M.E. (1992) A Sequential-Decision Strategy for Abating Climate Change. *Nature* **357** 315-318.

Hoozemans, F.M.J., Marchand, M., Pennkamp, H.A. (1993) *A Global Vulnerability Analysis: Vulnerability Assessment for Population, Coastal Wetlands, and Rice Production on a Global Scale*. 2nd Edition, Delft Hydraulics, The Netherlands.

Hope C (2006) The marginal impact of CO2 from PAGE2002: An integrated assessment model incorporating the IPCC's five reasons for concern, *Integrated Assessment*, 6, 1.

IPCC (2001) Intergovernmental Panel on Climate Change (IPCC).: 2001, '*Climate Change 2001: Volume II Impacts, Adaptation and Vulnerability*', Cambridge University Press, 397 pp.

Johns, T.C., Gregory, J.M., Ingram, W.J., Johnson, C.E., Jones, A., Lowe, J.A., Mitchell, J.F.B., Roberts, D.L., Sexton, D.M.H., Stevenson, D.S., Tett, S.F.B., and Woodage, M.J. (2003) Anthropogenic climate change for 1860 to 2100 simulated with the HadCM3 model under updated emissions scenarios. *Climate Dynamics* 20, 583-612.

Kattenberg, A., Giorgi, F., Grassl, H., Meehl, G.A., Mitchell, J.F.B., Stouffer, R.J., Tokioka, T., Weaver, A.J., and Wigley, T.M.L. (1996) *Climate Models-Projections of Future Climate* in Houghton, J.T., MeiroFilho, L.G., Callander, B.A., Harris, N., Kattenberg, A., and Maskell, K. (eds) *Climate Change 1995: The Science of Climate Change-Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge: Cambridge University Press, pp285-357

Kelly, D.L., Kolstad, C.D. and Mitchell, G.T. (2005) Adjustment costs from environmental change, *Journal of Environmental Economics and Management*, 50: 468-495.

Leary, N. A. (1999) A framework for benefit cost analysis of adaptation to climate change and climate variability. *Mitigation and Adaptation Strategies for Global Change* 4:307-318.

Maier-Reimer, E. and Hasselmann, K. (1987) Transport and Storage of Carbon Dioxide in the Ocean: An Inorganic Ocean Circulation Carbon Cycle Model. *Climate Dynamics* **2** 63-90

Manne, A. (2004) Global Climate Change: An Opponent's Notes. Copenhagen Consensus Opponent Note, Copenhagen Consensus.

Manne, A., Mendelsohn, R., and Richels, R. (1995) A model for evaluating regional and global effects of greenhouse policies. *Energy Policy* 23, 17-34.

Manne, A., and Richels, R. (1995) The Greenhouse Debate: Economic Efficiency, Burden Sharing and Hedging Strategies, *Environmental Economics* **16**, 1-38

Manne, A., and Stephan, G. (1999) Climate-change policies and international rate-if-return differentials *Energy Policy* 27, 309-316

Mendelsohn, R. (2000) Efficient adaptation to climate change, *Climatic Change*, 45:583-600.

Mendelsohn, R. and Neumann, J. (eds) (1999) *The Impact of Climate Change on the United States Economy* Cambridge University Press, Cambridge UK.

Mendelsohn, R., Morrison, W., Schlesinger, M.E., and Andronova, N.G., (2000) Country-specific market impacts of climate change, *Climatic Change*, 45, 553-569.

Murray, C.J.L., and Lopez, A.D. (eds) (1996) *The Global Burden of Disease.* Harvard School of Public Health. Cambridge, UK. Cambridge University Press.

Nicholls, R.J., and Leatherman, S.P. (1995a) *Global Sea Level Rise* in Strzepek, S., and Smith, J.B. (eds) *When Climate Changes: Potential Impact and Implications.* Cambridge, Cambridge University Press.

Nicholls, R.J., Leatherman, S.P., Dennis, K.C., and Volonte, C.R. (1995b) Impacts and Responses to Sea Level Rise: Qualitative and Quantitative Assessments *Journal of Coastal Research* 14, 26-43

Nicholls, Robert J. and Richard J.T. Klein (2003) *Climate change and coastal management on Europe's Coast.* EVA Working Paper No.3. PIK.

Nordhaus, W.D. (1991) To Slow or Not to Slow: The Economics of the Greenhouse Effect *The Economic Journal* 101, 920-937

Nordhaus, W.D. (1992) An Optimal Transition Path for Controlling Greenhouse Gases," *Science,* 258, 1315-1319

Nordhaus, W.D. (1994) Expert Opinion on Climate Change. *American Scientist* 82, 45-51.

Nordhaus, W.D. (1998) New Estimates of the Economic Impacts of Climate Change, available at http://www.econ.yale.edu/%7Enordhaus/homepage/impact%20text%20122998a.PDF

Nordhaus, W.D. (2006) Geography and macroeconomics: new data and new findings. *Proceedings of the National Academy of Sciences*

Nordhaus, W.D., and Boyer, M. (2000). *Warming the World: Economic Models of Global Warming.* Cambridge, Massachusets, MIT Press.

Pearce, D.W., Cline, W.R., Achanta, A., Fankhauser, S., Pachauri, R., Tol. R., and Vellinga, P. , 1996. The social costs of climate change: greenhouse damage and the benefits of control, in Bruce, J., Lee. H., and Haites, E. (1995) (eds) *Climate Change 1995: Economics and Social Dimensions of Climate Change,*Cambridge University Press, pp. 183-224.

Peck , S.C. and Teisberg, T.J. (1992). CETA: A model for carbon emissions trajectory assessment. *The Energy Journal* 13, issue 1, pp. 55-67.

Plambeck, E., and Hope, C. (1997). The PAGE model: integrating the science ad economics of global warming. *Energy Economics* 19, pp. 77-101

Reilly, J.M., Hohmann, N., and Kane, S. (1994) Climate Change and Agricultural Trade: Who Benefits, Who Loses? *Global Environmental Change* 4, 24-36

Rosenzweig, C., and Parry, M.L. (1994). Potential impacts of climate change on world food supply. *Nature* 367, 133-138.

Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F.N. Erasmus, M.F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A.S. van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega-Huerta, A.T. Peterson, O.L. Phillips, and S.E. Williams, 2004: Extinction risk from climate change. *Nature* (London), 427(6970), pp. 145-148.

Thomas, D., Osbahr, H., Twyman, C., Adger, W.N. and Hewitson, B. (2005) *ADAPTIVE: adaptation to climate change amongst natural resource-dependent societies in the developing world: across the Southern African climate gradient.* Technical report 35, Tyndall Centre for Climate Change Research, UEA, Norwich.

Tol, R.S.J. 1999 Spatial and Temporal Efficiency in Climate Policy: Applications of FUND. *Environmental and Resource Economics* 14, 33-49

Tol, R.S.J., 2002a: Estimates of the damage costs of climate change. Part 1: Benchmark estimates. *Environmental and Resource Economics*, 21(1), pp. 47-73.

Tol, R.S.J., 2002b: Estimates of the damage costs of climate change. Part 2: Dynamic estimates. *Environmental and Resource Economics*, 21(1), pp. 135-160.

Tompkins, E.L., Boyd, E., Nicholson-Cole, S.A., Weatherhead, K., Arnell, N.W. and Adger, W.N. (2005) Linking adaptation research and practice. Tyndall Centre for Climate Change Research, UEA, Norwich.

Warren, R., Arnell, N.W., Nicholls. R.J., Levy, P., and Price, J. *Understanding the Regional Impacts of Climate Change.* Tyndall Working Paper no …..www .tyndall.ac.uk

Yohe, G., and Schlesinger, M. (1988) Sea Level Change: the Expected Economic Cost of Protection or Abandonment in the United States. *Climatic Change* 38, 447-472

Table A3.1a. Regional impacts of different levels of temperature change for the EU between 2020 and 2200 ($$ million)

Global mean temperature rise above 1990				Economic impacts $$ million			Non-economic impacts $ million			Discontinuity impacts $$ million			Total impacts $$ million		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	0	0	0	2674	290	7146	0	0	0	2674	290	7146
2040	0.96	0.34	1.82	11	0	9	9941	1188	25975	0	0	0	9952	1188	25977
2060	1.73	0.78	3.06	190	0	1060	26630	4076	66279	871	0	0	27691	4099	71847
2080	2.65	1.32	4.52	1166	0	5001	66217	10331	164699	9485	0	64270	76868	11066	238685
2100	3.65	1.90	6.03	4291	0	15292	155177	23671	410357	54113	0	320820	213581	26358	716875
2150	5.90	3.30	9.30	40079	2324	132445	906480	125877	2642860	655784	0	2384995	1602343	175849	4625044
2200	7.39	4.22	11.56	181465	13240	607975	3522563	441963	10597250	2840952	0	8732939	6544980	831555	18073590

Table A3.1b. Regional impacts of different levels of temperature change for the EU between 2020 and 2200 (%GDP)

Global mean temperature rise above 1990				Economic impacts % GDP			Non-economic impacts % GDP			Discontinuity impacts % GDP			Total impacts % GDP		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	0.00	0.00	0.00	0.02	0.00	0.06	0.00	0.00	0.00	0.02	0.00	0.06
2040	0.96	0.34	1.82	0.00	0.00	0.00	0.06	0.01	0.16	0.00	0.00	0.00	0.06	0.01	0.16
2060	1.73	0.78	3.06	0.00	0.00	0.00	0.12	0.02	0.30	0.00	0.00	0.00	0.12	0.02	0.32
2080	2.65	1.32	4.52	0.00	0.00	0.02	0.22	0.03	0.56	0.03	0.00	0.22	0.26	0.04	0.80
2100	3.65	1.90	6.03	0.01	0.00	0.04	0.39	0.06	1.04	0.14	0.00	0.81	0.54	0.07	1.81
2150	5.90	3.30	9.30	0.04	0.00	0.13	0.91	0.13	2.66	0.66	0.00	2.40	1.62	0.18	4.66
2200	7.39	4.22	11.56	0.07	0.01	0.24	1.42	0.18	4.27	1.14	0.00	3.52	2.63	0.33	7.28

Table A3.2a. Regional impacts of different levels of temperature change for the Eastern Europe and Former Soviet Union between 2020 and 2200 ($$ million)

Global mean temperature rise above 1990				Economic impacts $$ million			Non-economic impacts $ million			Discontinuity impacts $$ million			T	
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	M	
2020	0.38	0.10	0.80	0	0	0	-2781	-8716	175	0	0	0	-2	
2040	0.96	0.34	1.82	-22	-119	0	-8483	-26855	564	0	0	0	-8	
2060	1.73	0.78	3.06	-273	-1342	1	-22463	-69475	1204	-537	0	0	-2	
2080	2.65	1.32	4.52	-1450	-6044	53	-58822	-186630	2858	-5612	-38934	0	-6	
2100	3.65	1.90	6.03	-5237	-21149	274	-148155	-477248	6823	-34658	-232335	0	-1	
2150	5.90	3.30	9.30	-41841	-167428	2529	-836187	-2775385	34933	-416692	-1856134	1714	-1	
2200	7.39	4.22	11.56	-176146	-692159	9455	-3139917	-11042240	116070	-1806448	-7074760	90184	-5	

Table A3.2b. Regional impacts of different levels of temperature change for Eastern Europe & Former Soviet Union between 2020 and 2200 (%GDP)

Global mean temperature rise above 1990				Economic impacts % GDP			Non-economic impacts % GDP			Discontinuity impacts % GDP			Total impacts % GDP		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	0.00	0.00	0.00	-0.07	-0.20	0.00	0.00	0.00	0.00	-0.07	-0.20	0.00
2040	0.96	0.34	1.82	0.00	0.00	0.00	-0.12	-0.39	0.01	0.00	0.00	0.00	-0.12	-0.39	0.01
2060	1.73	0.78	3.06	0.00	-0.01	0.00	-0.21	-0.65	0.01	0.00	0.00	0.00	-0.22	-0.69	0.01
2080	2.65	1.32	4.52	-0.01	-0.04	0.00	-0.35	-1.12	0.02	-0.03	-0.23	0.00	-0.40	-1.33	0.02
2100	3.65	1.90	6.03	-0.02	-0.08	0.00	-0.58	-1.85	0.03	-0.13	-0.90	0.00	-0.73	-2.52	0.03
2150	5.90	3.30	9.30	-0.06	-0.26	0.00	-1.30	-4.30	0.05	-0.65	-2.88	0.00	-2.01	-7.05	0.09
2200	7.39	4.22	11.56				-1.94	-6.83	0.07	-1.12	-4.38	0.06	-3.17	-10.73	0.14

Table A3.3a. Regional impacts of different levels of temperature change for the USA between 2020 and 2200 ($$ million)

Global mean temperature rise above 1990				Economic impacts $$ million			Non-economic impacts $ million			Discontinuity impacts $$ million			Total impacts $$ million		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	0	0	0	765	74	2159	0	0	0	765	74	2159
2040	0.96	0.34	1.82	6	0	32	3110	327	8820	0	0	0	3116	327	8822
2060	1.73	0.78	3.06	93	0	461	8863	969	23880	230	0	0	9187	969	25193
2080	2.65	1.32	4.52	518	0	2107	23353	2409	65422	2562	0	15040	26433	2494	80000
2100	3.65	1.90	6.03	1878	31	6886	58495	5852	170537	16158	0	95173	76531	6219	258854
2150	5.90	3.30	9.30	15593	746	53042	327696	31295	960327	200333	0	788173	543622	44172	1630456
2200	7.39	4.22	11.56	67801	3323	225733	1247334	110233	3578630	869367	0	2839733	2184501	183498	6302201

Table A3.3bRegional impacts of different levels of temperature change for the USA between 2020 and 2200 (%GDP)

Global mean temperature rise above 1990				Economic impacts % GDP			Non-economic impacts % GDP			Discontinuity impacts % GDP			Total impacts % GDP		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.02
2040	0.96	0.34	1.82	0.00	0.00	0.00	0.02	0.00	0.05	0.00	0.00	0.00	0.02	0.00	0.05
2060	1.73	0.78	3.06	0.00	0.00	0.00	0.04	0.00	0.10	0.00	0.00	0.00	0.04	0.00	0.10
2080	2.65	1.32	4.52	0.00	0.00	0.01	0.07	0.01	0.20	0.01	0.00	0.05	0.08	0.01	0.24
2100	3.65	1.90	6.03	0.00	0.00	0.02	0.13	0.01	0.38	0.04	0.00	0.21	0.17	0.01	0.58
2150	5.90	3.30	9.30	0.01	0.00	0.05	0.29	0.03	0.86	0.18	0.00	0.71	0.49	0.04	1.46
2200	7.39	4.22	11.56	0.02	0.00	0.08	0.45	0.04	1.28	0.31	0.00	1.02	0.78	0.07	2.25

Table A3.4a Regional impacts of different levels of temperature change for China between 2020 and 2200 ($$ million)

Global mean temperature rise above 1990				Economic impacts $$ million			Non-economic impacts $ million			Discontinuity impacts $$ million				
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max		
2020	0.38	0.10	0.80	83	0	474	174	0	1082	0	0	0		
2040	0.96	0.34	1.82	445	0	2645	971	0	5642	0	0	0		
2060	1.73	0.78	3.06	2636	0	11671	5836	0	25178	837	0	0		
2080	2.65	1.32	4.52	13306	182	46483	29365	739	102038	9944	0	57676		
2100	3.65	1.90	6.03	47708	2347	156270	104976	7876	326579	59192	0	343356		
2150	5.90	3.30	9.30	369971	23112	1249852	807984	72885	2482477	699311	0	2585619		
2200	7.39	4.22	11.56	1531516	89850	5445028	3329953	284605	10732760	3035695	0	9903641		

Table A3.4b Regional impacts of different levels of temperature change for China between 2020 and 2200 (%GDP)

Global mean temperature rise above 1990				Economic impacts % GDP			Non-economic impacts % GDP			Discontinuity impacts % GDP			Total impacts % GDP		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02
2040	0.96	0.34	1.82	0.00	0.00	0.02	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.05
2060	1.73	0.78	3.06	0.01	0.00	0.05	0.03	0.00	0.11	0.00	0.00	0.00	0.04	0.00	0.18
2080	2.65	1.32	4.52	0.04	0.00	0.15	0.09	0.00	0.32	0.03	0.00	0.18	0.16	0.00	0.62
2100	3.65	1.90	6.03	0.11	0.01	0.35	0.23	0.02	0.73	0.13	0.00	0.76	0.47	0.03	1.71
2150	5.90	3.30	9.30	0.33	0.02	1.11	0.72	0.06	2.21	0.62	0.00	2.30	1.67	0.14	5.22
2200	7.39	4.22	11.56	0.54	0.03	1.93	1.18	0.10	3.81	1.08	0.00	3.51	2.80	0.26	8.55

Table A3.5a Regional impacts of different levels of temperature change for India between 2020 and 2200 ($$ million)

Global mean temperature rise above 1990				Economic impacts $$ million			Non-economic impacts $ million			Discontinuity impacts $$ million			
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	
2020	0.38	0.10	0.80	19777	1326	56259	42996	4732	132036	0	0	0	
2040	0.96	0.34	1.82	82360	7185	234479	179458	23127	516074	0	0	0	
2060	1.73	0.78	3.06	260965	26447	722604	569844	90160	1551985	17093	0	0	
2080	2.65	1.32	4.52	712667	86386	2051023	1558000	264875	4185445	203748	0	1269555	
2100	3.65	1.90	6.03	1686336	212198	4942781	3688221	607283	10049840	1108327	0	6143224	
2150	5.90	3.30	9.30	10130400	1183751	33536480	22125990	3319951	60399210	13369870	0	47348590	
2200	7.39	4.22	11.56	38988210	4196394	138374200	85010580	11735550	249796300	57467810	0	170060800	

Table A3.5b Regional impacts of different levels of temperature change for India between 2020 and 2200 (%GDP)

Global mean temperature rise above 1990				Economic impacts % GDP			Non-economic impacts % GDP			Discontinuity impacts % GDP			Total impacts % GDP		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	0.25	0.02	0.72	0.55	0.06	1.69	0.00	0.00	0.00	0.80	0.10	2.20
2040	0.96	0.34	1.82	0.59	0.05	1.69	1.29	0.17	3.71	0.00	0.00	0.00	1.88	0.30	5.08
2060	1.73	0.78	3.06	1.32	0.13	3.67	2.89	0.46	7.87	0.09	0.00	0.00	4.30	0.80	11.47
2080	2.65	1.32	4.52	2.55	0.31	7.34	5.58	0.95	14.99	0.73	0.00	4.55	8.86	1.70	25.07
2100	3.65	1.90	6.03	4.26	0.54	12.49	9.32	1.53	25.39	2.80	0.00	15.52	16.38	2.86	49.99
2150	5.90	3.30	9.30	10.22	1.19	33.83	22.32	3.35	60.93	13.49	0.00	47.76	46.02	6.96	132.68
2200	7.39	4.22	11.56	15.70	1.69	55.73	34.24	4.73	100.60	23.14	0.00	68.49	73.08	12.22	212.15

Table A3.6a Regional impacts of different levels of temperature change for the Africa between 2020 and 2200 ($$ million)

Global mean temperature rise above 1990				Economic impacts $$ million			Non-economic impacts $ million			Discontinuity impacts $$ million				
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max		
2020	0.38	0.10	0.80	10450	1005	28512	22757	3780	58018	0	0	0		
2040	0.96	0.34	1.82	47808	5151	122232	104156	16934	257328	0	0	0		
2060	1.73	0.78	3.06	151150	18217	384231	329670	57845	843444	8680	0	0		
2080	2.65	1.32	4.52	401747	50160	1059862	876927	159302	2253393	102004	0	668053		
2100	3.65	1.90	6.03	927032	115034	2462154	2023839	359925	5271611	557614	0	3152364		
2150	5.90	3.30	9.30	5246023	543667	15133850	11443390	1811905	31295700	6651060	0	23248260		
2200	7.39	4.22	11.56	19882320	1856552	60662740	43310900	6127983	123160000	28751300	0	84473740		

Table A3.6b Regional impacts of different levels of temperature change for Africa between 2020 and 2200 (%GDP)

Global mean temperature rise above 1990				Economic impacts % GDP			Non-economic impacts % GDP			Discontinuity impacts % GDP			Total impacts % GDP		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	0.16	0.02	0.44	0.35	0.06	0.90	0.00	0.00	0.00	0.51	0.10	1.26
2040	0.96	0.34	1.82	0.35	0.04	0.89	0.76	0.12	1.88	0.00	0.00	0.00	1.11	0.23	2.54
2060	1.73	0.78	3.06	0.70	0.08	1.78	1.53	0.27	3.92	0.04	0.00	0.00	2.27	0.51	5.50
2080	2.65	1.32	4.52	1.19	0.15	3.13	2.59	0.47	6.65	0.30	0.00	1.97	4.08	0.92	11.32
2100	3.65	1.90	6.03	1.74	0.22	4.62	3.80	0.68	9.90	1.05	0.00	5.92	6.59	1.24	19.86
2150	5.90	3.30	9.30	3.93	0.41	11.35	8.58	1.36	23.46	4.99	0.00	17.43	17.50	2.85	46.72
2200	7.39	4.22	11.56	5.95	0.56	18.16	12.96	1.83	36.87	8.61	0.00	25.29	27.52	4.53	69.29

Table A3.7a. Regional impacts of different levels of temperature change for Latin America between 2020 and 2200 ($$ million)

Global mean temperature rise above 1990				Economic impacts $$ million			Non-economic impacts $ million			Discontinuity impacts $$ million			Total impacts $$ million		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	5106	450	13233	11190	1593	27256	0	0	0	16296	3105	37270
2040	0.96	0.34	1.82	21453	2307	54283	47086	7026	119427	0	0	0	68540	13189	167084
2060	1.73	0.78	3.06	66581	7898	175284	146388	24013	376762	3720	0	0	216689	41788	555884
2080	2.65	1.32	4.52	188179	22874	526714	414243	69624	1079439	48357	0	335859	650779	118079	1883132
2100	3.65	1.90	6.03	488178	58668	1452686	1075451	185613	2984154	300765	0	1752892	1864395	312806	5445291
2150	5.90	3.30	9.30	2810353	292444	9324687	6188381	881942	18605640	3626043	0	13275550	12624780	2019515	37497870
2200	7.39	4.22	11.56	10723110	1026594	36637150	23586440	3181729	70261750	15631410	0	48940560	49940960	7534222	142634100

Table A3.7b. Regional impacts of different levels of temperature change for Latin America between 2020 and 2200 (% GDP)

Global mean temperature rise above 1990				Economic impacts % GDP			Non-economic impacts % GDP			Discontinuity impacts % GDP			Total impacts % GDP		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	0.07	0.01	0.18	0.15	0.02	0.37	0.00	0.00	0.00	0.22	0.04	0.50
2040	0.96	0.34	1.82	0.14	0.01	0.35	0.30	0.04	0.76	0.00	0.00	0.00	0.44	0.08	1.07
2060	1.73	0.78	3.06	0.27	0.03	0.71	0.59	0.10	1.53	0.02	0.00	0.00	0.88	0.17	2.26
2080	2.65	1.32	4.52	0.49	0.06	1.36	1.07	0.18	2.79	0.12	0.00	0.87	1.68	0.31	4.86
2100	3.65	1.90	6.03	0.80	0.10	2.39	1.77	0.30	4.90	0.49	0.00	2.88	3.06	0.51	8.95
2150	5.90	3.30	9.30	1.84	0.19	6.12	4.06	0.58	12.21	2.38	0.00	8.71	8.28	1.32	24.60
2200	7.39	4.22	11.56	2.81	0.27	9.60	6.18	0.83	18.40	4.09	0.00	12.82	13.08	1.97	37.36

Table A3.8a Regional impacts of different levels of temperature change for Rest of OECD between 2020 and 2200 ($$ million)

Global mean temperature rise above 1990				Economic impacts $$ million			Non-economic impacts $ million			Discontinuity impacts $$ million		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	0	0	0	983	123	2519	0	0	0
2040	0.96	0.34	1.82	16	0	96	2858	355	7883	0	0	0
2060	1.73	0.78	3.06	112	0	479	6376	754	18077	94	0	0
2080	2.65	1.32	4.52	397	7	1458	13828	1556	41480	1012	0	6865
2100	3.65	1.90	6.03	1120	47	3977	29878	3036	88973	6111	0	33129
2150	5.90	3.30	9.30	7949	459	26400	156547	13545	469995	75926	0	296876
2200	7.39	4.22	11.56	32764	1987	114340	578683	46411	1815734	330163	0	1109101

Table A3.8b Regional impacts of different levels of temperature change for Rest of OECD between 2020 and 2200 (% GDP)

Global mean temperature rise above 1990				Economic impacts % GDP			Non-economic impacts % GDP			Discontinuity impacts % GDP			Total impacts % GDP		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2020	0.38	0.10	0.80	0.00	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.03
2040	0.96	0.34	1.82	0.00	0.00	0.00	0.02	0.00	0.06	0.00	0.00	0.00	0.02	0.00	0.06
2060	1.73	0.78	3.06	0.00	0.00	0.00	0.04	0.00	0.11	0.00	0.00	0.00	0.04	0.00	0.11
2080	2.65	1.32	4.52	0.00	0.00	0.01	0.06	0.01	0.19	0.00	0.00	0.03	0.07	0.01	0.21
2100	3.65	1.90	6.03	0.00	0.00	0.01	0.10	0.01	0.30	0.02	0.00	0.11	0.13	0.01	0.42
2150	5.90	3.30	9.30	0.01	0.00	0.04	0.21	0.02	0.63	0.10	0.00	0.40	0.32	0.03	1.06
2200	7.39	4.22	11.56	0.02	0.00	0.06	0.31	0.03	0.98	0.18	0.00	0.60	0.51	0.05	1.62

Table A4.1. The regions in FUND.

Acronym	*Name*	*Countries*
USA	USA	United States of America
CAN	Canada	Canada
WEU	Western Europe	Andorra, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland, United Kingdom
JPK	Japan and South Korea	Japan, South Korea
ANZ	Australia and New Zealand	Australia, New Zealand
CEE	Central and Eastern Europe	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, FYR Macedonia, Poland, Romania, Slovakia, Slovenia, Yugoslavia
FSU	Former Soviet Union	Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan
MDE	Middle East	Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, West Bank and Gaza, Yemen
CAM	Central America	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama
SAM	South America	Argentina, Bolivia, Brazil, Chile, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela
SAS	South Asia	Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka
SEA	Southeast Asia	Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar, Papua New Guinea, Philippines, Singapore, Taiwan, Thailand, Vietnam
CHI	China plus	China, Hong Kong, North Korea, Macau, Mongolia
NAF	North Africa	Algeria, Egypt, Libya, Morocco, Tunisia, Western Sahara
SSA	Sub-Saharan	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape

Acronym	*Name*	*Countries*
	Africa	Verde, Central African Republic, Chad, Congo-Brazzaville, Congo-Kinshasa, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea- Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe
SIS	Small Island States	Antigua and Barbuda, Aruba, Bahamas, Barbados, Bermuda, Comoros, Cuba, Dominica, Dominican Republic, Fiji, French Polynesia, Grenada, Guadeloupe, Haiti, Jamaica, Kiribati, Maldives, Marshall Islands, Martinique, Mauritius, Micronesia, Nauru, Netherlands Antilles, New Caledonia, Palau, Puerto Rico, Reunion, Samoa, Sao Tome and Principe, Seychelles, Solomon Islands, St Kitts and Nevis, St Lucia, St Vincent and Grenadines, Tonga, Trinidad and Tobago, Tuvalu, Vanuatu, Virgin Islands

Table A4.2a. FUND Population in standard Scenario: 2000 = 100.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.57	0.44	0.79	0.60	0.49	0.70	0.62	0.25	0.27	0.33	0.34	0.35	0.43	0.31	0.28	0.43
1960	0.67	0.57	0.84	0.69	0.61	0.79	0.74	0.32	0.36	0.43	0.42	0.43	0.51	0.39	0.34	0.52
1970	0.75	0.68	0.91	0.79	0.73	0.86	0.83	0.43	0.50	0.56	0.53	0.55	0.65	0.50	0.44	0.64
1980	0.83	0.79	0.94	0.89	0.81	0.94	0.91	0.58	0.66	0.70	0.67	0.69	0.78	0.64	0.58	0.75
1990	0.91	0.89	0.97	0.96	0.87	0.99	0.99	0.80	0.82	0.85	0.83	0.85	0.90	0.82	0.77	0.87
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.06	1.06	1.01	1.07	1.11	1.01	1.00	1.23	1.15	1.13	1.16	1.15	1.09	1.23	1.27	1.13
2020	1.07	1.08	1.02	1.16	1.19	1.01	1.01	1.47	1.26	1.24	1.30	1.29	1.16	1.50	1.55	1.23
2030	1.08	1.09	1.03	1.20	1.24	1.02	1.01	1.67	1.34	1.32	1.42	1.41	1.20	1.75	1.80	1.31
2040	1.08	1.09	1.03	1.23	1.27	1.02	1.01	1.82	1.41	1.39	1.53	1.51	1.24	1.96	2.01	1.38
2050	1.07	1.08	1.02	1.25	1.30	1.01	1.01	1.94	1.47	1.44	1.64	1.61	1.26	2.14	2.20	1.43
2060	1.07	1.08	1.02	1.27	1.31	1.01	1.01	2.04	1.50	1.48	1.72	1.70	1.27	2.31	2.37	1.47
2070	1.06	1.07	1.01	1.28	1.32	1.00	1.00	2.15	1.54	1.52	1.81	1.78	1.28	2.49	2.56	1.50
2080	1.06	1.07	1.01	1.29	1.33	1.00	1.00	2.23	1.57	1.54	1.88	1.85	1.29	2.65	2.72	1.53
2090	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.27	1.57	1.55	1.91	1.89	1.30	2.75	2.83	1.54
2100	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.29	1.58	1.55	1.93	1.90	1.30	2.81	2.88	1.54
2110	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2120	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2130	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2140	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2150	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2160	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2170	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2180	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2190	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2200	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2210	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2220	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2230	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2240	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2250	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54

2260	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2270	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2280	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2290	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54
2300	1.06	1.07	1.01	1.30	1.34	1.00	1.00	2.30	1.58	1.55	1.93	1.91	1.30	2.83	2.91	1.54

Table A4.2b. FUND Population in A1B Scenario: 2000 = 100.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.57	0.44	0.79	0.60	0.49	0.70	0.62	0.25	0.27	0.33	0.34	0.35	0.43	0.31	0.28	0.43
1960	0.67	0.57	0.84	0.69	0.61	0.79	0.74	0.32	0.36	0.43	0.42	0.43	0.51	0.39	0.34	0.52
1970	0.75	0.68	0.91	0.79	0.73	0.86	0.83	0.43	0.50	0.56	0.53	0.55	0.65	0.50	0.44	0.64
1980	0.83	0.79	0.94	0.89	0.81	0.94	0.91	0.58	0.66	0.70	0.67	0.69	0.78	0.64	0.58	0.75
1990	0.91	0.89	0.97	0.96	0.87	0.99	0.99	0.80	0.82	0.85	0.83	0.85	0.90	0.82	0.77	0.87
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.06	1.07	1.03	1.04	1.07	1.01	1.01	1.16	1.19	1.18	1.14	1.12	1.09	1.20	1.23	1.17
2020	1.11	1.12	1.07	1.08	1.12	1.02	1.02	1.26	1.40	1.38	1.23	1.21	1.18	1.41	1.45	1.37
2030	1.14	1.15	1.11	1.12	1.15	1.02	1.02	1.31	1.57	1.54	1.29	1.27	1.23	1.58	1.62	1.53
2040	1.16	1.18	1.13	1.14	1.18	1.01	1.01	1.33	1.69	1.67	1.30	1.28	1.24	1.70	1.75	1.65
2050	1.18	1.19	1.14	1.15	1.19	0.98	0.98	1.30	1.78	1.75	1.28	1.26	1.22	1.79	1.84	1.74
2060	1.19	1.20	1.15	1.16	1.20	0.95	0.94	1.24	1.80	1.78	1.21	1.20	1.16	1.81	1.86	1.76
2070	1.19	1.20	1.15	1.16	1.20	0.91	0.90	1.17	1.80	1.77	1.14	1.13	1.09	1.81	1.86	1.76
2080	1.20	1.21	1.16	1.17	1.21	0.87	0.86	1.07	1.75	1.72	1.05	1.03	1.00	1.75	1.80	1.70
2090	1.20	1.22	1.17	1.18	1.22	0.82	0.82	0.96	1.66	1.63	0.94	0.93	0.90	1.67	1.71	1.62
2100	1.21	1.22	1.17	1.18	1.22	0.78	0.78	0.87	1.58	1.55	0.85	0.84	0.82	1.59	1.63	1.54
2110	1.22	1.23	1.18	1.19	1.23	0.75	0.75	0.79	1.51	1.48	0.77	0.76	0.74	1.51	1.55	1.47
2120	1.23	1.24	1.19	1.20	1.24	0.72	0.72	0.72	1.44	1.42	0.71	0.70	0.68	1.45	1.49	1.41
2130	1.23	1.24	1.19	1.20	1.24	0.69	0.69	0.67	1.39	1.37	0.66	0.65	0.63	1.40	1.43	1.36
2140	1.24	1.25	1.20	1.21	1.25	0.67	0.67	0.63	1.34	1.32	0.61	0.60	0.59	1.35	1.39	1.31
2150	1.24	1.25	1.20	1.21	1.25	0.65	0.65	0.59	1.31	1.29	0.58	0.57	0.55	1.31	1.35	1.28
2160	1.24	1.25	1.20	1.21	1.25	0.64	0.64	0.56	1.28	1.26	0.55	0.55	0.53	1.28	1.32	1.25
2170	1.25	1.26	1.21	1.22	1.26	0.63	0.63	0.54	1.25	1.24	0.53	0.53	0.51	1.26	1.30	1.23
2180	1.25	1.26	1.21	1.22	1.26	0.62	0.62	0.53	1.24	1.22	0.52	0.51	0.50	1.25	1.28	1.21
2190	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.24	1.27	1.20
2200	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.23	1.27	1.20
2210	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.23	1.27	1.20
2220	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.23	1.27	1.20
2230	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.23	1.27	1.20
2240	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.23	1.27	1.20
2250	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.23	1.27	1.20

2260	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.23	1.27	1.20
2270	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.23	1.27	1.20
2280	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.23	1.27	1.20
2290	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.23	1.27	1.20
2300	1.25	1.26	1.21	1.22	1.26	0.61	0.61	0.52	1.23	1.21	0.51	0.50	0.49	1.23	1.27	1.20

Table A4.2c. FUND Population in A2 Scenario: 2000 = 100

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.57	0.44	0.79	0.60	0.49	0.70	0.62	0.25	0.27	0.33	0.34	0.35	0.43	0.31	0.28	0.43
1960	0.67	0.57	0.84	0.69	0.61	0.79	0.74	0.32	0.36	0.43	0.42	0.43	0.51	0.39	0.34	0.52
1970	0.75	0.68	0.91	0.79	0.73	0.86	0.83	0.43	0.50	0.56	0.53	0.55	0.65	0.50	0.44	0.64
1980	0.83	0.79	0.94	0.89	0.81	0.94	0.91	0.58	0.66	0.70	0.67	0.69	0.78	0.64	0.58	0.75
1990	0.91	0.89	0.97	0.96	0.87	0.99	0.99	0.80	0.82	0.85	0.83	0.85	0.90	0.82	0.77	0.87
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.07	1.08	1.04	1.05	1.08	1.02	1.02	1.19	1.21	1.19	1.16	1.15	1.12	1.22	1.25	1.19
2020	1.12	1.13	1.09	1.10	1.13	1.06	1.06	1.34	1.46	1.44	1.31	1.29	1.25	1.47	1.51	1.43
2030	1.18	1.19	1.14	1.15	1.19	1.12	1.12	1.51	1.77	1.74	1.47	1.45	1.41	1.78	1.83	1.73
2040	1.22	1.23	1.18	1.19	1.23	1.17	1.17	1.66	2.08	2.05	1.63	1.60	1.56	2.09	2.15	2.03
2050	1.26	1.27	1.22	1.23	1.27	1.22	1.22	1.75	2.26	2.23	1.72	1.69	1.64	2.28	2.34	2.21
2060	1.30	1.31	1.26	1.27	1.31	1.28	1.28	1.84	2.44	2.40	1.80	1.78	1.73	2.45	2.52	2.38
2070	1.36	1.37	1.32	1.33	1.37	1.36	1.35	1.94	2.64	2.60	1.90	1.88	1.82	2.65	2.73	2.58
2080	1.48	1.49	1.43	1.45	1.49	1.49	1.49	2.08	2.91	2.87	2.03	2.01	1.95	2.93	3.01	2.84
2090	1.58	1.59	1.53	1.54	1.59	1.59	1.59	2.15	3.06	3.01	2.11	2.08	2.02	3.08	3.16	2.99
2100	1.63	1.64	1.58	1.59	1.64	1.64	1.64	2.19	3.13	3.09	2.14	2.11	2.05	3.15	3.24	3.06
2110	1.68	1.69	1.63	1.64	1.69	1.69	1.69	2.22	3.21	3.16	2.18	2.15	2.09	3.22	3.31	3.13
2120	1.72	1.74	1.67	1.68	1.74	1.74	1.74	2.26	3.27	3.22	2.21	2.18	2.12	3.29	3.38	3.20
2130	1.76	1.78	1.71	1.72	1.78	1.78	1.78	2.29	3.33	3.28	2.24	2.21	2.14	3.35	3.44	3.26
2140	1.80	1.82	1.74	1.76	1.82	1.82	1.82	2.31	3.39	3.33	2.26	2.23	2.17	3.40	3.50	3.31
2150	1.83	1.85	1.77	1.79	1.85	1.85	1.85	2.33	3.43	3.38	2.28	2.25	2.19	3.45	3.54	3.35
2160	1.86	1.87	1.80	1.81	1.87	1.88	1.88	2.35	3.47	3.41	2.30	2.27	2.20	3.49	3.58	3.39
2170	1.88	1.89	1.82	1.83	1.89	1.90	1.90	2.37	3.50	3.44	2.32	2.29	2.22	3.52	3.61	3.42
2180	1.89	1.91	1.83	1.85	1.91	1.92	1.91	2.38	3.52	3.46	2.33	2.29	2.23	3.54	3.64	3.44
2190	1.90	1.92	1.84	1.86	1.92	1.93	1.92	2.38	3.53	3.48	2.33	2.30	2.23	3.55	3.65	3.45
2200	1.90	1.92	1.84	1.86	1.92	1.93	1.93	2.38	3.54	3.48	2.33	2.30	2.24	3.56	3.65	3.46
2210	1.90	1.92	1.84	1.86	1.92	1.93	1.93	2.38	3.54	3.48	2.33	2.30	2.24	3.56	3.65	3.46
2220	1.90	1.92	1.84	1.86	1.92	1.93	1.93	2.38	3.54	3.48	2.33	2.30	2.24	3.56	3.65	3.46
2230	1.90	1.92	1.84	1.86	1.92	1.93	1.93	2.38	3.54	3.48	2.33	2.30	2.24	3.56	3.65	3.46
2240	1.90	1.92	1.84	1.86	1.92	1.93	1.93	2.38	3.54	3.48	2.33	2.30	2.24	3.56	3.65	3.46
2250	1.90	1.92	1.84	1.86	1.92	1.93	1.93	2.38	3.54	3.48	2.33	2.30	2.24	3.56	3.65	3.46

2260	1.90	1.92	1.84	1.86	1.92	1.93	1.93	2.38	3.54	3.48	2.33	2.30	2.24	3.56	3.65	3.46
2270	1.90	1.92	1.84	1.86	1.92	1.93	1.93	2.38	3.54	3.48	2.33	2.30	2.24	3.56	3.65	3.46
2280	1.90	1.92	1.84	1.86	1.92	1.93	1.93	2.38	3.54	3.48	2.33	2.30	2.24	3.56	3.65	3.46
2290	1.90	1.92	1.84	1.86	1.92	1.93	1.93	2.38	3.54	3.48	2.33	2.30	2.24	3.56	3.65	3.46
2300	1.90	1.92	1.84	1.86	1.92	1.93	1.93	2.38	3.54	3.48	2.33	2.30	2.24	3.56	3.65	3.46

Table A4.2d. FUND Population in B1 Scenario: 2000 = 100

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.57	0.44	0.79	0.60	0.49	0.70	0.62	0.25	0.27	0.33	0.34	0.35	0.43	0.31	0.28	0.43
1960	0.67	0.57	0.84	0.69	0.61	0.79	0.74	0.32	0.36	0.43	0.42	0.43	0.51	0.39	0.34	0.52
1970	0.75	0.68	0.91	0.79	0.73	0.86	0.83	0.43	0.50	0.56	0.53	0.55	0.65	0.50	0.44	0.64
1980	0.83	0.79	0.94	0.89	0.81	0.94	0.91	0.58	0.66	0.70	0.67	0.69	0.78	0.64	0.58	0.75
1990	0.91	0.89	0.97	0.96	0.87	0.99	0.99	0.80	0.82	0.85	0.83	0.85	0.90	0.82	0.77	0.87
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.07	1.08	1.03	1.04	1.08	1.01	1.01	1.17	1.19	1.17	1.14	1.13	1.09	1.20	1.23	1.17
2020	1.11	1.12	1.08	1.09	1.12	1.02	1.02	1.25	1.39	1.37	1.22	1.21	1.17	1.40	1.44	1.36
2030	1.15	1.16	1.11	1.12	1.16	1.02	1.02	1.30	1.55	1.53	1.27	1.26	1.22	1.56	1.61	1.52
2040	1.17	1.18	1.13	1.14	1.18	1.01	1.00	1.31	1.67	1.65	1.29	1.27	1.23	1.68	1.73	1.63
2050	1.18	1.19	1.14	1.15	1.19	0.98	0.98	1.29	1.76	1.73	1.27	1.25	1.21	1.76	1.81	1.71
2060	1.18	1.19	1.15	1.16	1.19	0.94	0.94	1.24	1.80	1.77	1.21	1.20	1.16	1.81	1.86	1.76
2070	1.19	1.20	1.15	1.16	1.20	0.90	0.90	1.16	1.80	1.77	1.14	1.12	1.09	1.81	1.86	1.76
2080	1.20	1.21	1.17	1.18	1.21	0.86	0.86	1.07	1.75	1.72	1.05	1.03	1.00	1.75	1.80	1.71
2090	1.21	1.22	1.17	1.18	1.22	0.82	0.82	0.96	1.65	1.62	0.94	0.93	0.90	1.65	1.70	1.61
2100	1.21	1.22	1.18	1.19	1.23	0.78	0.78	0.85	1.52	1.50	0.83	0.82	0.80	1.53	1.57	1.49
2110	1.22	1.23	1.18	1.19	1.23	0.74	0.74	0.75	1.41	1.39	0.74	0.73	0.71	1.42	1.46	1.38
2120	1.22	1.23	1.18	1.19	1.23	0.71	0.71	0.68	1.32	1.30	0.67	0.66	0.64	1.33	1.37	1.29
2130	1.22	1.23	1.19	1.20	1.23	0.68	0.68	0.62	1.25	1.23	0.61	0.60	0.58	1.26	1.29	1.22
2140	1.23	1.24	1.19	1.20	1.24	0.66	0.66	0.57	1.19	1.17	0.56	0.55	0.54	1.19	1.23	1.16
2150	1.23	1.24	1.19	1.20	1.24	0.64	0.64	0.53	1.14	1.12	0.52	0.52	0.50	1.14	1.18	1.11
2160	1.23	1.24	1.19	1.20	1.24	0.63	0.63	0.51	1.10	1.08	0.49	0.49	0.47	1.10	1.13	1.07
2170	1.23	1.24	1.19	1.20	1.24	0.62	0.62	0.48	1.07	1.05	0.47	0.47	0.45	1.07	1.10	1.04
2180	1.23	1.24	1.19	1.20	1.24	0.61	0.61	0.47	1.05	1.03	0.46	0.45	0.44	1.05	1.08	1.02
2190	1.23	1.24	1.19	1.20	1.24	0.61	0.60	0.46	1.04	1.02	0.45	0.44	0.43	1.04	1.07	1.01
2200	1.23	1.24	1.19	1.20	1.24	0.60	0.60	0.46	1.03	1.01	0.45	0.44	0.43	1.04	1.07	1.01
2210	1.23	1.24	1.19	1.20	1.24	0.60	0.60	0.46	1.03	1.01	0.45	0.44	0.43	1.04	1.07	1.01
2220	1.23	1.24	1.19	1.20	1.24	0.60	0.60	0.46	1.03	1.01	0.45	0.44	0.43	1.04	1.07	1.01
2230	1.23	1.24	1.19	1.20	1.24	0.60	0.60	0.46	1.03	1.01	0.45	0.44	0.43	1.04	1.07	1.01
2240	1.23	1.24	1.19	1.20	1.24	0.60	0.60	0.46	1.03	1.01	0.45	0.44	0.43	1.04	1.07	1.01
2250	1.23	1.24	1.19	1.20	1.24	0.60	0.60	0.46	1.03	1.01	0.45	0.44	0.43	1.04	1.07	1.01

2260	1.23	1.24	1.19	1.20	1.24	0.60	0.60	0.46	1.03	1.01	0.45	0.44	0.43	1.04	1.07	1.01
2270	1.23	1.24	1.19	1.20	1.24	0.60	0.60	0.46	1.03	1.01	0.45	0.44	0.43	1.04	1.07	1.01
2280	1.23	1.24	1.19	1.20	1.24	0.60	0.60	0.46	1.03	1.01	0.45	0.44	0.43	1.04	1.07	1.01
2290	1.23	1.24	1.19	1.20	1.24	0.60	0.60	0.46	1.03	1.01	0.45	0.44	0.43	1.04	1.07	1.01
2300	1.23	1.24	1.19	1.20	1.24	0.60	0.60	0.46	1.03	1.01	0.45	0.44	0.43	1.04	1.07	1.01

Table A4.2e. FUND Population in B2 Scenario: 2000 = 100

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.57	0.44	0.79	0.60	0.49	0.70	0.62	0.25	0.27	0.33	0.34	0.35	0.43	0.31	0.28	0.43
1960	0.67	0.57	0.84	0.69	0.61	0.79	0.74	0.32	0.36	0.43	0.42	0.43	0.51	0.39	0.34	0.52
1970	0.75	0.68	0.91	0.79	0.73	0.86	0.83	0.43	0.50	0.56	0.53	0.55	0.65	0.50	0.44	0.64
1980	0.83	0.79	0.94	0.89	0.81	0.94	0.91	0.58	0.66	0.70	0.67	0.69	0.78	0.64	0.58	0.75
1990	0.91	0.89	0.97	0.96	0.87	0.99	0.99	0.80	0.82	0.85	0.83	0.85	0.90	0.82	0.77	0.87
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.06	1.07	1.02	1.03	1.07	1.00	1.00	1.17	1.21	1.19	1.15	1.13	1.10	1.21	1.24	1.18
2020	1.08	1.09	1.05	1.06	1.09	1.00	1.00	1.27	1.44	1.41	1.25	1.23	1.19	1.44	1.48	1.40
2030	1.09	1.10	1.05	1.06	1.10	0.99	0.99	1.36	1.65	1.63	1.33	1.31	1.27	1.66	1.71	1.62
2040	1.08	1.09	1.04	1.05	1.09	0.98	0.98	1.42	1.85	1.82	1.39	1.37	1.33	1.86	1.91	1.80
2050	1.06	1.07	1.03	1.04	1.07	0.96	0.96	1.46	2.01	1.98	1.43	1.41	1.37	2.02	2.08	1.97
2060	1.05	1.06	1.02	1.03	1.06	0.94	0.94	1.48	2.16	2.12	1.45	1.43	1.39	2.17	2.23	2.11
2070	1.04	1.05	1.00	1.01	1.05	0.93	0.93	1.50	2.27	2.24	1.47	1.45	1.41	2.28	2.35	2.22
2080	1.03	1.04	0.99	1.00	1.04	0.92	0.92	1.51	2.36	2.32	1.48	1.46	1.42	2.37	2.44	2.31
2090	1.02	1.03	0.99	1.00	1.03	0.91	0.91	1.52	2.42	2.39	1.49	1.47	1.43	2.44	2.50	2.37
2100	1.01	1.02	0.98	0.99	1.02	0.91	0.91	1.53	2.47	2.44	1.50	1.48	1.43	2.49	2.56	2.42
2110	1.01	1.02	0.98	0.99	1.02	0.90	0.90	1.54	2.52	2.49	1.51	1.49	1.44	2.54	2.61	2.47
2120	1.00	1.01	0.97	0.98	1.01	0.90	0.90	1.55	2.57	2.53	1.51	1.49	1.45	2.58	2.66	2.51
2130	1.00	1.01	0.97	0.98	1.01	0.90	0.89	1.55	2.61	2.57	1.52	1.50	1.46	2.62	2.70	2.55
2140	1.00	1.00	0.96	0.97	1.00	0.89	0.89	1.56	2.65	2.61	1.53	1.51	1.46	2.66	2.73	2.59
2150	0.99	1.00	0.96	0.97	1.00	0.89	0.89	1.57	2.68	2.64	1.53	1.51	1.47	2.69	2.77	2.62
2160	0.99	1.00	0.96	0.97	1.00	0.89	0.89	1.57	2.70	2.66	1.54	1.52	1.47	2.72	2.79	2.64
2170	0.99	1.00	0.96	0.96	1.00	0.89	0.89	1.57	2.72	2.68	1.54	1.52	1.47	2.74	2.81	2.66
2180	0.99	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.74	2.70	1.54	1.52	1.48	2.75	2.83	2.68
2190	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.76	2.84	2.68
2200	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.77	2.84	2.69
2210	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.77	2.84	2.69
2220	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.77	2.84	2.69
2230	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.77	2.84	2.69
2240	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.77	2.84	2.69
2250	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.77	2.84	2.69
2260	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.77	2.84	2.69

2270	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.77	2.84	2.69
2280	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.77	2.84	2.69
2290	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.77	2.84	2.69
2300	0.98	0.99	0.95	0.96	0.99	0.89	0.88	1.58	2.75	2.71	1.54	1.52	1.48	2.77	2.84	2.69

Table A4.3a. FUND per capita income in standard Scenario; 2000=1.00.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.33	0.28	0.24	0.17	0.48	0.33	0.53	0.48	0.35	0.39	0.29	0.09	0.04	0.23	1.03	0.30
1960	0.39	0.37	0.32	0.23	0.54	0.44	0.69	0.60	0.50	0.54	0.31	0.15	0.05	0.33	1.12	0.40
1970	0.47	0.48	0.41	0.32	0.61	0.59	0.91	0.76	0.71	0.75	0.34	0.23	0.08	0.47	1.21	0.53
1980	0.57	0.63	0.54	0.44	0.68	0.78	1.20	0.96	1.01	1.04	0.36	0.35	0.12	0.67	1.30	0.71
1990	0.78	0.86	0.85	0.88	0.83	0.90	1.79	0.87	0.85	0.84	0.72	0.69	0.46	0.88	1.07	0.81
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.22	1.22	1.22	1.22	1.23	1.33	1.38	1.14	1.17	1.18	1.34	1.41	1.45	1.18	1.16	1.22
2020	1.45	1.46	1.46	1.46	1.47	1.88	1.96	1.46	1.49	1.50	1.71	1.80	1.91	1.51	1.49	1.56
2030	1.70	1.71	1.71	1.71	1.72	2.61	2.71	1.85	1.89	1.91	2.17	2.28	2.54	1.92	1.89	1.98
2040	1.96	1.98	1.97	1.96	1.98	3.43	3.56	2.35	2.40	2.42	2.75	2.89	3.39	2.43	2.40	2.52
2050	2.22	2.24	2.23	2.22	2.24	4.27	4.43	2.98	3.04	3.07	3.48	3.66	4.51	3.08	3.03	3.19
2060	2.49	2.51	2.50	2.48	2.50	5.15	5.35	3.78	3.87	3.89	4.43	4.65	6.00	3.91	3.85	4.05
2070	2.79	2.80	2.79	2.78	2.80	6.23	6.46	4.84	4.95	4.99	5.67	5.96	7.95	5.01	4.94	5.18
2080	3.11	3.13	3.11	3.11	3.13	7.51	7.79	6.24	6.38	6.42	7.30	7.68	10.50	6.45	6.36	6.68
2090	3.43	3.46	3.44	3.43	3.46	8.78	9.11	7.89	8.06	8.12	9.23	9.71	13.48	8.16	8.04	8.44
2100	3.75	3.77	3.75	3.75	3.78	9.90	10.27	9.74	9.96	10.03	11.40	11.99	16.73	10.07	9.93	10.42
2110	4.05	4.07	4.05	4.05	4.08	10.92	11.33	11.77	12.03	12.12	13.77	14.48	20.22	12.17	11.99	12.59
2120	4.36	4.39	4.36	4.36	4.39	11.99	12.44	13.94	14.25	14.36	16.32	17.16	23.95	14.42	14.21	14.92
2130	4.68	4.70	4.68	4.68	4.71	13.12	13.61	16.20	16.56	16.68	18.95	19.93	27.83	16.75	16.51	17.33
2140	4.99	5.03	5.00	4.99	5.03	14.29	14.83	18.45	18.86	19.00	21.59	22.70	31.70	19.08	18.80	19.74
2150	5.31	5.35	5.31	5.31	5.36	15.51	16.09	20.60	21.06	21.21	24.11	25.35	35.40	21.31	21.00	22.05
2160	5.64	5.68	5.64	5.64	5.69	16.80	17.43	22.76	23.26	23.43	26.63	28.00	39.10	23.54	23.19	24.35
2170	5.99	6.03	5.99	5.99	6.04	18.19	18.87	25.14	25.69	25.88	29.42	30.93	43.19	26.00	25.62	26.90
2180	6.36	6.40	6.36	6.36	6.41	19.70	20.44	27.77	28.38	28.59	32.49	34.17	47.71	28.72	28.30	29.72
2190	6.75	6.79	6.75	6.75	6.80	21.34	22.14	30.68	31.35	31.58	35.89	37.74	52.70	31.73	31.26	32.83
2200	7.17	7.21	7.17	7.17	7.22	23.10	23.97	33.89	34.63	34.89	39.65	41.69	58.21	35.05	34.53	36.26
2210	7.61	7.66	7.61	7.61	7.67	24.98	25.91	37.36	38.19	38.47	43.72	45.97	64.19	38.65	38.07	39.98
2220	8.08	8.13	8.08	8.08	8.14	26.89	27.90	41.04	41.94	42.25	48.02	50.49	70.50	42.44	41.82	43.91
2230	8.58	8.63	8.58	8.57	8.64	28.84	29.92	44.89	45.88	46.22	52.53	55.24	77.12	46.43	45.75	48.04

2240	9.10	9.16	9.11	9.10	9.18	30.81	31.96	48.92	49.99	50.36	57.23	60.19	84.03	50.59	49.85	52.34
2250	9.67	9.73	9.67	9.66	9.74	32.78	34.01	53.09	54.26	54.66	62.12	65.32	91.20	54.91	54.10	56.81
2260	10.26	10.33	10.26	10.26	10.34	34.80	36.11	57.39	58.65	59.09	67.15	70.61	98.59	59.36	58.48	61.41
2270	10.89	10.96	10.89	10.89	10.98	36.95	38.33	61.79	63.15	63.62	72.30	76.03	106.15	63.91	62.97	66.12
2280	11.57	11.64	11.57	11.56	11.66	39.22	40.69	66.27	67.73	68.23	77.54	81.54	113.85	68.54	67.53	70.91
2290	12.28	12.36	12.28	12.28	12.38	41.64	43.20	70.79	72.35	72.88	82.83	87.10	121.61	73.22	72.14	75.75
2300	13.04	13.12	13.04	13.03	13.14	44.21	45.87	75.32	76.98	77.54	88.13	92.67	129.39	77.90	76.75	80.60

Table A4.3b. FUND per capita income in A1B Scenario; 2000=1.00.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.33	0.28	0.24	0.17	0.48	0.33	0.53	0.48	0.35	0.39	0.29	0.09	0.04	0.23	1.03	0.30
1960	0.39	0.37	0.32	0.23	0.54	0.44	0.69	0.60	0.50	0.54	0.31	0.15	0.05	0.33	1.12	0.40
1970	0.47	0.48	0.41	0.32	0.61	0.59	0.91	0.76	0.71	0.75	0.34	0.23	0.08	0.47	1.21	0.53
1980	0.57	0.63	0.54	0.44	0.68	0.78	1.20	0.96	1.01	1.04	0.36	0.35	0.12	0.67	1.30	0.71
1990	0.78	0.86	0.85	0.88	0.83	0.90	1.79	0.87	0.85	0.84	0.72	0.69	0.46	0.88	1.07	0.81
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.20	1.21	1.20	1.20	1.21	1.09	1.13	1.53	1.40	1.39	1.79	1.84	1.90	1.40	1.38	1.44
2020	1.42	1.42	1.41	1.41	1.42	2.00	2.07	3.02	2.29	2.28	3.52	3.63	3.73	2.29	2.25	2.37
2030	1.66	1.67	1.66	1.66	1.67	3.40	3.52	5.33	3.62	3.60	6.20	6.40	6.59	3.62	3.57	3.75
2040	1.95	1.95	1.94	1.94	1.96	5.27	5.47	8.17	5.48	5.45	9.52	9.82	10.10	5.47	5.39	5.66
2050	2.29	2.30	2.28	2.29	2.30	7.57	7.85	12.14	7.78	7.74	14.14	14.60	15.02	7.77	7.66	8.04
2060	2.70	2.71	2.69	2.69	2.71	9.90	10.27	17.36	10.22	10.17	20.22	20.87	21.47	10.21	10.06	10.57
2070	3.17	3.18	3.16	3.16	3.18	12.82	13.31	24.34	13.29	13.22	28.36	29.28	30.11	13.28	13.09	13.74
2080	3.69	3.70	3.68	3.68	3.70	16.27	16.88	32.72	16.88	16.80	38.12	39.35	40.48	16.88	16.63	17.46
2090	4.28	4.28	4.26	4.26	4.29	20.40	21.16	42.96	21.17	21.07	50.05	51.67	53.15	21.16	20.85	21.90
2100	4.96	4.97	4.94	4.94	4.97	25.26	26.21	55.77	26.22	26.08	64.97	67.07	68.99	26.20	25.82	27.11
2110	5.74	5.75	5.72	5.73	5.76	30.65	31.80	70.92	31.82	31.66	82.62	85.29	87.73	31.80	31.33	32.90
2120	6.61	6.63	6.60	6.60	6.64	36.84	38.22	88.87	38.24	38.04	103.53	106.88	109.94	38.22	37.65	39.54
2130	7.58	7.60	7.56	7.56	7.61	43.84	45.48	109.75	45.51	45.27	127.86	131.99	135.77	45.48	44.81	47.06
2140	8.65	8.67	8.63	8.63	8.68	51.66	53.60	133.56	53.62	53.35	155.59	160.62	165.22	53.59	52.80	55.45
2150	9.82	9.84	9.80	9.80	9.86	60.28	62.54	160.15	62.57	62.25	186.57	192.60	198.11	62.54	61.61	64.70
2160	11.10	11.12	11.07	11.07	11.14	69.65	72.26	189.23	72.29	71.93	220.45	227.57	234.09	72.26	71.19	74.76
2170	12.48	12.50	12.44	12.44	12.52	79.68	82.67	220.32	82.71	82.29	256.66	264.95	272.54	82.67	81.44	85.53
2180	13.96	13.98	13.92	13.92	14.00	90.26	93.65	252.74	93.70	93.22	294.43	303.95	312.65	93.65	92.26	96.89
2190	15.54	15.57	15.49	15.50	15.59	101.25	105.05	285.68	105.10	104.56	332.80	343.56	353.39	105.04	103.49	108.68
2200	17.21	17.24	17.16	17.16	17.27	112.45	116.67	318.15	116.73	116.13	370.63	382.61	393.57	116.66	114.94	120.70
2210	18.97	19.01	18.92	18.93	19.04	123.99	128.65	350.81	128.71	128.05	408.68	421.89	433.97	128.64	126.74	133.09
2220	20.84	20.88	20.78	20.79	20.91	136.18	141.29	385.30	141.36	140.64	448.85	463.36	476.62	141.29	139.20	146.18
2230	22.80	22.84	22.73	22.74	22.87	148.98	154.57	421.50	154.64	153.85	491.02	506.89	521.40	154.56	152.28	159.91

2240	24.84	24.89	24.77	24.78	24.92	162.33	168.42	459.27	168.50	167.64	535.03	552.32	568.13	168.41	165.93	174.24
2250	26.96	27.01	26.88	26.89	27.05	176.18	182.79	498.45	182.88	181.94	580.67	599.44	616.60	182.78	180.08	189.10
2260	29.14	29.20	29.06	29.07	29.24	190.45	197.59	538.83	197.69	196.68	627.71	648.00	666.55	197.58	194.67	204.42
2270	31.38	31.44	31.29	31.30	31.49	205.06	212.75	580.17	212.86	211.77	675.87	697.71	717.69	212.75	209.60	220.11
2280	33.65	33.72	33.56	33.57	33.77	219.92	228.17	622.21	228.28	227.12	724.84	748.27	769.69	228.16	224.79	236.06
2290	35.95	36.02	35.85	35.86	36.07	234.92	243.73	664.65	243.85	242.61	774.28	799.31	822.19	243.72	240.12	252.16
2300	38.25	38.32	38.14	38.15	38.38	249.95	259.32	707.17	259.45	258.13	823.81	850.44	874.79	259.31	255.49	268.29

Table A4.3c. FUND per capita income in A2 Scenario; 2000=1.00

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.33	0.28	0.24	0.17	0.48	0.33	0.53	0.48	0.35	0.39	0.29	0.09	0.04	0.23	1.03	0.30
1960	0.39	0.37	0.32	0.23	0.54	0.44	0.69	0.60	0.50	0.54	0.31	0.15	0.05	0.33	1.12	0.40
1970	0.47	0.48	0.41	0.32	0.61	0.59	0.91	0.76	0.71	0.75	0.34	0.23	0.08	0.47	1.21	0.53
1980	0.57	0.63	0.54	0.44	0.68	0.78	1.20	0.96	1.01	1.04	0.36	0.35	0.12	0.67	1.30	0.71
1990	0.78	0.86	0.85	0.88	0.83	0.90	1.79	0.87	0.85	0.84	0.72	0.69	0.46	0.88	1.07	0.81
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.15	1.15	1.15	1.16	1.16	0.92	0.96	1.17	1.15	1.16	1.37	1.42	1.46	1.17	1.15	1.21
2020	1.27	1.28	1.27	1.28	1.28	1.23	1.27	1.54	1.45	1.46	1.80	1.86	1.91	1.47	1.45	1.52
2030	1.45	1.45	1.44	1.45	1.45	1.73	1.80	2.09	1.87	1.88	2.44	2.52	2.59	1.89	1.86	1.96
2040	1.62	1.62	1.62	1.62	1.63	2.25	2.33	2.70	2.29	2.31	3.15	3.26	3.35	2.32	2.29	2.40
2050	1.75	1.75	1.75	1.76	1.76	2.66	2.76	3.19	2.64	2.66	3.73	3.86	3.97	2.67	2.63	2.76
2060	1.90	1.91	1.90	1.91	1.91	3.16	3.27	3.80	3.06	3.08	4.45	4.60	4.73	3.10	3.05	3.21
2070	2.10	2.11	2.10	2.11	2.11	3.87	4.02	4.71	3.66	3.69	5.51	5.69	5.85	3.71	3.65	3.84
2080	2.46	2.47	2.45	2.47	2.47	5.25	5.45	6.53	4.88	4.92	7.64	7.89	8.12	4.94	4.87	5.11
2090	2.74	2.75	2.73	2.75	2.75	6.44	6.68	8.17	5.97	6.02	9.56	9.87	10.15	6.05	5.96	6.26
2100	2.95	2.95	2.94	2.96	2.96	7.11	7.38	9.06	6.57	6.62	10.60	10.95	11.26	6.65	6.56	6.88
2110	3.26	3.26	3.25	3.27	3.27	7.85	8.15	10.01	7.26	7.32	11.70	12.09	12.44	7.35	7.24	7.60
2120	3.60	3.60	3.59	3.61	3.61	8.67	9.00	11.05	8.02	8.08	12.93	13.36	13.74	8.12	8.00	8.40
2130	3.97	3.98	3.96	3.99	3.99	9.58	9.94	12.21	8.86	8.93	14.28	14.75	15.18	8.97	8.84	9.28
2140	4.39	4.40	4.38	4.40	4.40	10.58	10.98	13.49	9.78	9.86	15.78	16.30	16.76	9.91	9.76	10.25
2150	4.85	4.86	4.83	4.86	4.86	11.69	12.13	14.90	10.81	10.89	17.43	18.00	18.52	10.94	10.78	11.32
2160	5.35	5.37	5.34	5.37	5.37	12.92	13.40	16.46	11.94	12.03	19.25	19.89	20.46	12.09	11.91	12.51
2170	5.92	5.93	5.90	5.93	5.94	14.27	14.80	18.18	13.18	13.29	21.26	21.97	22.60	13.35	13.16	13.82
2180	6.53	6.55	6.52	6.55	6.56	15.76	16.35	20.08	14.56	14.68	23.49	24.27	24.96	14.75	14.53	15.26
2190	7.22	7.23	7.20	7.24	7.24	17.41	18.06	22.18	16.09	16.22	25.95	26.80	27.57	16.29	16.05	16.86
2200	7.97	7.99	7.95	8.00	8.00	19.23	19.95	24.50	17.77	17.92	28.66	29.61	30.46	18.00	17.73	18.62
2210	8.79	8.81	8.77	8.82	8.82	21.20	22.00	27.02	19.60	19.76	31.60	32.65	33.58	19.85	19.55	20.53
2220	9.66	9.67	9.63	9.69	9.69	23.29	24.16	29.68	21.52	21.70	34.71	35.86	36.88	21.80	21.48	22.55
2230	10.56	10.58	10.53	10.60	10.60	25.48	26.43	32.46	23.54	23.74	37.97	39.23	40.35	23.84	23.49	24.67

2240	11.51	11.53	11.48	11.55	11.55	27.76	28.80	35.37	25.65	25.86	41.37	42.74	43.97	25.98	25.60	26.88
2250	12.49	12.52	12.46	12.53	12.53	30.13	31.26	38.39	27.84	28.07	44.90	46.39	47.72	28.20	27.78	29.17
2260	13.50	13.53	13.47	13.55	13.55	32.57	33.79	41.50	30.10	30.34	48.54	50.15	51.58	30.48	30.03	31.54
2270	14.54	14.57	14.50	14.59	14.59	35.07	36.38	44.69	32.41	32.67	52.26	53.99	55.54	32.82	32.34	33.96
2280	15.59	15.62	15.55	15.64	15.65	37.61	39.02	47.92	34.75	35.04	56.05	57.91	59.56	35.20	34.68	36.42
2290	16.66	16.69	16.61	16.71	16.71	40.17	41.68	51.19	37.12	37.43	59.87	61.86	63.63	37.60	37.05	38.90
2300	17.72	17.76	17.67	17.78	17.78	42.74	44.35	54.47	39.50	39.82	63.70	65.81	67.70	40.01	39.42	41.39

Table A4.3d. FUND per capita income in B1 Scenario; 2000=1.00

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.33	0.28	0.24	0.17	0.48	0.33	0.53	0.48	0.35	0.39	0.29	0.09	0.04	0.23	1.03	0.30
1960	0.39	0.37	0.32	0.23	0.54	0.44	0.69	0.60	0.50	0.54	0.31	0.15	0.05	0.33	1.12	0.40
1970	0.47	0.48	0.41	0.32	0.61	0.59	0.91	0.76	0.71	0.75	0.34	0.23	0.08	0.47	1.21	0.53
1980	0.57	0.63	0.54	0.44	0.68	0.78	1.20	0.96	1.01	1.04	0.36	0.35	0.12	0.67	1.30	0.71
1990	0.78	0.86	0.85	0.88	0.83	0.90	1.79	0.87	0.85	0.84	0.72	0.69	0.46	0.88	1.07	0.81
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.21	1.21	1.21	1.21	1.22	1.04	1.08	1.36	1.31	1.31	1.59	1.64	1.69	1.31	1.29	1.36
2020	1.42	1.42	1.41	1.41	1.42	1.71	1.78	2.25	1.96	1.96	2.63	2.71	2.79	1.97	1.94	2.04
2030	1.60	1.61	1.60	1.60	1.61	2.72	2.82	3.68	2.95	2.95	4.29	4.43	4.56	2.96	2.92	3.06
2040	1.80	1.80	1.79	1.79	1.80	4.12	4.27	5.79	4.31	4.31	6.75	6.97	7.17	4.33	4.27	4.48
2050	2.00	2.01	2.00	2.00	2.01	5.86	6.08	8.49	5.93	5.93	9.91	10.24	10.53	5.95	5.87	6.16
2060	2.19	2.19	2.18	2.18	2.20	7.85	8.15	11.62	7.71	7.71	13.56	14.01	14.41	7.74	7.63	8.01
2070	2.38	2.38	2.37	2.37	2.38	10.26	10.65	15.35	9.84	9.84	17.91	18.50	19.03	9.88	9.74	10.22
2080	2.61	2.62	2.61	2.60	2.62	13.16	13.65	19.92	12.38	12.38	23.24	24.00	24.69	12.43	12.25	12.86
2090	2.89	2.90	2.89	2.88	2.90	16.50	17.12	25.46	15.34	15.34	29.71	30.68	31.56	15.41	15.18	15.94
2100	3.21	3.21	3.20	3.20	3.22	20.31	21.07	31.74	18.85	18.84	37.05	38.26	39.35	18.92	18.64	19.58
2110	3.54	3.55	3.53	3.53	3.56	24.65	25.57	38.53	22.87	22.86	44.96	46.43	47.76	22.96	22.63	23.76
2120	3.91	3.92	3.90	3.90	3.93	29.62	30.73	46.30	27.49	27.47	54.03	55.80	57.39	27.60	27.19	28.55
2130	4.32	4.33	4.31	4.31	4.34	35.25	36.57	55.10	32.71	32.69	64.30	66.40	68.30	32.84	32.36	33.98
2140	4.78	4.78	4.76	4.76	4.79	41.54	43.10	64.93	38.55	38.52	75.77	78.24	80.48	38.70	38.13	40.04
2150	5.28	5.29	5.26	5.26	5.29	48.47	50.29	75.76	44.98	44.95	88.41	91.30	93.91	45.16	44.49	46.72
2160	5.83	5.84	5.81	5.81	5.85	56.00	58.10	87.53	51.97	51.94	102.15	105.49	108.51	52.18	51.41	53.98
2170	6.44	6.45	6.42	6.41	6.46	64.07	66.47	100.14	59.45	59.42	116.87	120.68	124.14	59.69	58.81	61.76
2180	7.11	7.12	7.09	7.09	7.13	72.58	75.30	113.44	67.35	67.31	132.39	136.71	140.63	67.62	66.62	69.96
2190	7.85	7.87	7.83	7.83	7.88	81.41	84.47	127.25	75.55	75.50	148.50	153.35	157.74	75.85	74.73	78.48
2200	8.68	8.69	8.65	8.65	8.71	90.42	93.81	141.33	83.90	83.86	164.93	170.32	175.19	84.24	83.00	87.16
2210	9.57	9.59	9.54	9.53	9.60	99.70	103.44	155.84	92.52	92.47	181.86	187.80	193.18	92.89	91.52	96.11
2220	10.51	10.53	10.48	10.47	10.54	109.50	113.61	171.16	101.61	101.56	199.74	206.26	212.17	102.02	100.52	105.55
2230	11.49	11.52	11.46	11.45	11.53	119.79	124.29	187.24	111.16	111.10	218.50	225.64	232.10	111.61	109.96	115.47

2240	12.52	12.55	12.49	12.48	12.57	130.53	135.42	204.02	121.12	121.05	238.09	245.86	252.90	121.61	119.82	125.82
2250	13.59	13.62	13.55	13.54	13.64	141.66	146.98	221.42	131.45	131.38	258.40	266.84	274.48	131.98	130.04	136.55
2260	14.69	14.72	14.65	14.64	14.74	153.14	158.88	239.36	142.10	142.02	279.33	288.45	296.71	142.68	140.57	147.62
2270	15.82	15.85	15.78	15.76	15.87	164.89	171.07	257.73	153.01	152.92	300.76	310.59	319.48	153.62	151.36	158.94
2280	16.97	17.00	16.92	16.91	17.02	176.84	183.47	276.40	164.09	164.00	322.56	333.09	342.63	164.76	162.32	170.46
2290	18.12	18.16	18.07	18.06	18.19	188.90	195.98	295.25	175.28	175.19	344.56	355.81	366.00	175.99	173.39	182.08
2300	19.28	19.32	19.23	19.22	19.35	200.98	208.52	314.14	186.50	186.39	366.60	378.57	389.41	187.25	184.49	193.73

Table A4.3e. FUND per capita income in B2 Scenario; 2000=1.00 2000=1.0

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.33	0.28	0.24	0.17	0.48	0.33	0.53	0.48	0.35	0.39	0.29	0.09	0.04	0.23	1.03	0.30
1960	0.39	0.37	0.32	0.23	0.54	0.44	0.69	0.60	0.50	0.54	0.31	0.15	0.05	0.33	1.12	0.40
1970	0.47	0.48	0.41	0.32	0.61	0.59	0.91	0.76	0.71	0.75	0.34	0.23	0.08	0.47	1.21	0.53
1980	0.57	0.63	0.54	0.44	0.68	0.78	1.20	0.96	1.01	1.04	0.36	0.35	0.12	0.67	1.30	0.71
1990	0.78	0.86	0.85	0.88	0.83	0.90	1.79	0.87	0.85	0.84	0.72	0.69	0.46	0.88	1.07	0.81
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.16	1.16	1.15	1.16	1.16	0.99	1.03	1.37	1.13	1.14	1.60	1.65	1.70	1.15	1.13	1.19
2020	1.27	1.27	1.26	1.27	1.27	1.52	1.57	2.18	1.46	1.48	2.55	2.63	2.70	1.48	1.46	1.53
2030	1.37	1.38	1.37	1.38	1.38	2.41	2.50	3.14	2.06	2.08	3.67	3.78	3.89	2.09	2.06	2.17
2040	1.49	1.49	1.49	1.50	1.50	3.77	3.91	4.22	2.99	3.02	4.93	5.09	5.24	3.03	2.98	3.13
2050	1.61	1.62	1.61	1.62	1.62	5.34	5.54	5.40	4.11	4.15	6.30	6.51	6.70	4.17	4.11	4.31
2060	1.76	1.76	1.75	1.76	1.76	6.90	7.16	6.59	5.27	5.32	7.69	7.94	8.17	5.34	5.26	5.53
2070	1.93	1.93	1.92	1.93	1.93	8.28	8.59	7.79	6.31	6.37	9.08	9.38	9.65	6.40	6.30	6.62
2080	2.10	2.11	2.10	2.11	2.11	9.39	9.75	8.94	7.18	7.25	10.43	10.77	11.08	7.28	7.18	7.54
2090	2.30	2.31	2.30	2.31	2.31	10.44	10.84	10.11	7.99	8.06	11.80	12.18	12.53	8.10	7.98	8.38
2100	2.53	2.54	2.53	2.54	2.54	11.54	11.97	11.28	8.82	8.90	13.16	13.59	13.98	8.94	8.81	9.25
2110	2.80	2.80	2.79	2.80	2.81	12.74	13.22	12.46	9.74	9.83	14.54	15.01	15.44	9.88	9.73	10.22
2120	3.09	3.10	3.08	3.10	3.10	14.08	14.61	13.76	10.76	10.86	16.06	16.58	17.06	10.91	10.75	11.29
2130	3.41	3.42	3.40	3.42	3.42	15.55	16.13	15.20	11.88	12.00	17.74	18.32	18.84	12.05	11.87	12.47
2140	3.77	3.78	3.76	3.78	3.78	17.18	17.82	16.79	13.13	13.25	19.59	20.23	20.81	13.31	13.12	13.77
2150	4.16	4.17	4.15	4.18	4.18	18.97	19.69	18.55	14.50	14.64	21.64	22.35	22.99	14.71	14.49	15.21
2160	4.60	4.61	4.59	4.61	4.62	20.96	21.75	20.49	16.02	16.17	23.91	24.69	25.39	16.24	16.00	16.81
2170	5.08	5.09	5.07	5.10	5.10	23.15	24.02	22.63	17.69	17.86	26.41	27.27	28.05	17.94	17.68	18.56
2180	5.61	5.62	5.60	5.63	5.63	25.57	26.53	25.00	19.55	19.73	29.17	30.12	30.99	19.82	19.53	20.51
2190	6.20	6.21	6.18	6.22	6.22	28.25	29.31	27.61	21.59	21.79	32.22	33.27	34.23	21.89	21.57	22.65
2200	6.85	6.86	6.83	6.87	6.87	31.21	32.38	30.50	23.85	24.07	35.59	36.76	37.81	24.19	23.83	25.02
2210	7.55	7.57	7.53	7.57	7.58	34.41	35.70	33.64	26.30	26.55	39.25	40.53	41.69	26.67	26.27	27.59
2220	8.29	8.31	8.27	8.32	8.32	37.79	39.21	36.94	28.88	29.16	43.11	44.51	45.79	29.29	28.86	30.30
2230	9.07	9.09	9.05	9.10	9.11	41.34	42.89	40.41	31.60	31.89	47.16	48.69	50.09	32.04	31.57	33.15

2240	9.89	9.91	9.86	9.91	9.92	45.05	46.74	44.03	34.43	34.75	51.38	53.06	54.58	34.91	34.40	36.12
2250	10.73	10.75	10.70	10.76	10.77	48.89	50.72	47.79	37.37	37.72	55.77	57.59	59.23	37.89	37.33	39.20
2260	11.60	11.62	11.57	11.63	11.64	52.85	54.83	51.66	40.39	40.77	60.28	62.25	64.03	40.96	40.36	42.38
2270	12.49	12.51	12.45	12.52	12.53	56.91	59.04	55.63	43.49	43.90	64.91	67.03	68.95	44.10	43.45	45.63
2280	13.39	13.42	13.36	13.43	13.44	61.03	63.32	59.66	46.64	47.08	69.61	71.88	73.94	47.30	46.60	48.94
2290	14.31	14.34	14.27	14.35	14.36	65.19	67.64	63.73	49.82	50.29	74.36	76.79	78.98	50.53	49.78	52.27
2300	15.22	15.25	15.18	15.26	15.28	69.36	71.96	67.80	53.01	53.51	79.12	81.70	84.04	53.76	52.96	55.62

Table A4.4a. Autonomous energy efficiency (AEEI) in FUND standard scenario 2000=1.0

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.66	0.60	0.60	1.42	1.05	0.80	1.21	2.75	1.12	0.97	1.76	1.65	1.23	1.23	1.53	1.25
1960	0.74	0.70	0.59	1.16	1.06	0.70	1.03	1.91	1.08	0.98	1.51	1.33	0.46	1.32	1.36	1.02
1970	0.71	0.68	0.59	0.79	1.11	0.65	1.00	1.41	1.15	1.01	1.39	1.03	0.62	1.06	1.17	0.87
1980	0.79	0.73	0.65	0.86	1.11	0.66	0.99	1.34	1.04	1.09	1.14	1.08	0.60	0.99	1.10	0.85
1990	0.96	0.98	0.90	1.04	0.98	0.86	1.20	1.09	1.01	1.04	1.02	1.11	0.81	1.04	0.99	1.06
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.08	1.07	1.09	1.05	1.07	1.09	0.99	1.00	1.06	1.05	1.06	1.02	1.16	1.05	1.07	1.03
2020	1.17	1.16	1.16	1.14	1.16	1.16	1.09	1.06	1.16	1.15	1.16	1.12	1.27	1.15	1.17	1.11
2030	1.23	1.22	1.21	1.19	1.22	1.25	1.18	1.14	1.26	1.25	1.26	1.22	1.39	1.25	1.27	1.21
2040	1.27	1.26	1.26	1.24	1.26	1.34	1.27	1.23	1.36	1.35	1.36	1.32	1.52	1.35	1.37	1.30
2050	1.31	1.30	1.30	1.28	1.30	1.42	1.34	1.32	1.46	1.45	1.46	1.41	1.65	1.45	1.47	1.40
2060	1.35	1.34	1.34	1.31	1.34	1.49	1.41	1.42	1.57	1.55	1.56	1.51	1.78	1.55	1.58	1.50
2070	1.39	1.38	1.37	1.35	1.38	1.55	1.47	1.51	1.67	1.65	1.66	1.61	1.92	1.65	1.68	1.60
2080	1.42	1.41	1.41	1.38	1.41	1.62	1.53	1.60	1.77	1.75	1.77	1.71	2.06	1.75	1.79	1.69
2090	1.46	1.45	1.44	1.42	1.45	1.68	1.59	1.70	1.87	1.85	1.87	1.81	2.20	1.85	1.89	1.79
2100	1.49	1.48	1.47	1.45	1.48	1.73	1.64	1.79	1.97	1.95	1.97	1.91	2.34	1.95	1.99	1.89
2110	1.52	1.51	1.50	1.48	1.51	1.78	1.69	1.88	2.07	2.05	2.06	2.00	2.48	2.05	2.09	1.98
2120	1.55	1.54	1.53	1.50	1.54	1.82	1.73	1.96	2.16	2.14	2.16	2.09	2.61	2.14	2.18	2.07
2130	1.58	1.57	1.56	1.54	1.57	1.86	1.76	2.04	2.25	2.23	2.25	2.18	2.75	2.23	2.27	2.15
2140	1.61	1.60	1.60	1.57	1.60	1.90	1.80	2.12	2.34	2.31	2.33	2.26	2.88	2.31	2.36	2.23
2150	1.65	1.63	1.63	1.60	1.63	1.94	1.83	2.19	2.41	2.39	2.40	2.33	3.00	2.39	2.43	2.31
2160	1.68	1.67	1.66	1.63	1.67	1.98	1.87	2.26	2.49	2.46	2.48	2.41	3.13	2.46	2.51	2.38
2170	1.71	1.70	1.69	1.66	1.70	2.02	1.91	2.34	2.58	2.55	2.57	2.50	3.27	2.55	2.60	2.47
2180	1.75	1.73	1.73	1.70	1.73	2.06	1.95	2.41	2.66	2.63	2.65	2.57	3.40	2.63	2.68	2.54
2190	1.78	1.77	1.76	1.73	1.77	2.10	1.99	2.46	2.71	2.68	2.70	2.62	3.49	2.68	2.73	2.59
2200	1.82	1.80	1.80	1.77	1.80	2.14	2.03	2.51	2.77	2.74	2.76	2.67	3.57	2.74	2.79	2.64
2210	1.86	1.84	1.84	1.80	1.84	2.18	2.07	2.56	2.82	2.79	2.81	2.73	3.64	2.79	2.84	2.70
2220	1.89	1.88	1.87	1.84	1.88	2.23	2.11	2.61	2.88	2.85	2.87	2.78	3.72	2.85	2.90	2.75
2230	1.93	1.92	1.91	1.87	1.92	2.27	2.15	2.66	2.94	2.90	2.93	2.84	3.79	2.90	2.96	2.81
2240	1.97	1.95	1.95	1.91	1.95	2.32	2.20	2.71	3.00	2.96	2.99	2.90	3.87	2.96	3.02	2.86
2250	2.01	1.99	1.99	1.95	1.99	2.37	2.24	2.77	3.06	3.02	3.05	2.96	3.95	3.02	3.08	2.92

2260	2.05	2.03	2.03	1.99	2.03	2.41	2.28	2.82	3.12	3.08	3.11	3.01	4.03	3.08	3.14	2.98
2270	2.09	2.08	2.07	2.03	2.08	2.46	2.33	2.88	3.18	3.15	3.17	3.08	4.11	3.15	3.21	3.04
2280	2.13	2.12	2.11	2.07	2.12	2.51	2.38	2.94	3.25	3.21	3.23	3.14	4.19	3.21	3.27	3.10
2290	2.18	2.16	2.15	2.11	2.16	2.56	2.43	3.00	3.31	3.27	3.30	3.20	4.28	3.27	3.34	3.17
2300	2.22	2.20	2.20	2.16	2.20	2.61	2.47	3.06	3.38	3.34	3.37	3.27	4.36	3.34	3.41	3.23

Table A4.4b Autonomous energy efficiency (AEEI) in FUND A1B 2000=1.0

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.66	0.60	0.60	1.42	1.05	0.80	1.21	2.75	1.12	0.97	1.76	1.65	1.23	1.23	1.53	1.25
1960	0.74	0.70	0.59	1.16	1.06	0.70	1.03	1.91	1.08	0.98	1.51	1.33	0.46	1.32	1.36	1.02
1970	0.71	0.68	0.59	0.79	1.11	0.65	1.00	1.41	1.15	1.01	1.39	1.03	0.62	1.06	1.17	0.87
1980	0.79	0.73	0.65	0.86	1.11	0.66	0.99	1.34	1.04	1.09	1.14	1.08	0.60	0.99	1.10	0.85
1990	0.96	0.98	0.90	1.04	0.98	0.86	1.20	1.09	1.01	1.04	1.02	1.11	0.81	1.04	0.99	1.06
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.08	1.07	1.09	1.05	1.07	1.09	0.99	1.00	1.06	1.05	1.06	1.02	1.16	1.05	1.07	1.03
2020	1.21	1.20	1.20	1.17	1.20	1.26	1.19	1.14	1.22	1.20	1.25	1.21	1.37	1.20	1.23	1.17
2030	1.37	1.36	1.35	1.33	1.36	1.70	1.61	1.51	1.51	1.49	1.66	1.61	1.82	1.49	1.52	1.44
2040	1.54	1.53	1.53	1.50	1.53	2.16	2.05	1.88	1.82	1.80	2.06	2.00	2.26	1.80	1.84	1.74
2050	1.71	1.69	1.69	1.66	1.69	2.63	2.49	2.23	2.14	2.12	2.45	2.37	2.68	2.12	2.16	2.05
2060	1.84	1.83	1.82	1.79	1.83	3.04	2.88	2.50	2.41	2.39	2.75	2.66	3.01	2.39	2.43	2.31
2070	1.99	1.98	1.97	1.93	1.98	3.50	3.32	2.79	2.74	2.71	3.07	2.98	3.36	2.71	2.77	2.62
2080	2.16	2.15	2.14	2.10	2.15	4.03	3.82	3.11	3.18	3.14	3.41	3.31	3.74	3.14	3.20	3.04
2090	2.36	2.34	2.33	2.29	2.34	4.64	4.39	3.44	3.71	3.67	3.78	3.67	4.14	3.67	3.74	3.55
2100	2.56	2.54	2.53	2.49	2.54	5.24	4.96	3.76	4.23	4.18	4.14	4.02	4.53	4.18	4.26	4.04
2110	2.76	2.73	2.73	2.68	2.73	5.78	5.47	4.05	4.66	4.61	4.46	4.32	4.88	4.61	4.70	4.45
2120	2.96	2.94	2.93	2.87	2.94	6.34	6.00	4.35	5.11	5.05	4.78	4.64	5.24	5.05	5.15	4.89
2130	3.17	3.14	3.13	3.08	3.14	6.91	6.54	4.66	5.58	5.52	5.12	4.97	5.61	5.52	5.62	5.33
2140	3.39	3.36	3.35	3.29	3.36	7.51	7.11	4.98	6.06	5.99	5.47	5.31	5.99	5.99	6.11	5.79
2150	3.61	3.58	3.57	3.50	3.58	8.11	7.68	5.31	6.54	6.47	5.83	5.66	6.39	6.47	6.60	6.26
2160	3.84	3.81	3.79	3.72	3.81	8.72	8.26	5.64	7.04	6.96	6.20	6.02	6.79	6.96	7.09	6.73
2170	4.07	4.04	4.02	3.95	4.04	9.33	8.83	5.98	7.53	7.44	6.58	6.38	7.20	7.44	7.59	7.20
2180	4.30	4.27	4.26	4.18	4.27	9.93	9.40	6.33	8.01	7.92	6.96	6.75	7.62	7.92	8.08	7.66
2190	4.54	4.51	4.49	4.41	4.50	10.52	9.96	6.68	8.49	8.39	7.34	7.12	8.04	8.39	8.56	8.11
2200	4.78	4.74	4.73	4.64	4.74	11.09	10.50	7.03	8.95	8.85	7.73	7.50	8.46	8.85	9.02	8.55
2210	5.02	4.98	4.97	4.88	4.98	11.66	11.03	7.39	9.40	9.30	8.12	7.88	8.89	9.30	9.48	8.99
2220	5.28	5.24	5.22	5.13	5.24	12.26	11.60	7.76	9.89	9.78	8.54	8.29	9.35	9.78	9.96	9.45
2230	5.55	5.51	5.49	5.39	5.51	12.88	12.19	8.16	10.39	10.28	8.98	8.71	9.82	10.28	10.47	9.93
2240	5.83	5.79	5.77	5.66	5.79	13.54	12.82	8.58	10.92	10.80	9.43	9.15	10.33	10.80	11.01	10.44
2250	6.13	6.09	6.07	5.95	6.08	14.23	13.47	9.02	11.48	11.35	9.92	9.62	10.86	11.35	11.57	10.98

2260	6.45	6.40	6.38	6.26	6.40	14.96	14.16	9.48	12.07	11.93	10.42	10.11	11.41	11.93	12.17	11.54
2270	6.78	6.72	6.70	6.58	6.72	15.73	14.88	9.96	12.69	12.54	10.96	10.63	11.99	12.54	12.79	12.13
2280	7.12	7.07	7.04	6.91	7.07	16.53	15.64	10.47	13.33	13.19	11.52	11.18	12.61	13.19	13.44	12.75
2290	7.49	7.43	7.41	7.27	7.43	17.38	16.44	11.01	14.02	13.86	12.11	11.75	13.25	13.86	14.13	13.40
2300	7.87	7.81	7.78	7.64	7.81	18.26	17.29	11.57	14.73	14.57	12.73	12.35	13.93	14.57	14.85	14.08

Table A4.4c Autonomous energy efficiency (AEEI) in FUND A2 2000=1.0

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.66	0.60	0.60	1.42	1.05	0.80	1.21	2.75	1.12	0.97	1.76	1.65	1.23	1.23	1.53	1.25
1960	0.74	0.70	0.59	1.16	1.06	0.70	1.03	1.91	1.08	0.98	1.51	1.33	0.46	1.32	1.36	1.02
1970	0.71	0.68	0.59	0.79	1.11	0.65	1.00	1.41	1.15	1.01	1.39	1.03	0.62	1.06	1.17	0.87
1980	0.79	0.73	0.65	0.86	1.11	0.66	0.99	1.34	1.04	1.09	1.14	1.08	0.60	0.99	1.10	0.85
1990	0.96	0.98	0.90	1.04	0.98	0.86	1.20	1.09	1.01	1.04	1.02	1.11	0.81	1.04	0.99	1.06
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.08	1.07	1.09	1.05	1.07	1.09	0.99	1.00	1.06	1.05	1.06	1.02	1.16	1.05	1.07	1.03
2020	1.20	1.19	1.19	1.16	1.19	1.23	1.15	1.09	1.20	1.19	1.20	1.16	1.31	1.19	1.21	1.15
2030	1.35	1.34	1.33	1.31	1.34	1.58	1.49	1.33	1.47	1.45	1.46	1.42	1.60	1.45	1.48	1.40
2040	1.47	1.46	1.45	1.43	1.46	1.90	1.80	1.55	1.71	1.69	1.71	1.66	1.87	1.69	1.72	1.63
2050	1.55	1.53	1.53	1.50	1.53	2.11	2.00	1.67	1.79	1.77	1.84	1.78	2.01	1.77	1.81	1.72
2060	1.64	1.63	1.63	1.60	1.63	2.40	2.27	1.86	1.92	1.90	2.05	1.98	2.24	1.90	1.94	1.84
2070	1.77	1.75	1.75	1.72	1.75	2.83	2.68	2.17	2.16	2.13	2.38	2.31	2.61	2.13	2.18	2.06
2080	2.00	1.99	1.98	1.94	1.99	3.74	3.54	2.85	2.72	2.69	3.13	3.04	3.43	2.69	2.74	2.60
2090	2.10	2.08	2.08	2.04	2.08	4.35	4.12	3.31	3.03	2.99	3.64	3.53	3.98	2.99	3.05	2.89
2100	2.11	2.09	2.08	2.05	2.09	4.50	4.26	3.43	3.09	3.05	3.77	3.66	4.13	3.05	3.11	2.95
2110	2.22	2.20	2.19	2.15	2.20	4.73	4.48	3.60	3.24	3.21	3.96	3.84	4.34	3.21	3.27	3.10
2120	2.33	2.31	2.30	2.26	2.31	4.97	4.71	3.79	3.41	3.37	4.16	4.04	4.56	3.37	3.44	3.26
2130	2.45	2.43	2.42	2.38	2.43	5.23	4.95	3.98	3.58	3.54	4.38	4.25	4.79	3.54	3.61	3.43
2140	2.57	2.55	2.54	2.50	2.55	5.50	5.20	4.18	3.77	3.72	4.60	4.46	5.04	3.72	3.80	3.60
2150	2.70	2.68	2.67	2.63	2.68	5.78	5.47	4.40	3.96	3.91	4.84	4.69	5.29	3.91	3.99	3.78
2160	2.84	2.82	2.81	2.76	2.82	6.07	5.75	4.62	4.16	4.11	5.08	4.93	5.56	4.12	4.19	3.98
2170	2.99	2.96	2.96	2.90	2.96	6.38	6.04	4.86	4.37	4.33	5.34	5.18	5.85	4.33	4.41	4.18
2180	3.14	3.12	3.11	3.05	3.12	6.71	6.35	5.11	4.60	4.55	5.62	5.45	6.15	4.55	4.63	4.40
2190	3.30	3.28	3.27	3.20	3.28	7.05	6.68	5.37	4.83	4.78	5.90	5.73	6.46	4.78	4.87	4.62
2200	3.47	3.44	3.43	3.37	3.44	7.41	7.02	5.64	5.08	5.02	6.21	6.02	6.79	5.02	5.12	4.86
2210	3.65	3.62	3.61	3.54	3.62	7.79	7.38	5.93	5.34	5.28	6.52	6.33	7.14	5.28	5.38	5.10
2220	3.83	3.80	3.79	3.72	3.80	8.19	7.75	6.23	5.61	5.55	6.86	6.65	7.51	5.55	5.66	5.37
2230	4.03	4.00	3.99	3.91	4.00	8.61	8.15	6.55	5.90	5.83	7.21	6.99	7.89	5.83	5.95	5.64
2240	4.24	4.20	4.19	4.11	4.20	9.05	8.57	6.89	6.20	6.13	7.58	7.35	8.29	6.13	6.25	5.93
2250	4.45	4.42	4.40	4.32	4.42	9.51	9.00	7.24	6.52	6.45	7.96	7.73	8.72	6.45	6.57	6.23

2260	4.68	4.64	4.63	4.54	4.64	10.00	9.46	7.61	6.85	6.78	8.37	8.12	9.16	6.78	6.91	6.55
2270	4.92	4.88	4.87	4.78	4.88	10.51	9.95	8.00	7.20	7.12	8.80	8.54	9.63	7.12	7.26	6.89
2280	5.17	5.13	5.11	5.02	5.13	11.05	10.46	8.41	7.57	7.49	9.25	8.97	10.12	7.49	7.63	7.24
2290	5.44	5.39	5.38	5.28	5.39	11.61	10.99	8.84	7.96	7.87	9.72	9.43	10.64	7.87	8.02	7.61
2300	5.71	5.67	5.65	5.55	5.67	12.21	11.55	9.29	8.37	8.27	10.22	9.92	11.19	8.27	8.43	8.00

Table A4.4d Autonomous energy efficiency (AEEI) in FUND B1. 2000=1.0

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.66	0.60	0.60	1.42	1.05	0.80	1.21	2.75	1.12	0.97	1.76	1.65	1.23	1.23	1.53	1.25
1960	0.74	0.70	0.59	1.16	1.06	0.70	1.03	1.91	1.08	0.98	1.51	1.33	0.46	1.32	1.36	1.02
1970	0.71	0.68	0.59	0.79	1.11	0.65	1.00	1.41	1.15	1.01	1.39	1.03	0.62	1.06	1.17	0.87
1980	0.79	0.73	0.65	0.86	1.11	0.66	0.99	1.34	1.04	1.09	1.14	1.08	0.60	0.99	1.10	0.85
1990	0.96	0.98	0.90	1.04	0.98	0.86	1.20	1.09	1.01	1.04	1.02	1.11	0.81	1.04	0.99	1.06
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.08	1.07	1.09	1.05	1.07	1.09	0.99	1.00	1.06	1.05	1.06	1.02	1.16	1.05	1.07	1.03
2020	1.23	1.22	1.22	1.20	1.22	1.26	1.19	1.15	1.22	1.21	1.26	1.22	1.38	1.21	1.23	1.17
2030	1.49	1.48	1.48	1.45	1.48	1.72	1.63	1.59	1.54	1.52	1.74	1.69	1.91	1.52	1.55	1.47
2040	1.84	1.82	1.82	1.78	1.82	2.38	2.25	2.34	1.99	1.97	2.57	2.50	2.82	1.97	2.01	1.90
2050	2.21	2.20	2.19	2.15	2.20	3.34	3.16	3.46	2.64	2.61	3.80	3.69	4.16	2.61	2.66	2.52
2060	2.60	2.58	2.58	2.53	2.58	4.62	4.38	4.89	3.60	3.56	5.38	5.22	5.89	3.56	3.63	3.44
2070	3.02	3.00	2.99	2.93	3.00	6.38	6.04	6.71	4.94	4.88	7.38	7.16	8.08	4.88	4.98	4.72
2080	3.52	3.49	3.48	3.42	3.49	8.64	8.18	8.96	6.66	6.58	9.85	9.56	10.79	6.58	6.71	6.36
2090	4.07	4.04	4.03	3.95	4.04	11.41	10.80	11.62	8.94	8.85	12.78	12.40	13.99	8.85	9.02	8.55
2100	4.61	4.58	4.56	4.48	4.57	14.43	13.66	14.60	11.52	11.39	16.05	15.57	17.57	11.39	11.61	11.01
2110	5.08	5.04	5.03	4.93	5.04	17.47	16.54	17.67	13.95	13.79	19.44	18.86	21.28	13.79	14.06	13.33
2120	5.57	5.53	5.51	5.41	5.53	20.85	19.74	21.09	16.64	16.46	23.19	22.50	25.39	16.46	16.78	15.91
2130	6.08	6.04	6.02	5.90	6.03	24.52	23.20	24.80	19.57	19.35	27.27	26.46	29.85	19.35	19.73	18.71
2140	6.60	6.55	6.53	6.41	6.55	28.40	26.88	28.73	22.67	22.42	31.59	30.65	34.58	22.42	22.85	21.67
2150	7.14	7.08	7.06	6.93	7.08	32.42	30.69	32.80	25.88	25.59	36.06	34.99	39.48	25.59	26.09	24.74
2160	7.67	7.61	7.59	7.45	7.61	36.47	34.52	36.89	29.11	28.78	40.56	39.36	44.40	28.78	29.34	27.83
2170	8.21	8.15	8.12	7.97	8.14	40.41	38.25	40.88	32.26	31.90	44.95	43.61	49.20	31.90	32.52	30.84
2180	8.74	8.67	8.64	8.48	8.67	44.13	41.76	44.63	35.22	34.83	49.08	47.62	53.72	34.83	35.50	33.67
2190	9.26	9.19	9.16	8.99	9.18	47.47	44.92	48.01	37.89	37.46	52.79	51.23	57.79	37.46	38.19	36.22
2200	9.76	9.68	9.65	9.47	9.68	50.31	47.61	50.88	40.15	39.70	55.95	54.29	61.25	39.71	40.47	38.39
2210	10.26	10.18	10.14	9.96	10.18	52.88	50.05	53.48	42.20	41.73	58.81	57.06	64.38	41.74	42.54	40.35
2220	10.78	10.70	10.66	10.47	10.70	55.58	52.60	56.22	44.36	43.87	61.82	59.98	67.67	43.87	44.72	42.41
2230	11.33	11.24	11.21	11.00	11.24	58.42	55.30	59.09	46.63	46.11	64.98	63.05	71.13	46.11	47.01	44.58
2240	11.91	11.82	11.78	11.56	11.82	61.41	58.12	62.11	49.02	48.47	68.30	66.28	74.77	48.47	49.41	46.86
2250	12.52	12.42	12.38	12.16	12.42	64.55	61.10	65.29	51.52	50.95	71.80	69.66	78.59	50.95	51.94	49.26

2260	13.16	13.06	13.02	12.78	13.06	67.85	64.22	68.63	54.16	53.55	75.47	73.23	82.61	53.56	54.59	51.78
2270	13.83	13.73	13.68	13.43	13.73	71.32	67.50	72.14	56.93	56.29	79.33	76.97	86.84	56.30	57.39	54.42
2280	14.54	14.43	14.38	14.12	14.43	74.97	70.96	75.83	59.84	59.17	83.39	80.91	91.28	59.17	60.32	57.21
2290	15.28	15.17	15.12	14.84	15.17	78.81	74.58	79.71	62.90	62.20	87.65	85.05	95.95	62.20	63.40	60.13
2300	16.07	15.94	15.89	15.60	15.94	82.84	78.40	83.78	66.12	65.38	92.13	89.40	100.85	65.38	66.65	63.21

Table A4.4e Autonomous energy efficiency (AEEI) in FUND B2 2000=1.0

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.66	0.60	0.60	1.42	1.05	0.80	1.21	2.75	1.12	0.97	1.76	1.65	1.23	1.23	1.53	1.25
1960	0.74	0.70	0.59	1.16	1.06	0.70	1.03	1.91	1.08	0.98	1.51	1.33	0.46	1.32	1.36	1.02
1970	0.71	0.68	0.59	0.79	1.11	0.65	1.00	1.41	1.15	1.01	1.39	1.03	0.62	1.06	1.17	0.87
1980	0.79	0.73	0.65	0.86	1.11	0.66	0.99	1.34	1.04	1.09	1.14	1.08	0.60	0.99	1.10	0.85
1990	0.96	0.98	0.90	1.04	0.98	0.86	1.20	1.09	1.01	1.04	1.02	1.11	0.81	1.04	0.99	1.06
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.08	1.07	1.09	1.05	1.07	1.09	0.99	1.00	1.06	1.05	1.06	1.02	1.16	1.05	1.07	1.03
2020	1.18	1.17	1.17	1.14	1.17	1.23	1.16	1.10	1.21	1.20	1.20	1.17	1.32	1.20	1.22	1.16
2030	1.24	1.24	1.23	1.21	1.24	1.61	1.52	1.33	1.48	1.47	1.46	1.42	1.60	1.47	1.49	1.42
2040	1.32	1.31	1.31	1.28	1.31	2.12	2.01	1.58	1.85	1.83	1.74	1.69	1.91	1.83	1.86	1.76
2050	1.37	1.36	1.36	1.33	1.36	2.68	2.54	1.84	2.21	2.19	2.02	1.96	2.21	2.19	2.23	2.12
2060	1.43	1.42	1.41	1.39	1.42	3.16	2.99	2.04	2.52	2.49	2.25	2.18	2.46	2.49	2.54	2.41
2070	1.50	1.48	1.48	1.45	1.48	3.48	3.29	2.21	2.72	2.69	2.43	2.36	2.66	2.69	2.74	2.60
2080	1.56	1.54	1.54	1.51	1.54	3.77	3.57	2.32	2.80	2.77	2.55	2.47	2.79	2.77	2.82	2.68
2090	1.66	1.65	1.64	1.61	1.65	4.04	3.82	2.42	2.91	2.87	2.66	2.58	2.91	2.87	2.93	2.78
2100	1.77	1.76	1.76	1.72	1.76	4.24	4.01	2.54	3.06	3.03	2.79	2.71	3.05	3.03	3.09	2.93
2110	1.87	1.85	1.84	1.81	1.85	4.45	4.21	2.67	3.22	3.18	2.93	2.84	3.21	3.18	3.25	3.08
2120	1.96	1.95	1.94	1.90	1.95	4.68	4.43	2.80	3.39	3.35	3.08	2.99	3.37	3.35	3.41	3.24
2130	2.06	2.04	2.04	2.00	2.04	4.92	4.66	2.95	3.56	3.52	3.24	3.14	3.55	3.52	3.59	3.40
2140	2.17	2.15	2.14	2.10	2.15	5.17	4.90	3.10	3.74	3.70	3.41	3.30	3.73	3.70	3.77	3.58
2150	2.28	2.26	2.25	2.21	2.26	5.44	5.15	3.25	3.93	3.89	3.58	3.47	3.92	3.89	3.96	3.76
2160	2.39	2.38	2.37	2.32	2.37	5.71	5.41	3.42	4.13	4.09	3.76	3.65	4.12	4.09	4.17	3.95
2170	2.52	2.50	2.49	2.44	2.50	6.01	5.69	3.60	4.34	4.30	3.95	3.84	4.33	4.30	4.38	4.15
2180	2.64	2.62	2.62	2.57	2.62	6.31	5.98	3.78	4.57	4.52	4.16	4.03	4.55	4.52	4.60	4.37
2190	2.78	2.76	2.75	2.70	2.76	6.64	6.28	3.97	4.80	4.75	4.37	4.24	4.78	4.75	4.84	4.59
2200	2.92	2.90	2.89	2.84	2.90	6.98	6.60	4.18	5.04	4.99	4.59	4.46	5.03	4.99	5.09	4.82
2210	3.07	3.05	3.04	2.98	3.05	7.33	6.94	4.39	5.30	5.24	4.83	4.68	5.28	5.24	5.35	5.07
2220	3.23	3.20	3.19	3.13	3.20	7.71	7.30	4.61	5.57	5.51	5.07	4.92	5.56	5.51	5.62	5.33
2230	3.39	3.37	3.36	3.29	3.37	8.10	7.67	4.85	5.86	5.79	5.33	5.18	5.84	5.79	5.91	5.60
2240	3.57	3.54	3.53	3.46	3.54	8.52	8.06	5.10	6.16	6.09	5.61	5.44	6.14	6.09	6.21	5.89
2250	3.75	3.72	3.71	3.64	3.72	8.95	8.47	5.36	6.47	6.40	5.89	5.72	6.45	6.40	6.53	6.19

2260	3.94	3.91	3.90	3.83	3.91	9.41	8.91	5.63	6.80	6.73	6.20	6.01	6.78	6.73	6.86	6.51
2270	4.14	4.11	4.10	4.02	4.11	9.89	9.36	5.92	7.15	7.07	6.51	6.32	7.13	7.07	7.21	6.84
2280	4.35	4.32	4.31	4.23	4.32	10.40	9.84	6.22	7.52	7.43	6.85	6.64	7.49	7.44	7.58	7.19
2290	4.58	4.54	4.53	4.44	4.54	10.93	10.34	6.54	7.90	7.82	7.20	6.98	7.88	7.82	7.97	7.56
2300	4.81	4.77	4.76	4.67	4.77	11.49	10.87	6.88	8.31	8.21	7.56	7.34	8.28	8.22	8.37	7.94

Table A4.5a Autonomous carbon efficiency improvement (ACEI) FUND standard scenario 2000=1.0

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.67	0.60	0.60	1.42	1.05	0.80	1.21	2.72	1.12	0.97	1.76	1.65	1.24	1.21	1.51	1.25
1960	0.74	0.70	0.60	1.16	1.06	0.70	1.03	1.90	1.08	0.98	1.51	1.33	0.46	1.30	1.34	1.02
1970	0.72	0.68	0.59	0.79	1.11	0.65	1.00	1.40	1.15	1.01	1.38	1.03	0.62	1.05	1.15	0.87
1980	0.79	0.73	0.66	0.86	1.11	0.66	0.99	1.33	1.04	1.09	1.14	1.08	0.60	0.98	1.08	0.84
1990	0.96	0.98	0.90	1.04	0.98	0.86	1.20	1.08	1.01	1.04	1.02	1.10	0.81	1.03	0.98	1.06
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.07	1.07	1.07	1.05	1.07	1.09	0.99	1.07	1.06	1.05	1.07	1.04	1.12	1.14	1.16	1.04
2020	1.14	1.15	1.11	1.14	1.16	1.13	1.07	1.23	1.16	1.14	1.20	1.17	1.17	1.39	1.41	1.12
2030	1.15	1.16	1.12	1.19	1.21	1.14	1.08	1.39	1.23	1.22	1.31	1.27	1.21	1.61	1.65	1.20
2040	1.15	1.16	1.12	1.22	1.24	1.14	1.08	1.51	1.30	1.28	1.41	1.37	1.24	1.81	1.84	1.26
2050	1.15	1.16	1.12	1.24	1.26	1.14	1.08	1.61	1.35	1.33	1.51	1.46	1.27	1.98	2.01	1.31
2060	1.15	1.16	1.12	1.25	1.28	1.14	1.08	1.70	1.38	1.37	1.58	1.54	1.28	2.13	2.17	1.34
2070	1.15	1.16	1.12	1.26	1.29	1.14	1.08	1.78	1.42	1.40	1.66	1.62	1.29	2.29	2.34	1.37
2080	1.15	1.16	1.12	1.27	1.30	1.14	1.08	1.85	1.44	1.42	1.73	1.68	1.30	2.44	2.49	1.40
2090	1.15	1.17	1.12	1.28	1.31	1.15	1.08	1.90	1.45	1.43	1.77	1.72	1.31	2.55	2.60	1.41
2100	1.17	1.19	1.14	1.30	1.33	1.16	1.10	1.94	1.47	1.46	1.81	1.76	1.34	2.62	2.68	1.43
2110	1.19	1.21	1.16	1.33	1.36	1.19	1.12	1.98	1.50	1.49	1.85	1.79	1.36	2.68	2.73	1.46
2120	1.22	1.23	1.19	1.36	1.39	1.21	1.14	2.02	1.53	1.52	1.88	1.83	1.39	2.73	2.78	1.49
2130	1.24	1.26	1.21	1.38	1.41	1.23	1.17	2.06	1.57	1.55	1.92	1.86	1.42	2.79	2.84	1.52
2140	1.27	1.29	1.24	1.41	1.44	1.26	1.19	2.10	1.60	1.58	1.96	1.90	1.45	2.84	2.90	1.55
2150	1.29	1.31	1.26	1.44	1.47	1.28	1.22	2.14	1.63	1.61	2.00	1.94	1.48	2.90	2.96	1.58
2160	1.32	1.34	1.29	1.47	1.50	1.31	1.24	2.19	1.66	1.64	2.04	1.98	1.51	2.96	3.02	1.61
2170	1.35	1.36	1.31	1.50	1.53	1.34	1.27	2.23	1.70	1.68	2.08	2.02	1.54	3.02	3.08	1.64
2180	1.37	1.39	1.34	1.53	1.56	1.36	1.29	2.28	1.73	1.71	2.12	2.06	1.57	3.08	3.14	1.68
2190	1.40	1.42	1.37	1.56	1.59	1.39	1.32	2.32	1.76	1.74	2.17	2.10	1.60	3.14	3.20	1.71
2200	1.43	1.45	1.39	1.59	1.63	1.42	1.34	2.37	1.80	1.78	2.21	2.14	1.63	3.21	3.27	1.75
2210	1.46	1.48	1.42	1.62	1.66	1.45	1.37	2.42	1.84	1.82	2.25	2.19	1.66	3.27	3.33	1.78
2220	1.49	1.51	1.45	1.66	1.69	1.48	1.40	2.46	1.87	1.85	2.30	2.23	1.70	3.34	3.40	1.82
2230	1.52	1.54	1.48	1.69	1.73	1.51	1.43	2.51	1.91	1.89	2.35	2.28	1.73	3.40	3.47	1.85
2240	1.55	1.57	1.51	1.72	1.76	1.54	1.46	2.56	1.95	1.93	2.39	2.32	1.77	3.47	3.54	1.89
2250	1.58	1.60	1.54	1.76	1.80	1.57	1.48	2.62	1.99	1.97	2.44	2.37	1.80	3.54	3.61	1.93

2260	1.61	1.63	1.57	1.79	1.83	1.60	1.51	2.67	2.03	2.01	2.49	2.42	1.84	3.61	3.68	1.97
2270	1.64	1.67	1.60	1.83	1.87	1.63	1.55	2.72	2.07	2.05	2.54	2.47	1.88	3.69	3.76	2.01
2280	1.68	1.70	1.63	1.87	1.91	1.66	1.58	2.78	2.11	2.09	2.59	2.52	1.91	3.76	3.83	2.05
2290	1.71	1.73	1.67	1.91	1.95	1.70	1.61	2.83	2.15	2.13	2.65	2.57	1.95	3.84	3.91	2.09
2300	1.74	1.77	1.70	1.94	1.99	1.73	1.64	2.89	2.20	2.17	2.70	2.62	1.99	3.91	3.99	2.13

Table A4.5b Autonomous carbon efficicency improvement (ACEI) in FUND A1B 2000=1.0

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.67	0.60	0.60	1.43	1.05	0.80	1.21	2.72	1.14	0.98	1.77	1.66	1.24	1.24	1.55	1.25
1960	0.74	0.70	0.60	1.17	1.07	0.70	1.03	1.90	1.09	0.99	1.52	1.34	0.46	1.33	1.37	1.02
1970	0.72	0.68	0.59	0.80	1.11	0.65	1.00	1.40	1.16	1.02	1.40	1.04	0.62	1.07	1.18	0.87
1980	0.79	0.73	0.66	0.87	1.11	0.66	0.99	1.33	1.05	1.10	1.15	1.09	0.60	1.01	1.11	0.84
1990	0.96	0.98	0.90	1.04	0.98	0.86	1.20	1.08	1.02	1.06	1.03	1.12	0.81	1.06	1.00	1.06
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.07	1.07	1.07	1.01	1.04	1.09	0.99	1.07	0.97	0.96	1.00	0.97	1.12	0.96	0.98	1.04
2020	1.16	1.17	1.13	1.07	1.10	1.18	1.11	1.22	0.99	0.98	1.05	1.02	1.20	0.98	1.00	1.15
2030	1.24	1.26	1.21	1.15	1.17	1.33	1.26	1.38	1.12	1.10	1.18	1.14	1.34	1.10	1.13	1.32
2040	1.33	1.35	1.30	1.23	1.26	1.56	1.47	1.63	1.28	1.27	1.39	1.35	1.58	1.27	1.29	1.51
2050	1.51	1.53	1.47	1.39	1.42	1.83	1.73	1.93	1.49	1.47	1.64	1.59	1.87	1.47	1.50	1.75
2060	1.81	1.84	1.77	1.67	1.71	2.18	2.06	2.28	1.76	1.74	1.94	1.88	2.21	1.74	1.78	2.08
2070	2.15	2.18	2.10	1.98	2.03	2.55	2.41	2.67	2.05	2.02	2.27	2.20	2.59	2.02	2.06	2.41
2080	2.49	2.52	2.43	2.29	2.35	2.90	2.74	3.05	2.28	2.25	2.59	2.52	2.95	2.25	2.29	2.68
2090	2.84	2.88	2.77	2.62	2.67	3.24	3.06	3.44	2.47	2.44	2.93	2.84	3.33	2.44	2.49	2.91
2100	3.19	3.24	3.11	2.94	3.01	3.56	3.37	3.84	2.64	2.61	3.27	3.17	3.72	2.61	2.66	3.11
2110	3.52	3.57	3.43	3.24	3.32	3.83	3.62	4.23	2.78	2.74	3.60	3.50	4.10	2.74	2.80	3.27
2120	3.86	3.91	3.76	3.56	3.64	4.11	3.89	4.64	2.92	2.88	3.95	3.83	4.50	2.88	2.94	3.44
2130	4.21	4.27	4.11	3.88	3.97	4.40	4.17	5.06	3.07	3.03	4.31	4.18	4.91	3.03	3.09	3.61
2140	4.58	4.64	4.46	4.22	4.31	4.70	4.45	5.50	3.22	3.19	4.68	4.54	5.33	3.19	3.25	3.80
2150	4.94	5.01	4.82	4.56	4.66	5.01	4.74	5.94	3.39	3.35	5.06	4.91	5.76	3.35	3.42	3.99
2160	5.32	5.39	5.18	4.90	5.01	5.33	5.04	6.39	3.56	3.52	5.44	5.28	6.19	3.52	3.59	4.20
2170	5.69	5.77	5.54	5.24	5.36	5.65	5.35	6.84	3.74	3.70	5.82	5.65	6.63	3.70	3.77	4.41
2180	6.05	6.14	5.90	5.58	5.70	5.98	5.66	7.28	3.94	3.89	6.20	6.01	7.06	3.89	3.97	4.64
2190	6.41	6.50	6.25	5.91	6.04	6.31	5.97	7.71	4.14	4.09	6.56	6.37	7.47	4.09	4.17	4.87
2200	6.76	6.85	6.59	6.23	6.37	6.64	6.28	8.12	4.35	4.30	6.92	6.71	7.88	4.30	4.38	5.12
2210	7.10	7.20	6.93	6.55	6.69	6.98	6.61	8.54	4.57	4.52	7.27	7.05	8.28	4.52	4.61	5.38
2220	7.47	7.57	7.28	6.88	7.03	7.33	6.94	8.98	4.80	4.75	7.64	7.42	8.70	4.75	4.84	5.66
2230	7.85	7.96	7.65	7.23	7.39	7.71	7.30	9.44	5.05	4.99	8.03	7.79	9.15	4.99	5.09	5.95
2240	8.25	8.37	8.04	7.60	7.77	8.10	7.67	9.92	5.31	5.25	8.45	8.19	9.62	5.25	5.35	6.25
2250	8.67	8.79	8.46	7.99	8.17	8.52	8.06	10.43	5.58	5.52	8.88	8.61	10.11	5.52	5.62	6.57

2260	9.12	9.24	8.89	8.40	8.59	8.95	8.48	10.96	5.87	5.80	9.33	9.05	10.62	5.80	5.91	6.91
2270	9.58	9.72	9.34	8.83	9.03	9.41	8.91	11.52	6.17	6.10	9.81	9.52	11.17	6.10	6.22	7.26
2280	10.07	10.21	9.82	9.28	9.49	9.89	9.37	12.11	6.48	6.41	10.31	10.00	11.74	6.41	6.53	7.63
2290	10.59	10.74	10.32	9.76	9.97	10.40	9.84	12.73	6.81	6.74	10.84	10.51	12.34	6.74	6.87	8.02
2300	11.13	11.29	10.85	10.26	10.48	10.93	10.35	13.38	7.16	7.08	11.39	11.05	12.97	7.08	7.22	8.43

Table A4.5c Autonomous carbon efficicency improvement (ACEI) in FUND A2 2000=1.0

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.67	0.60	0.60	1.44	1.06	0.80	1.21	2.72	1.13	0.97	1.77	1.66	1.24	1.24	1.54	1.25
1960	0.74	0.70	0.60	1.17	1.07	0.70	1.03	1.90	1.09	0.98	1.52	1.34	0.46	1.33	1.37	1.02
1970	0.72	0.68	0.59	0.80	1.12	0.65	1.00	1.40	1.16	1.02	1.40	1.04	0.62	1.07	1.17	0.87
1980	0.79	0.73	0.66	0.87	1.12	0.66	0.99	1.33	1.04	1.09	1.15	1.09	0.60	1.00	1.11	0.84
1990	0.96	0.98	0.90	1.05	0.99	0.86	1.20	1.08	1.02	1.05	1.03	1.11	0.81	1.05	1.00	1.06
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.07	1.07	1.07	0.98	1.01	1.09	0.99	1.07	1.00	0.99	1.01	0.98	1.12	0.99	1.01	1.04
2020	1.15	1.16	1.12	1.00	1.02	1.15	1.08	1.19	1.03	1.02	1.03	1.00	1.17	1.02	1.04	1.12
2030	1.19	1.21	1.16	1.03	1.05	1.20	1.14	1.24	1.09	1.08	1.06	1.03	1.20	1.08	1.10	1.19
2040	1.22	1.24	1.19	1.05	1.08	1.30	1.23	1.29	1.18	1.17	1.11	1.08	1.25	1.17	1.19	1.29
2050	1.25	1.27	1.22	1.08	1.10	1.36	1.28	1.32	1.20	1.19	1.13	1.10	1.28	1.19	1.21	1.32
2060	1.27	1.29	1.24	1.09	1.12	1.38	1.31	1.31	1.17	1.15	1.13	1.09	1.27	1.15	1.18	1.28
2070	1.29	1.31	1.26	1.11	1.13	1.40	1.33	1.31	1.14	1.13	1.13	1.10	1.27	1.13	1.15	1.25
2080	1.31	1.33	1.28	1.13	1.15	1.41	1.33	1.32	1.13	1.11	1.14	1.10	1.28	1.11	1.13	1.23
2090	1.33	1.35	1.29	1.14	1.17	1.41	1.33	1.33	1.12	1.10	1.14	1.11	1.29	1.10	1.12	1.22
2100	1.37	1.39	1.33	1.18	1.20	1.44	1.37	1.37	1.14	1.12	1.17	1.14	1.33	1.12	1.14	1.24
2110	1.44	1.46	1.40	1.24	1.27	1.52	1.44	1.44	1.19	1.18	1.23	1.20	1.39	1.18	1.20	1.31
2120	1.51	1.53	1.47	1.30	1.33	1.59	1.51	1.51	1.25	1.24	1.30	1.26	1.47	1.24	1.26	1.37
2130	1.59	1.61	1.55	1.37	1.40	1.68	1.59	1.59	1.32	1.30	1.36	1.32	1.54	1.30	1.33	1.44
2140	1.67	1.69	1.63	1.44	1.47	1.76	1.67	1.67	1.39	1.37	1.43	1.39	1.62	1.37	1.40	1.52
2150	1.75	1.78	1.71	1.51	1.55	1.85	1.75	1.76	1.46	1.44	1.51	1.46	1.70	1.44	1.47	1.59
2160	1.84	1.87	1.80	1.59	1.62	1.95	1.84	1.85	1.53	1.51	1.58	1.54	1.79	1.51	1.54	1.68
2170	1.94	1.97	1.89	1.67	1.71	2.05	1.94	1.94	1.61	1.59	1.67	1.62	1.88	1.59	1.62	1.76
2180	2.04	2.07	1.99	1.76	1.79	2.15	2.04	2.04	1.69	1.67	1.75	1.70	1.98	1.67	1.71	1.85
2190	2.14	2.17	2.09	1.85	1.89	2.26	2.14	2.14	1.78	1.76	1.84	1.79	2.08	1.76	1.79	1.95
2200	2.25	2.28	2.19	1.94	1.98	2.38	2.25	2.25	1.87	1.85	1.93	1.88	2.18	1.85	1.89	2.05
2210	2.37	2.40	2.31	2.04	2.08	2.50	2.36	2.37	1.97	1.94	2.03	1.97	2.30	1.94	1.98	2.15
2220	2.49	2.52	2.42	2.14	2.19	2.62	2.48	2.49	2.07	2.04	2.14	2.07	2.41	2.04	2.08	2.26
2230	2.61	2.65	2.55	2.25	2.30	2.76	2.61	2.62	2.17	2.15	2.25	2.18	2.54	2.15	2.19	2.38
2240	2.75	2.79	2.68	2.37	2.42	2.90	2.75	2.75	2.28	2.26	2.36	2.29	2.67	2.26	2.30	2.50
2250	2.89	2.93	2.82	2.49	2.54	3.05	2.89	2.89	2.40	2.37	2.48	2.41	2.80	2.37	2.42	2.63

2260	3.04	3.08	2.96	2.62	2.67	3.20	3.03	3.04	2.52	2.49	2.61	2.53	2.95	2.49	2.54	2.76
2270	3.19	3.24	3.11	2.75	2.81	3.37	3.19	3.19	2.65	2.62	2.74	2.66	3.10	2.62	2.67	2.90
2280	3.35	3.40	3.27	2.89	2.95	3.54	3.35	3.36	2.79	2.76	2.88	2.80	3.25	2.76	2.81	3.05
2290	3.53	3.58	3.44	3.04	3.11	3.72	3.52	3.53	2.93	2.90	3.03	2.94	3.42	2.90	2.95	3.20
2300	3.71	3.76	3.61	3.19	3.26	3.91	3.70	3.71	3.08	3.04	3.19	3.09	3.60	3.05	3.10	3.37

Table A4.5d Autonomous carbon efficicency improvement (ACEI) in FUND B1 2000 = 1.00.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.67	0.60	0.60	1.43	1.05	0.80	1.21	2.72	1.14	0.98	1.77	1.66	1.24	1.24	1.55	1.25
1960	0.74	0.70	0.60	1.17	1.07	0.70	1.03	1.90	1.09	0.99	1.52	1.34	0.46	1.33	1.38	1.02
1970	0.72	0.68	0.59	0.80	1.11	0.65	1.00	1.40	1.16	1.03	1.39	1.04	0.62	1.07	1.18	0.87
1980	0.79	0.73	0.66	0.87	1.11	0.66	0.99	1.33	1.05	1.10	1.15	1.09	0.60	1.01	1.11	0.84
1990	0.96	0.98	0.90	1.04	0.98	0.86	1.20	1.08	1.03	1.06	1.03	1.11	0.81	1.06	1.00	1.06
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.07	1.07	1.07	1.01	1.04	1.09	0.99	1.07	0.96	0.95	1.01	0.98	1.12	0.95	0.97	1.04
2020	1.17	1.18	1.14	1.08	1.10	1.16	1.10	1.20	0.93	0.92	1.05	1.02	1.17	0.92	0.94	1.10
2030	1.27	1.29	1.24	1.17	1.19	1.28	1.21	1.26	0.91	0.90	1.10	1.06	1.22	0.90	0.92	1.08
2040	1.39	1.41	1.36	1.28	1.31	1.36	1.29	1.35	1.02	1.01	1.17	1.13	1.30	1.01	1.03	1.22
2050	1.58	1.60	1.54	1.45	1.48	1.40	1.33	1.48	1.11	1.09	1.29	1.25	1.44	1.09	1.12	1.32
2060	1.76	1.78	1.72	1.62	1.66	1.56	1.48	1.65	1.19	1.18	1.43	1.39	1.60	1.18	1.20	1.42
2070	1.84	1.87	1.79	1.69	1.73	1.78	1.68	1.84	1.27	1.25	1.59	1.55	1.78	1.25	1.28	1.51
2080	1.89	1.92	1.84	1.74	1.78	1.94	1.83	2.05	1.35	1.33	1.78	1.72	1.98	1.33	1.36	1.61
2090	1.97	2.00	1.93	1.82	1.86	1.95	1.85	2.25	1.40	1.38	1.95	1.89	2.18	1.38	1.41	1.67
2100	2.07	2.10	2.02	1.91	1.95	1.84	1.74	2.39	1.45	1.43	2.07	2.01	2.31	1.43	1.46	1.73
2110	2.18	2.21	2.12	2.01	2.05	1.84	1.75	2.51	1.52	1.50	2.18	2.11	2.43	1.50	1.53	1.81
2120	2.29	2.32	2.23	2.11	2.15	1.86	1.76	2.64	1.60	1.58	2.29	2.22	2.56	1.58	1.61	1.91
2130	2.41	2.44	2.35	2.22	2.26	1.88	1.78	2.77	1.68	1.66	2.41	2.33	2.69	1.66	1.69	2.00
2140	2.53	2.57	2.47	2.33	2.38	1.91	1.81	2.91	1.76	1.74	2.53	2.45	2.83	1.75	1.78	2.11
2150	2.66	2.70	2.59	2.45	2.50	1.96	1.85	3.06	1.86	1.83	2.66	2.58	2.97	1.83	1.87	2.21
2160	2.80	2.84	2.73	2.57	2.63	2.01	1.90	3.22	1.95	1.93	2.79	2.71	3.12	1.93	1.97	2.33
2170	2.94	2.98	2.87	2.71	2.77	2.08	1.97	3.39	2.05	2.03	2.94	2.85	3.28	2.03	2.07	2.45
2180	3.09	3.13	3.01	2.84	2.91	2.15	2.04	3.56	2.15	2.13	3.09	2.99	3.45	2.13	2.17	2.57
2190	3.25	3.29	3.17	2.99	3.06	2.25	2.13	3.74	2.26	2.24	3.24	3.15	3.63	2.24	2.28	2.70
2200	3.41	3.46	3.33	3.14	3.21	2.36	2.23	3.93	2.38	2.35	3.41	3.31	3.81	2.35	2.40	2.84
2210	3.59	3.64	3.50	3.30	3.38	2.48	2.34	4.13	2.50	2.47	3.59	3.48	4.01	2.47	2.52	2.99
2220	3.77	3.83	3.68	3.47	3.55	2.60	2.46	4.34	2.63	2.60	3.77	3.66	4.21	2.60	2.65	3.14
2230	3.97	4.02	3.87	3.65	3.73	2.74	2.59	4.57	2.76	2.73	3.96	3.84	4.43	2.73	2.79	3.30
2240	4.17	4.23	4.06	3.84	3.92	2.88	2.72	4.80	2.91	2.87	4.16	4.04	4.65	2.87	2.93	3.47
2250	4.38	4.44	4.27	4.03	4.12	3.02	2.86	5.04	3.05	3.02	4.38	4.25	4.89	3.02	3.08	3.65

2260	4.61	4.67	4.49	4.24	4.33	3.18	3.01	5.30	3.21	3.17	4.60	4.46	5.14	3.17	3.24	3.83
2270	4.84	4.91	4.72	4.45	4.55	3.34	3.16	5.57	3.37	3.34	4.84	4.69	5.40	3.34	3.40	4.03
2280	5.09	5.16	4.96	4.68	4.79	3.51	3.32	5.86	3.55	3.51	5.08	4.93	5.68	3.51	3.58	4.24
2290	5.35	5.42	5.21	4.92	5.03	3.69	3.49	6.16	3.73	3.69	5.34	5.18	5.97	3.69	3.76	4.45
2300	5.62	5.70	5.48	5.17	5.29	3.88	3.67	6.47	3.92	3.88	5.62	5.45	6.28	3.88	3.95	4.68

Table A4.5e Autonomous carbon efficicency improvement (ACEI) in FUND B2 2000 = 1.00.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.67	0.60	0.60	1.43	1.05	0.80	1.21	2.72	1.13	0.97	1.77	1.66	1.24	1.23	1.54	1.25
1960	0.74	0.70	0.60	1.17	1.07	0.70	1.03	1.90	1.08	0.98	1.52	1.33	0.46	1.32	1.36	1.02
1970	0.72	0.68	0.59	0.80	1.11	0.65	1.00	1.40	1.15	1.02	1.39	1.03	0.62	1.06	1.17	0.87
1980	0.79	0.73	0.66	0.87	1.11	0.66	0.99	1.33	1.04	1.09	1.15	1.09	0.60	1.00	1.10	0.84
1990	0.96	0.98	0.90	1.04	0.99	0.86	1.20	1.08	1.02	1.05	1.03	1.11	0.81	1.05	1.00	1.06
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.07	1.07	1.07	1.01	1.03	1.09	0.99	1.07	1.02	1.01	1.02	0.99	1.12	1.01	1.03	1.04
2020	1.16	1.17	1.13	1.05	1.07	1.13	1.07	1.20	1.08	1.07	1.08	1.05	1.18	1.07	1.09	1.12
2030	1.23	1.25	1.20	1.12	1.14	1.15	1.09	1.29	1.15	1.14	1.15	1.11	1.25	1.14	1.16	1.21
2040	1.33	1.35	1.30	1.20	1.23	1.16	1.10	1.41	1.27	1.25	1.25	1.21	1.37	1.25	1.28	1.32
2050	1.42	1.44	1.39	1.29	1.32	1.21	1.15	1.56	1.36	1.34	1.38	1.34	1.51	1.34	1.37	1.42
2060	1.51	1.53	1.48	1.37	1.40	1.31	1.24	1.70	1.45	1.44	1.51	1.47	1.65	1.44	1.46	1.52
2070	1.60	1.63	1.56	1.45	1.48	1.38	1.30	1.82	1.57	1.55	1.59	1.54	1.74	1.55	1.58	1.64
2080	1.65	1.68	1.61	1.49	1.53	1.43	1.35	1.86	1.67	1.65	1.59	1.54	1.74	1.65	1.68	1.74
2090	1.68	1.70	1.64	1.52	1.55	1.51	1.43	1.81	1.76	1.74	1.55	1.51	1.70	1.74	1.77	1.84
2100	1.73	1.76	1.69	1.57	1.60	1.60	1.51	1.82	1.85	1.83	1.55	1.51	1.70	1.83	1.86	1.93
2110	1.82	1.85	1.78	1.65	1.68	1.68	1.59	1.91	1.94	1.92	1.63	1.58	1.79	1.92	1.96	2.03
2120	1.91	1.94	1.87	1.73	1.77	1.77	1.67	2.01	2.04	2.02	1.72	1.67	1.88	2.02	2.06	2.13
2130	2.01	2.04	1.96	1.82	1.86	1.86	1.76	2.11	2.15	2.12	1.80	1.75	1.97	2.12	2.16	2.24
2140	2.12	2.15	2.06	1.91	1.96	1.95	1.85	2.22	2.26	2.23	1.90	1.84	2.07	2.23	2.28	2.36
2150	2.22	2.25	2.17	2.01	2.06	2.05	1.94	2.33	2.37	2.35	1.99	1.93	2.18	2.35	2.39	2.48
2160	2.34	2.37	2.28	2.11	2.16	2.16	2.04	2.45	2.49	2.47	2.10	2.03	2.29	2.47	2.51	2.60
2170	2.46	2.49	2.40	2.22	2.27	2.27	2.14	2.58	2.62	2.59	2.20	2.14	2.41	2.59	2.64	2.74
2180	2.58	2.62	2.52	2.34	2.39	2.38	2.25	2.71	2.76	2.72	2.32	2.25	2.53	2.72	2.78	2.88
2190	2.71	2.75	2.65	2.45	2.51	2.50	2.37	2.85	2.90	2.86	2.43	2.36	2.66	2.86	2.92	3.02
2200	2.85	2.89	2.78	2.58	2.64	2.63	2.49	2.99	3.04	3.01	2.56	2.48	2.80	3.01	3.07	3.18
2210	3.00	3.04	2.92	2.71	2.77	2.77	2.62	3.14	3.20	3.16	2.69	2.61	2.94	3.16	3.23	3.34
2220	3.15	3.20	3.07	2.85	2.91	2.91	2.75	3.31	3.36	3.33	2.83	2.74	3.09	3.33	3.39	3.51
2230	3.31	3.36	3.23	3.00	3.06	3.06	2.89	3.47	3.54	3.50	2.97	2.88	3.25	3.50	3.56	3.69
2240	3.48	3.53	3.40	3.15	3.22	3.21	3.04	3.65	3.72	3.68	3.12	3.03	3.42	3.68	3.75	3.88
2250	3.66	3.71	3.57	3.31	3.38	3.38	3.20	3.84	3.91	3.86	3.28	3.19	3.59	3.86	3.94	4.08

2260	3.85	3.90	3.75	3.48	3.56	3.55	3.36	4.04	4.11	4.06	3.45	3.35	3.77	4.06	4.14	4.29
2270	4.05	4.10	3.94	3.66	3.74	3.73	3.53	4.24	4.32	4.27	3.63	3.52	3.97	4.27	4.35	4.51
2280	4.25	4.31	4.15	3.85	3.93	3.92	3.71	4.46	4.54	4.49	3.81	3.70	4.17	4.49	4.57	4.74
2290	4.47	4.53	4.36	4.04	4.13	4.12	3.90	4.69	4.77	4.72	4.01	3.89	4.38	4.72	4.81	4.98
2300	4.70	4.76	4.58	4.25	4.34	4.33	4.10	4.93	5.01	4.96	4.21	4.09	4.61	4.96	5.05	5.23

Table A4.6a.FUND standard scenario: Carbon dioxide emissions from land use; million metric tones carbon.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1960	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1970	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1980	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1990	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
2000	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
2010	3	3	0	0	0	0	0	0	44	400	56	169	18	0	164	0
2020	3	3	0	0	0	0	0	0	41	373	53	158	17	0	153	0
2030	2	2	0	0	0	0	0	0	38	341	48	144	15	0	140	0
2040	2	2	0	0	0	0	0	0	33	301	42	127	13	0	124	0
2050	2	2	0	0	0	0	0	0	29	262	37	111	12	0	108	0
2060	1	1	0	0	0	0	0	0	23	203	29	86	9	0	83	0
2070	1	1	0	0	0	0	0	0	16	144	20	61	6	0	59	0
2080	1	1	0	0	0	0	0	0	9	85	12	36	4	0	35	0
2090	0	0	0	0	0	0	0	0	3	26	4	11	1	0	11	0
2100	0	0	0	0	0	0	0	0	-4	-33	-5	-14	-1	0	-13	0
2110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A4.6b FUND A1B scenario Carbon dioxide emissions from land use; million metric tonnes of carbon.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1960	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1970	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1980	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1990	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
2000	8	8	6	0	6	0	100	0	39	355	51	152	92	0	245	0
2010	13	13	13	0	13	0	200	0	32	284	41	124	165	0	315	0
2020	8	8	8	0	8	0	30	0	20	180	6	19	25	0	200	0
2030	5	5	5	0	5	0	10	0	16	144	15	45	60	0	160	0
2040	0	0	0	0	0	0	-60	0	15	131	21	64	85	0	145	0
2050	-3	-3	-3	0	-3	0	-130	0	13	117	31	94	125	0	130	0
2060	3	3	3	0	3	0	-110	0	13	113	20	60	80	0	125	0
2070	15	15	15	0	15	0	-90	0	12	104	14	41	55	0	115	0
2080	28	28	28	0	28	0	-70	0	11	95	13	38	50	0	105	0
2090	23	23	23	0	23	0	-50	0	10	86	18	53	70	0	95	0
2100	18	18	18	0	18	0	-30	0	8	72	24	71	95	0	80	0
2110	16	16	16	0	16	0	-27	0	7	65	21	64	86	0	72	0
2120	14	14	14	0	14	0	-24	0	6	58	19	57	76	0	64	0
2130	12	12	12	0	12	0	-21	0	6	50	17	50	67	0	56	0
2140	11	11	11	0	11	0	-18	0	5	43	14	43	57	0	48	0
2150	9	9	9	0	9	0	-15	0	4	36	12	36	48	0	40	0
2160	7	7	7	0	7	0	-12	0	3	29	10	29	38	0	32	0
2170	5	5	5	0	5	0	-9	0	2	22	7	21	29	0	24	0
2180	4	4	4	0	4	0	-6	0	2	14	5	14	19	0	16	0
2190	2	2	2	0	2	0	-3	0	1	7	2	7	10	0	8	0
2200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A4.6c FUND A2 secnario. Carbon dioxide emissions from land use; million metric tonnes of carbon.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1960	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1970	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1980	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1990	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
2000	2	2	0	0	0	0	0	0	43	386	51	154	94	0	280	0
2010	0	0	0	0	0	0	0	0	39	347	43	128	170	0	385	0
2020	0	0	0	0	0	0	0	0	43	383	49	146	195	0	425	0
2030	0	0	0	0	0	0	0	0	42	378	44	131	175	0	420	0
2040	0	0	0	0	0	0	0	0	39	351	35	105	140	0	390	0
2050	0	0	0	0	0	0	0	0	36	320	28	83	110	0	355	0
2060	0	0	0	0	0	0	0	0	26	234	19	56	75	0	260	0
2070	0	0	0	0	0	0	0	0	16	144	10	30	40	0	160	0
2080	0	0	0	0	0	0	0	0	11	95	5	15	20	0	105	0
2090	0	0	0	0	0	0	0	0	9	81	4	11	15	0	90	0
2100	0	0	0	0	0	0	0	0	8	72	3	8	10	0	80	0
2110	0	0	0	0	0	0	0	0	7	65	2	7	9	0	72	0
2120	0	0	0	0	0	0	0	0	6	58	2	6	8	0	64	0
2130	0	0	0	0	0	0	0	0	6	50	2	5	7	0	56	0
2140	0	0	0	0	0	0	0	0	5	43	2	5	6	0	48	0
2150	0	0	0	0	0	0	0	0	4	36	1	4	5	0	40	0
2160	0	0	0	0	0	0	0	0	3	29	1	3	4	0	32	0
2170	0	0	0	0	0	0	0	0	2	22	1	2	3	0	24	0
2180	0	0	0	0	0	0	0	0	2	14	1	2	2	0	16	0
2190	0	0	0	0	0	0	0	0	1	7	0	1	1	0	8	0
2200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A4.6d FUND B1 secnario. Carbon dioxide emissions from land use; million metric tonnes of carbon.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1960	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1970	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1980	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1990	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
2000	14	14	13	0	13	0	-5	0	35	314	45	135	69	0	200	0
2010	25	25	25	0	25	0	-10	0	23	203	30	90	120	0	225	0
2020	15	15	15	0	15	0	-100	0	23	203	28	83	110	0	225	0
2030	-5	-5	-5	0	-5	0	-310	0	2	18	26	79	105	0	20	0
2040	-18	-18	-18	0	-18	0	-350	0	-13	-113	24	71	95	0	-125	0
2050	-23	-23	-23	0	-23	0	-360	0	-7	-59	23	68	90	0	-65	0
2060	-20	-20	-20	0	-20	0	-380	0	-8	-68	20	60	80	0	-75	0
2070	-15	-15	-15	0	-15	0	-410	0	-5	-45	19	56	75	0	-50	0
2080	-35	-35	-35	0	-35	0	-360	0	-11	-95	14	41	55	0	-105	0
2090	-30	-30	-30	0	-30	0	-340	0	-11	-99	-11	-34	-45	0	-110	0
2100	-28	-28	-28	0	-28	0	-290	0	-11	-99	-44	-131	-175	0	-110	0
2110	-25	-25	-25	0	-25	0	-261	0	-10	-89	-39	-118	-158	0	-99	0
2120	-22	-22	-22	0	-22	0	-232	0	-9	-79	-35	-105	-140	0	-88	0
2130	-19	-19	-19	0	-19	0	-203	0	-8	-69	-31	-92	-123	0	-77	0
2140	-17	-17	-17	0	-17	0	-174	0	-7	-59	-26	-79	-105	0	-66	0
2150	-14	-14	-14	0	-14	0	-145	0	-6	-50	-22	-66	-88	0	-55	0
2160	-11	-11	-11	0	-11	0	-116	0	-4	-40	-18	-53	-70	0	-44	0
2170	-8	-8	-8	0	-8	0	-87	0	-3	-30	-13	-39	-53	0	-33	0
2180	-6	-6	-6	0	-6	0	-58	0	-2	-20	-9	-26	-35	0	-22	0
2190	-3	-3	-3	0	-3	0	-29	0	-1	-10	-4	-13	-18	0	-11	0
2200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A4.6e FUND B2 scenario. Carbon dioxide emissions from land use; million metric tonnes of carbon.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1960	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1970	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1980	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
1990	3	3	0	0	0	0	0	0	47	426	60	180	19	0	175	0
2000	-1	-1	-3	0	-3	0	-5	0	39	355	42	127	59	0	245	0
2010	-5	-5	-5	0	-5	0	-10	0	32	284	25	75	100	0	315	0
2020	-15	-15	-15	0	-15	0	-180	0	21	189	-19	-56	-75	0	210	0
2030	-20	-20	-20	0	-20	0	-140	0	6	54	-20	-60	-80	0	60	0
2040	-15	-15	-15	0	-15	0	-90	0	1	5	-11	-34	-45	0	5	0
2050	-13	-13	-13	0	-13	0	-40	0	-6	-50	-4	-11	-15	0	-55	0
2060	-15	-15	-15	0	-15	0	-40	0	-6	-50	-4	-11	-15	0	-55	0
2070	-20	-20	-20	0	-20	0	-30	0	-5	-45	-5	-15	-20	0	-50	0
2080	-28	-28	-28	0	-28	0	-30	0	-6	-54	-6	-19	-25	0	-60	0
2090	-38	-38	-38	0	-38	0	-40	0	-8	-72	-6	-19	-25	0	-80	0
2100	-48	-48	-48	0	-48	0	-40	0	-10	-90	-8	-23	-30	0	-100	0
2110	-43	-43	-43	0	-43	0	-36	0	-9	-81	-7	-20	-27	0	-90	0
2120	-38	-38	-38	0	-38	0	-32	0	-8	-72	-6	-18	-24	0	-80	0
2130	-33	-33	-33	0	-33	0	-28	0	-7	-63	-5	-16	-21	0	-70	0
2140	-29	-29	-29	0	-29	0	-24	0	-6	-54	-5	-14	-18	0	-60	0
2150	-24	-24	-24	0	-24	0	-20	0	-5	-45	-4	-11	-15	0	-50	0
2160	-19	-19	-19	0	-19	0	-16	0	-4	-36	-3	-9	-12	0	-40	0
2170	-14	-14	-14	0	-14	0	-12	0	-3	-27	-2	-7	-9	0	-30	0
2180	-10	-10	-10	0	-10	0	-8	0	-2	-18	-2	-5	-6	0	-20	0
2190	-5	-5	-5	0	-5	0	-4	0	-1	-9	-1	-2	-3	0	-10	0
2200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A4.7a. Methane emissions for all FUND scenarios; 2000 = 100.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.59	0.59	0.59	0.61	0.59	0.60	0.59	0.59	0.60	0.59	0.60	0.60	0.60	0.60	0.60	0.63
1960	0.76	0.77	0.76	0.79	0.77	0.75	0.76	0.75	0.75	0.76	0.76	0.76	0.76	0.77	0.76	0.75
1970	0.91	0.92	0.91	0.93	0.91	0.91	0.91	0.91	0.90	0.91	0.91	0.91	0.91	0.91	0.91	0.94
1980	1.06	1.08	1.07	1.07	1.07	1.06	1.07	1.07	1.06	1.06	1.06	1.06	1.07	1.06	1.07	1.06
1990	1.22	1.23	1.21	1.21	1.22	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.22	1.25
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.08	1.28	1.08	1.11	0.74	1.00	1.17	1.41	1.37	1.18	1.19	1.33	1.14	1.38	1.43	1.13
2020	1.14	1.64	1.09	1.11	0.74	1.39	1.47	1.92	1.77	1.46	1.36	1.64	1.27	1.84	1.75	1.25
2030	1.27	1.54	1.09	1.14	0.77	1.31	1.65	2.58	2.13	1.79	1.57	1.85	1.49	2.43	1.90	1.38
2040	1.34	1.38	1.08	1.18	0.78	1.22	1.69	3.51	2.40	1.96	1.77	2.01	1.77	3.25	2.34	1.50
2050	1.34	1.64	1.06	1.21	0.77	1.17	1.67	4.54	2.58	2.16	2.00	2.14	2.08	4.06	2.81	1.63
2060	1.39	1.79	1.04	1.21	0.90	1.16	1.92	5.63	2.77	2.37	2.14	2.32	2.42	4.25	3.44	1.75
2070	1.42	1.87	1.05	1.21	1.07	1.23	2.25	6.30	3.00	2.59	2.02	2.68	2.76	3.94	4.00	1.88
2080	1.52	2.03	1.10	1.25	1.29	1.36	2.52	5.88	3.29	2.77	1.91	2.77	3.12	4.38	4.23	1.94
2090	1.70	2.28	1.19	1.32	1.51	1.47	2.66	5.11	3.56	3.27	1.88	2.74	3.41	5.04	4.27	2.00
2100	1.90	2.56	1.30	1.32	1.96	1.44	2.79	4.67	3.73	3.59	1.89	2.70	3.61	5.40	4.29	2.06
2110	1.99	2.69	1.35	1.39	2.03	1.51	2.91	4.87	3.88	3.74	1.97	2.81	3.76	5.62	4.47	2.19
2120	2.06	2.79	1.41	1.43	2.12	1.56	3.03	5.07	4.04	3.89	2.05	2.93	3.91	5.86	4.66	2.25
2130	2.15	2.90	1.46	1.50	2.20	1.62	3.14	5.26	4.21	4.05	2.13	3.04	4.07	6.08	4.84	2.38
2140	2.23	3.00	1.52	1.54	2.29	1.69	3.26	5.46	4.37	4.20	2.21	3.15	4.22	6.31	5.02	2.44
2150	2.31	3.13	1.57	1.61	2.36	1.75	3.38	5.66	4.52	4.35	2.29	3.27	4.37	6.55	5.21	2.50
2160	2.39	3.23	1.62	1.64	2.45	1.81	3.50	5.86	4.67	4.50	2.37	3.38	4.52	6.77	5.38	2.63
2170	2.47	3.33	1.68	1.71	2.54	1.87	3.62	6.05	4.83	4.66	2.45	3.50	4.68	7.00	5.57	2.69
2180	2.55	3.44	1.73	1.75	2.61	1.94	3.73	6.25	5.00	4.81	2.53	3.61	4.83	7.22	5.75	2.81
2190	2.63	3.56	1.79	1.82	2.70	1.99	3.85	6.45	5.15	4.96	2.61	3.73	4.98	7.45	5.93	2.88
2200	2.71	3.67	1.84	1.89	2.78	2.05	3.97	6.64	5.31	5.11	2.69	3.84	5.13	7.68	6.11	3.00
2210	2.83	3.82	1.92	1.96	2.90	2.14	4.14	6.92	5.54	5.33	2.80	4.00	5.35	8.00	6.37	3.13
2220	2.94	3.97	1.99	2.07	3.01	2.22	4.31	7.21	5.75	5.55	2.92	4.17	5.57	8.32	6.62	3.25
2230	3.05	4.13	2.07	2.14	3.13	2.31	4.47	7.49	5.98	5.76	3.04	4.33	5.79	8.65	6.88	3.44
2240	3.17	4.31	2.15	2.21	3.25	2.40	4.64	7.76	6.21	5.98	3.15	4.49	6.01	8.96	7.14	3.56
2250	3.28	4.46	2.23	2.29	3.38	2.48	4.81	8.05	6.42	6.20	3.26	4.65	6.22	9.29	7.40	3.69
2260	3.40	4.62	2.30	2.39	3.49	2.57	4.98	8.33	6.65	6.41	3.38	4.81	6.44	9.61	7.66	3.81

2270	3.51	4.77	2.38	2.46	3.61	2.66	5.14	8.61	6.88	6.63	3.49	4.98	6.66	9.94	7.92	3.94
2280	3.63	4.92	2.46	2.54	3.72	2.75	5.31	8.89	7.10	6.84	3.60	5.14	6.87	10.26	8.18	4.06
2290	3.74	5.08	2.53	2.64	3.84	2.83	5.48	9.17	7.33	7.06	3.72	5.30	7.09	10.58	8.43	4.25
2300	3.86	5.23	2.62	2.71	3.96	2.92	5.65	9.45	7.56	7.27	3.83	5.47	7.31	10.91	8.69	4.38

Table A4.7b Parameters of the methane emission reduction cost curve; the 67% confidence interval is given in brackets.

	Quadratic			Exponential - constant			Exponential - exponent		
USA	5.74E-04	(4.15E-04	7.90E-04)	5.43E-06	(4.44E-06	6.64E-06)	10.28	(9.66	10.90)
CAN	1.20E-03	(8.70E-04	1.64E-03)	7.69E-06	(6.30E-06	9.37E-06)	12.49	(11.75	13.23)
WEU	3.71E-04	(2.34E-04	5.80E-04)	1.82E-06	(1.37E-06	2.43E-06)	14.27	(13.10	15.45)
JPK	1.27E-04	(8.75E-05	1.84E-04)	4.19E-07	(3.32E-07	5.29E-07)	17.43	(16.23	18.63)
ANZ	4.12E-03	(3.03E-03	5.57E-03)	1.25E-05	(1.03E-05	1.51E-05)	18.18	(17.14	19.21)
EEU	3.90E-03	(2.81E-03	5.38E-03)	3.13E-05	(2.56E-05	3.83E-05)	11.17	(10.49	11.85)
FSU	8.87E-03	(7.49E-03	1.05E-02)	8.51E-05	(7.65E-05	9.46E-05)	10.21	(9.89	10.52)
MDE	6.32E-03	(4.86E-03	8.19E-03)	1.26E-05	(1.07E-05	1.49E-05)	22.38	(21.29	23.47)
CAM	3.65E-03	(2.87E-03	4.62E-03)	1.30E-05	(1.12E-05	1.51E-05)	16.77	(16.03	17.52)
SAM	2.75E-02	(1.81E-02	4.14E-02)	4.07E-06	(3.14E-06	5.27E-06)	82.24	(75.89	88.58)
SAS	3.16E-02	(2.43E-02	4.08E-02)	2.51E-05	(2.13E-05	2.95E-05)	35.45	(33.74	37.16)
SEA	1.43E-02	(1.06E-02	1.91E-02)	1.94E-05	(1.62E-05	2.33E-05)	27.15	(25.66	28.65)
CHI	1.26E-02	(9.50E-03	1.67E-02)	3.18E-05	(2.67E-05	3.80E-05)	19.93	(18.88	20.97)
MAF	1.43E-02	(1.06E-02	1.91E-02)	1.94E-05	(1.62E-05	2.33E-05)	27.15	(25.66	28.65)
SSA	1.43E-02	(1.06E-02	1.91E-02)	1.94E-05	(1.62E-05	2.33E-05)	27.15	(25.66	28.65)
SIS	1.43E-02	(1.06E-02	1.91E-02)	1.94E-05	(1.62E-05	2.33E-05)	27.15	(25.66	28.65)

Table A4.8a Nitrous oxide emissions in all FUND scenarios; 2000 = 100.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
1950	0.16	0.17	0.17	0.11	0.13	0.16	0.18	0.15	0.14	0.17	0.16	0.16	0.17	0.17	0.16	0.00
1960	0.29	0.25	0.29	0.33	0.25	0.26	0.27	0.31	0.29	0.29	0.29	0.28	0.29	0.30	0.28	0.00
1970	0.44	0.42	0.43	0.44	0.38	0.42	0.45	0.46	0.43	0.44	0.44	0.44	0.43	0.43	0.44	0.00
1980	0.74	0.75	0.74	0.78	0.75	0.74	0.73	0.77	0.71	0.74	0.73	0.75	0.74	0.73	0.74	1.00
1990	0.78	0.75	0.78	0.78	0.75	0.79	0.82	0.85	0.79	0.78	0.79	0.78	0.80	0.77	0.79	1.00
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	1.06	1.08	1.00	1.11	1.00	1.11	1.18	1.38	1.14	1.06	1.11	1.16	1.03	1.33	1.21	1.00
2020	1.09	1.08	0.97	1.11	1.13	1.16	1.36	1.62	1.36	1.16	1.21	1.25	1.03	1.57	1.42	1.00
2030	1.09	1.08	0.93	1.22	1.25	1.16	1.55	2.00	1.50	1.26	1.30	1.34	1.03	1.73	1.58	1.00
2040	1.08	1.17	0.90	1.22	1.38	1.11	1.73	2.15	1.57	1.32	1.38	1.44	1.03	1.83	1.79	1.00
2050	1.15	1.25	0.92	1.33	1.38	1.05	1.91	2.31	1.57	1.40	1.46	1.50	1.06	1.97	1.95	1.00
2060	1.21	1.33	0.94	1.33	1.50	1.05	2.09	2.38	1.64	1.52	1.53	1.56	1.11	2.10	2.12	1.00
2070	1.30	1.42	0.99	1.33	1.50	1.05	2.27	2.46	1.71	1.61	1.55	1.72	1.09	2.20	2.23	1.00
2080	1.40	1.58	1.03	1.33	1.63	1.05	2.45	2.54	1.71	1.69	1.58	1.75	1.14	2.23	2.28	1.00
2090	1.53	1.67	1.10	1.44	1.63	1.05	2.73	2.62	1.86	1.87	1.62	1.81	1.17	2.30	2.30	1.00
2100	1.67	1.83	1.17	1.44	1.63	1.05	2.91	2.62	1.86	1.99	1.63	1.91	1.20	2.43	2.30	1.00
2110	1.68	1.83	1.17	1.44	1.63	1.05	2.91	2.62	1.86	2.00	1.64	1.91	1.20	2.47	2.32	1.00
2120	1.69	1.83	1.17	1.44	1.63	1.05	2.91	2.69	1.86	2.01	1.65	1.91	1.20	2.47	2.32	1.00
2130	1.70	1.83	1.18	1.44	1.63	1.05	2.91	2.69	1.93	2.03	1.66	1.94	1.20	2.47	2.33	1.00
2140	1.70	1.83	1.18	1.44	1.63	1.11	2.91	2.69	1.93	2.04	1.67	1.94	1.23	2.50	2.35	1.00
2150	1.71	1.92	1.19	1.56	1.63	1.11	3.00	2.69	1.93	2.05	1.68	1.94	1.23	2.50	2.37	1.00
2160	1.72	1.92	1.19	1.56	1.75	1.11	3.00	2.69	1.93	2.06	1.69	1.97	1.23	2.53	2.37	1.00
2170	1.74	1.92	1.21	1.56	1.75	1.11	3.00	2.77	1.93	2.06	1.70	1.97	1.23	2.53	2.39	1.00
2180	1.75	1.92	1.21	1.56	1.75	1.11	3.00	2.77	1.93	2.08	1.71	1.97	1.26	2.57	2.40	1.00
2190	1.76	1.92	1.22	1.56	1.75	1.11	3.00	2.77	2.00	2.09	1.71	2.00	1.26	2.57	2.42	1.00
2200	1.76	1.92	1.22	1.56	1.75	1.11	3.00	2.77	2.00	2.10	1.72	2.00	1.26	2.57	2.42	1.00
2210	1.77	1.92	1.22	1.56	1.75	1.11	3.00	2.77	2.00	2.12	1.73	2.00	1.26	2.57	2.44	1.00
2220	1.78	1.92	1.24	1.56	1.75	1.11	3.00	2.77	2.00	2.13	1.74	2.03	1.26	2.60	2.44	1.00
2230	1.79	1.92	1.24	1.56	1.75	1.11	3.00	2.85	2.07	2.14	1.75	2.03	1.29	2.60	2.46	1.00
2240	1.79	1.92	1.25	1.56	1.75	1.11	3.00	2.85	2.07	2.16	1.76	2.03	1.29	2.63	2.47	1.00
2250	1.80	2.00	1.25	1.67	1.88	1.16	3.09	2.85	2.07	2.17	1.77	2.06	1.29	2.63	2.49	1.00
2260	1.82	2.00	1.26	1.67	1.88	1.16	3.09	2.85	2.07	2.18	1.78	2.06	1.29	2.67	2.49	1.00

2270	1.83	2.00	1.26	1.67	1.88	1.16	3.09	2.85	2.14	2.19	1.79	2.06	1.29	2.67	2.51	1.00
2280	1.84	2.00	1.26	1.67	1.88	1.16	3.09	2.92	2.14	2.21	1.79	2.09	1.31	2.67	2.53	1.00
2290	1.85	2.00	1.28	1.67	1.88	1.16	3.09	2.92	2.14	2.22	1.80	2.09	1.31	2.70	2.54	1.00
2300	1.85	2.00	1.28	1.67	1.88	1.16	3.09	2.92	2.14	2.23	1.82	2.09	1.31	2.70	2.54	1.00

Table A4.8b Parameters of the nitrous oxide emission reduction cost curve; the 67% confidence interval is given in brackets.

	Quadratic			Exponential - constant			Exponential - exponent		
USA	2.14E-05	(1.91E-05	2.39E-05)	1.36E-08	(1.29E-08	1.45E-08)	39.61	(38.56	40.65)
CAN	6.92E-05	(6.29E-05	7.60E-05)	1.62E-08	(1.54E-08	1.70E-08)	65.33	(63.88	66.78)
WEU	7.26E-06	(6.60E-06	7.98E-06)	1.97E-08	(1.88E-08	2.08E-08)	19.18	(18.75	19.60)
JPK	5.32E-07	(3.21E-07	8.57E-07)	9.54E-09	(7.38E-09	1.23E-08)	7.46	(6.60	8.33)
ANZ	2.08E-04	(1.89E-04	2.29E-04)	4.62E-09	(4.39E-09	4.86E-09)	212.40	(207.68	217.11)
EEU	9.39E-05	(8.89E-05	9.93E-05)	8.35E-08	(7.91E-08	8.83E-08)	33.53	(33.53	33.53)
FSU	1.05E-05	(1.00E-05	1.10E-05)	1.94E-08	(1.91E-08	1.98E-08)	23.25	(22.91	23.60)
MDE	1.05E-05	(1.00E-05	1.10E-05)	1.94E-08	(1.91E-08	1.98E-08)	23.25	(22.91	23.60)
CAM	2.35E-04	(2.19E-04	2.53E-04)	2.00E-08	(1.89E-08	2.13E-08)	108.39	(107.83	108.95)
SAM	1.05E-05	(1.00E-05	1.10E-05)	1.94E-08	(1.91E-08	1.98E-08)	23.25	(22.91	23.60)
SAS	5.64E-04	(5.29E-04	6.01E-04)	1.71E-07	(1.62E-07	1.80E-07)	57.44	(57.14	57.74)
SEA	2.55E-15	(2.16E-15	3.01E-15)	4.72E-18	(4.12E-18	5.40E-18)	23.25	(22.91	23.60)
CHI	2.16E-05	(2.02E-05	2.30E-05)	1.42E-07	(1.35E-07	1.50E-07)	12.32	(12.26	12.39)
MAF	1.05E-05	(1.00E-05	1.10E-05)	1.94E-08	(1.91E-08	1.98E-08)	23.25	(22.91	23.60)
SSA	1.05E-05	(1.00E-05	1.10E-05)	1.94E-08	(1.91E-08	1.98E-08)	23.25	(22.91	23.60)
SIS	1.05E-05	(1.00E-05	1.10E-05)	1.94E-08	(1.91E-08	1.98E-08)	23.25	(22.91	23.60)

Table A4.9. Determinants of SF_6 emissions in FUND.

	C	GDP	GDP/cap
1990	1.6722E-01	5.0931E-06	-5.7537E-05
	(1.9297E-01)	(2.3482E-07)	(1.8505E-05)
1995	1.6255E-01	5.7234E-06	-6.0384E-05
	(2.1143E-01)	(2.3082E-07)	(1.8727E-05)
Used	1.6489E-01	5.4083E-06	-5.8961E-05
	(1.4312E-01)	(1.6464E-07)	(1.3164E-05)

SF_6 emissions are in million metric tonnes of carbon dioxide equivalent. GDP is in million dollar (1995, MEX). GDP/capita is in dollar (1995, MEX)

Table A4.10 Parameters of equation (C.1).

Gas	α^a	β^b	pre-industrial concentration
Methane (CH_4)	0.3597	1/8.6	790 ppb
Nitrous oxide (N_2O)	0.2079	1/120	285 ppb
Sulphur hexafluoride (SF_6)	0.0398	1/3200	0.04 ppt

[a] The parameter α translates emissions (in million metric tonnes) into concentrations (in parts per billion or trillion by volume).

[b] The parameter β determines how fast concentrations return to their pre-industrial (and assumedly equilibrium) concentrations; $1/\beta$ is the atmospheric life-time (in years) of the gases.

Source: Schimel, D., Alves, D., Enting, I., et al (1996) Radiative Forcing of Climate Change. In: Houghton, J.T., Meiro Filho, L.G., Callander, B.A., Harris, N., Kattenberg, A. and Maskell, K., (Eds.) *Climate Change 1995: The Science of Climate Change -- Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, 1 edn. pp. 65-131. Cambridge: Cambridge University Press.

Table A4.11 Impacts of climate change on agriculture

	Rate of change		Benchmark impact		Optimal temperature		CO_2 fertilisation	
	(% Ag. Prod/0.04C)		(% Ag Prod /0.04 ºC)		(ºC)		(% Ag. Prod)	
USA	-0.00021	(0.00176)	-0.0389	(0.0750)	1.09	(4.14)	0.0890	(0.1484)
CAN	-0.00029	(0.00073)	0.1336	(0.0319)	2.92	(7.64)	0.0402	(0.0650)
WEU	-0.00039	(0.00138)	-0.0718	(0.0588)	0.79	(3.29)	0.1541	(0.1183)
JPK	-0.00033	(0.00432)	-0.0936	(0.1834)	0.98	(6.61)	0.2319	(0.3660)
ANZ	-0.00015	(0.00142)	0.0824	(0.0613)	2.00	(8.00)	0.1048	(0.0850)
EEU	-0.00027	(0.00062)	-0.0337	(0.0280)	1.31	(2.73)	0.0952	(0.0514)
FSU	-0.00018	(0.00066)	-0.0184	(0.0294)	1.46	(2.44)	0.0671	(0.0548)
MDE	-0.00022	(0.00032)	-0.0465	(0.0140)	1.32	(2.03)	0.0943	(0.0266)
CAM	-0.00034	(0.00061)	-0.1070	(0.0260)	1.05	(3.60)	0.1641	(0.0538)
SAM	-0.00009	(0.00060)	-0.0348	(0.0258)	0.35	(8.82)	0.0596	(0.0504)
SAS	-0.00014	(0.00021)	-0.0339	(0.0093)	1.13	(2.41)	0.0580	(0.0164)
SEA	-0.00009	(0.00482)	-0.0556	(0.2045)	0.70	(5.12)	0.0845	(0.4181)
CHI	-0.00013	(0.00075)	-0.0794	(0.0319)	1.43	(2.49)	0.1921	(0.0613)
NAF	-0.00016	(0.00023)	-0.0357	(0.0099)	1.20	(2.74)	0.0727	(0.0190)
SSA	-0.00011	(0.00026)	-0.0244	(0.0114)	1.22	(2.76)	0.0505	(0.0220)
SIS	-0.00050	(0.00103)	-0.0689	(0.0442)	1.51	(2.92)	0.2377	(0.0864)

Standard deviations are given in brackets.

Table A4.12. Impact of a 1°C warming on forestry, water, heating, and cooling, in fraction of GDP.

	Forestry (% GDP)		Water (% GDP)		Heating (% GDP)		Cooling (% GDP)	
USA	0.000053	(0.000014)	-0.00065	(0.00065)	0.00429	(0.00429)	-0.00212	(0.00212)
CAN	0.000011	(0.000072)	-0.00057	(0.00057)	0.00378	(0.00378)	-0.00186	(0.00186)
WEU	0.000025	(0.000006)	-0.00027	(0.00027)	0.00241	(0.00241)	-0.00372	(0.00372)
JPK	0.000042	(0.000012)	0.00000	(0.00000)	0.00207	(0.00207)	-0.00029	(0.00029)
ANZ	-0.000121	(0.000033)	0.00000	(0.00000)	0.00151	(0.00151)	-0.00021	(0.00021)
EEU	0.000055	(0.000025)	-0.00697	(0.00697)	0.00456	(0.00456)	-0.00185	(0.00185)
FSU	-0.000023	(0.000053)	-0.02754	(0.02754)	0.01663	(0.01663)	-0.00674	(0.00674)
MDE	0.000000	(0.000034)	-0.00133	(0.00133)	0.02074	(0.02074)	-0.00233	(0.00233)
CAM	0.000018	(0.000034)	-0.00130	(0.00130)	0.00366	(0.00366)	-0.00239	(0.00239)
SAM	0.000024	(0.000012)	-0.00140	(0.00140)	0.00395	(0.00395)	-0.00259	(0.00259)
SAS	0.000062	(0.000023)	-0.00156	(0.00156)	0.00361	(0.00361)	-0.00384	(0.00384)
SEA	0.000067	(0.000028)	-0.00314	(0.00314)	0.00695	(0.00695)	-0.00740	(0.00740)
CHI	0.000087	(0.000032)	0.00569	(0.00569)	0.03971	(0.03971)	-0.02891	(0.02891)
NAF	0.000000	(0.000034)	-0.00902	(0.00902)	0.00015	(0.00015)	-0.01892	(0.01892)
SSA	0.000011	(0.000035)	-0.00360	(0.00360)	0.00006	(0.00006)	-0.00797	(0.00797)
SIS	0.000000	(0.000034)	-0.00130	(0.00130)	0.00366	(0.00366)	-0.00239	(0.00239)

Standard deviations are given in brackets.

Table A4.13. Impact of a one metre sea level rise.														
	level prot.	dryland loss		dryland value		wetland loss		wetland value		protection costs		emigrants	
	%	10^3 km^2		10^6\$/km^2		10^3 km^2		10^6\$/km^2		10^9\$		10^6	
OECD-A	0.77	4.8	(2.4)	1.3	(0.6)	12.0	(8.6)	5.4	(2.7)	83	(74)	0.13	(0.07)
OECD-E	0.86	0.7	(0.4)	13.1	(6.6)	4.0	(2.3)	4.3	(2.2)	136	(45)	0.22	(0.10)
OECD-P	0.95	0.3	(0.4)	13.7	(6.7)	1.0	(1.1)	5.9	(2.9)	63	(38)	0.04	(0.02)
CEE&fSU	0.93	1.2	(2.7)	0.9	(0.5)	0.0	(0.0)	2.9	(1.5)	53	(50)	0.03	(0.03)
ME	0.30	0.6	(1.2)	0.5	(0.3)	0.0	(0.0)	1.3	(0.7)	5	(3)	0.05	(0.08)
LA	0.86	7.8	(7.1)	0.3	(0.2)	50.2	(36.4)	0.9	(0.5)	147	(74)	0.71	(1.27)
S&SEA	0.93	9.3	(9.6)	0.5	(0.3)	54.9	(48.0)	0.3	(0.2)	305	(158)	2.30	(1.40)
CPA	0.93	8.4	(15.1)	0.3	(0.2)	15.6	(17.1)	0.2	(0.1)	171	(126)	2.39	(3.06)
AFR	0.89	15.4	(18.4)	0.4	(0.2)	30.8	(14.8)	0.4	(0.2)	92	(35)	2.74	(2.85)

Standard deviations in brackets.

Table A4.14. Migration from row to column.

	USA	CAN	WEU	JPK	ANZ	EEU	FSU	MDE	CAM	SAM	SAS	SEA	CHI	NAF	SSA	SIS
USA	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.040	0.100	0.100	0.040	0.040	0.040	0.010	0.030	0.150
	(0.100)	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)	(0.040)	(0.100)	(0.100)	(0.040)	(0.040)	(0.040)	(0.010)	(0.030)	(0.150)
CAN	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.010	0.010	0.010	0.000	0.005	0.100
	(0.050)	(0.100)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.010)	(0.050)	(0.050)	(0.010)	(0.010)	(0.010)	(0.005)	(0.005)	(0.100)
WEU	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.040	0.000	0.000	0.040	0.020	0.020	0.090	0.060	0.150
	(0.020)	(0.020)	(0.100)	(0.020)	(0.020)	(0.020)	(0.020)	(0.040)	(0.050)	(0.050)	(0.040)	(0.020)	(0.020)	(0.090)	(0.060)	(0.150)
JPK	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.010	0.010	0.000	0.000	0.050
	(0.010)	(0.010)	(0.010)	(0.100)	(0.010)	(0.001)	(0.001)	(0.005)	(0.010)	(0.010)	(0.005)	(0.010)	(0.010)	(0.001)	(0.001)	(0.050)
ANZ	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.010	0.000	0.000	0.005	0.020	0.020	0.000	0.005	0.150
	(0.020)	(0.020)	(0.020)	(0.020)	(0.100)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.005)	(0.020)	(0.020)	(0.005)	(0.005)	(0.150)
EEU	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.100)	(0.050)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
FSU	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.100)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
MDE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.900	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.900)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
CAM	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.900	0.000	0.000	0.000	0.000	0.000	0.000	0.100
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.900)	(0.005)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.100)
SAM	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.900	0.000	0.000	0.000	0.000	0.000	0.100
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.005)	(0.900)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.100)
SAS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.900	0.000	0.000	0.000	0.000	0.100
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.900)	(0.005)	(0.001)	(0.001)	(0.001)	(0.100)
SEA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.900	0.000	0.000	0.000	0.100
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.005)	(0.900)	(0.005)	(0.001)	(0.001)	(0.100)
CHI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.900	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.900)	(0.001)	(0.001)	(0.001)
NAF	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.900	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.900)	(0.005)	(0.001)
SIS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.900	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.900)	(0.001)
SIS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)

Table A4.15 Diarrhoea mortality and morbidity due to a 2.5 C global warming.

Region	Population[a]	Mortality[b]	Morbidity[c]	ΔT[d]	Additional Mortality[e]			Additional Morbidity[f]		
USA	278357	0.041	1.704	3.0	40	(23	70)	1019	(767	1354)
CAN	31147	0.041	1.704	3.7	6	(3	11)	132	(94	185)
WEU	388581	0.015	0.632	2.8	18	(11	31)	506	(387	662)
JPK	173558	0.009	0.166	2.6	5	(3	8)	57	(44	73)
ANZ	22748	0.001	0.083	2.4	0	(0	0)	3	(3	4)
EEU	121191	0.018	0.847	2.9	7	(4	13)	217	(164	287)
FSU	291538	0.122	6.735	3.2	135	(74	244)	4443	(3279	6020)
MDE	237590	0.030	0.166	2.9	24	(14	41)	83	(63	109)
CAM	135222	0.162	0.643	2.2	54	(36	81)	151	(123	185)
LAM	345779	0.168	0.650	2.1	138	(94	202)	381	(313	463)
SAS	1366902	0.229	0.896	2.3	798	(526	1212)	2171	(1755	2687)
SEA	522462	0.135	0.631	1.8	136	(102	182)	492	(424	571)
CHI	1311659	0.033	0.401	3.0	150	(86	261)	1122	(846	1488)
MAF	143482	0.415	0.990	2.9	197	(116	337)	296	(225	389)
SSA	637887	3.167	5.707	2.2	4958	(3321	7404)	6306	(5141	7737)
SIS	44002	0.252	1.092	1.9	23	(17	31)	75	(63	88)

[a] Thousands of people, 2000.
[b] Deaths per thousand people.
[c] Years of life diseased per thousand people.
[d] Regional temperature change for a 2.5 C global warming.
[e] Additional deaths, thousands of people (67% confidence interval in brackets).
[f] Additional years of life diseased, thousands (67% confidence interval in brackets).

Table A4.16 . Parameters for vector-borne mortality.

	Malaria			Dengue fever			Schistosomiasis		
	Base[a]	Impact[b]		Base[a]	Impact[b]		Base[a]	Impact[b]	
USA	0.023	0.0794	(0.0575)	0.000	0.3534	(0.0614)	0.007	-0.1149	(0.0614)
CAN	0.023	0.0794	(0.0575)	0.000	0.3534	(0.0614)	0.007	-0.1149	(0.0614)
WEU	0.240	0.0794	(0.0575)	0.000	0.3534	(0.0614)	0.020	-0.1149	(0.0614)
JPK	2.358	0.0794	(0.0575)	0.125	0.3534	(0.0614)	0.423	-0.1149	(0.0614)
ANZ	0.069	0.0794	(0.0575)	0.000	0.3534	(0.0614)	0.037	-0.1149	(0.0614)
EEU	0.377	0.0794	(0.0575)	0.000	0.3534	(0.0614)	0.012	-0.1149	(0.0614)
FSU	0.133	0.0794	(0.0575)	0.000	0.3534	(0.0614)	0.003	-0.1149	(0.0614)
MDE	24.113	0.0794	(0.0575)	0.286	0.3534	(0.0614)	4.229	-0.1149	(0.0614)
CAM	2.913	0.0794	(0.0575)	0.508	0.3534	(0.0614)	1.235	-0.1149	(0.0614)
SAM	3.090	0.0794	(0.0575)	0.541	0.3534	(0.0614)	1.217	-0.1149	(0.0614)
SAS	48.413	0.0794	(0.0575)	6.896	0.3534	(0.0614)	0.898	-0.1149	(0.0614)
SEA	22.129	0.0794	(0.0575)	2.072	0.3534	(0.0614)	0.629	-0.1149	(0.0614)
CHI	8.987	0.0794	(0.0575)	0.593	0.3534	(0.0614)	1.430	-0.1149	(0.0614)
NAF	458.133	0.0794	(0.0575)	1.089	0.3534	(0.0614)	7.474	-0.1149	(0.0614)
SSA	1414.284	0.0794	(0.0575)	0.351	0.3534	(0.0614)	8.275	-0.1149	(0.0614)
SIS	116.586	0.0794	(0.0575)	1.010	0.3534	(0.0614)	1.296	-0.1149	(0.0614)

[a] Mortality (deaths per million people) in 1990.

[b] The change in mortality due to a one-degree global warming.

Table A4.17. Parameters of Equation (HC.1).

			Constant		Temperature	
Cardiovascular	Cold	65-	-2.9787	(0.5914)	0.0946	(0.0464)
		65+	-162.6459	(18.3041)	5.6628	(1.4367)
	Heat	65-	-1.4610	(0.9599)	0.0941	(0.0406)
		65+	-40.9953	(3.4570)	3.4570	(1.6218)
Respiratory			-17.9222	(6.0196)	0.8683	(0.2545)

Table A4.18. Parameters of Equation (HC.2) for cold-related cardiovascular mortality.

	65-				65+			
	linear		Quadratic		linear		Quadratic	
USA	151.6768	(3.4583)	-155.1251	(2.8292)	-161.4521	(62.3397)	2.8314	(62.3080)
CAN	195.6424	(3.4583)	-199.0906	(2.8292)	-205.4176	(62.3397)	2.8314	(62.3080)
WEU	19.2327	(1.2716)	-21.7191	(1.0403)	-145.9539	(23.8362)	2.8279	(23.8241)
JPK	65.5934	(3.5211)	-67.1850	(2.8805)	-33.6830	(24.9641)	1.2018	(24.9514)
ANZ	67.1775	(2.9403)	-68.9576	(2.4054)	-91.0606	(53.2451)	2.8314	(53.2180)
EEU	61.4840	(1.5395)	-65.2217	(1.2594)	-201.8789	(27.0842)	2.8314	(27.0704)
FSU	-3.4422	(3.4583)	0.0473	(2.8292)	-190.3936	(62.3397)	2.8314	(62.3080)
MDE	-2.4508	(1.5732)	0.0457	(1.2870)	-136.8033	(30.2768)	2.7443	(30.2614)
CAM	-0.6855	(2.6117)	-0.4840	(2.1366)	-54.1635	(45.5739)	2.7085	(45.5507)
SAM	16.6942	(1.8829)	-18.2021	(1.5404)	-78.4126	(32.7397)	2.8094	(32.7230)
SAS	-1.6072	(2.6242)	0.0473	(2.1468)	-80.2320	(51.2055)	2.8314	(51.1794)
SEA	-0.6838	(1.4722)	0.0413	(1.2044)	12.0899	(12.0535)	-1.1081	(12.0474)
CHI	81.1077	(3.4522)	-84.8815	(2.8242)	-66.6796	(43.8249)	2.0193	(43.8025)
NAF	-1.9826	(1.9196)	0.0473	(1.5704)	-102.4339	(35.4522)	2.8314	(35.4341)
SSA	-1.0407	(0.9609)	0.0448	(0.7861)	-49.9700	(16.5999)	2.6771	(16.5915)
SIS	1.6035	(1.1897)	-2.3428	(0.9733)	-10.4503	(7.4943)	0.5138	(7.4905)

Table A4.19. Parameters of Equation (HC.2) for heat-related cardiovascular mortality.

	65-				65+			
	linear		quadratic		linear		Quadratic	
USA	1.0988	(1.0738)	0.0471	(0.8815)	34.9374	(42.9155)	1.7285	(35.2319)
CAN	1.0705	(1.0738)	0.0471	(0.8815)	27.3280	(42.9155)	1.7285	(35.2319)
WEU	0.4022	(0.4226)	0.0467	(0.3469)	25.7570	(17.8447)	1.7966	(14.6498)
JPK	1.0356	(1.1234)	0.0559	(0.9223)	8.2986	(17.7713)	0.7493	(14.5895)
ANZ	0.4493	(0.9147)	0.0470	(0.7509)	18.8372	(36.7267)	1.7286	(30.1512)
EEU	0.6119	(0.4767)	0.0470	(0.3914)	29.6249	(18.8672)	1.7531	(15.4893)
FSU	0.6468	(1.0738)	0.0471	(0.8815)	36.4415	(42.9155)	1.7285	(35.2319)
MDE	1.0931	(0.4791)	0.0452	(0.3933)	50.5493	(20.6547)	1.7011	(16.9568)
CAM	0.9144	(0.8887)	0.0471	(0.7296)	44.7697	(34.4286)	1.6620	(28.2646)
SAM	0.5893	(0.5874)	0.0470	(0.4823)	33.7621	(23.0347)	1.7535	(18.9106)
SAS	1.6317	(0.8373)	0.0470	(0.6874)	74.5092	(36.2131)	1.7378	(29.7296)
SEA	0.8545	(0.4641)	0.0411	(0.3810)	-18.7223	(8.1867)	-0.6683	(6.7210)
CHI	0.7565	(1.0335)	0.0474	(0.8485)	82.0355	(29.0776)	1.2095	(23.8716)
NAF	1.0409	(0.5662)	0.0471	(0.4648)	50.4842	(23.0206)	1.7096	(18.8991)
SSA	0.8682	(0.3408)	0.0440	(0.2798)	43.4397	(13.5145)	1.6578	(11.0949)
SIS	1.0227	(0.4957)	0.0324	(0.4070)	16.9938	(8.0489)	0.4223	(6.6079)

Table A4.20 Parameters of Equation (HC.2) for (heat-related) respiratory mortality.

	linear		Quadratic	
USA	0.9452	(6.7337)	0.4342	(5.5281)
CAN	-1.9284	(6.7337)	0.4342	(5.5281)
WEU	-0.7650	(2.4863)	0.4341	(2.0412)
JPK	0.4185	(5.8130)	0.4342	(4.7723)
ANZ	0.2579	(5.7279)	0.4342	(4.7024)
EEU	-1.2946	(2.9883)	0.4342	(2.4533)
FSU	1.5277	(6.7337)	0.4342	(5.5281)
MDE	5.6711	(3.0690)	0.4194	(2.5196)
CAM	3.8894	(5.0789)	0.4342	(4.1696)
SAM	1.0893	(3.6563)	0.4335	(3.0017)
SAS	10.2485	(5.1264)	0.4342	(4.2086)
SEA	4.8562	(3.2809)	0.4339	(2.6935)
CHI	4.4083	(6.5634)	0.4319	(5.3883)
NAF	5.1980	(3.7408)	0.4341	(3.0711)
SSA	3.6196	(1.8681)	0.411	(1.5337)
SIS	4.1354	(2.0330)	0.2522	(1.6690)

Table A4.21 Ratio of morbidity impacts (measured in years of life disabled) to mortality impacts (measured in number of cases).

	Malaria	Schistosomiasis	Dengue fever	Cardiovascular	Respiratory
USA	0.0000	0.0000	0.0000	0.9609	8.7638
CAN	0.0000	0.0000	0.0000	0.9609	8.7638
WEU	0.0000	0.0000	0.0000	0.9609	8.7638
JPK	0.0000	0.0000	0.0000	0.9609	8.7638
ANZ	0.0000	0.0000	0.0000	0.9609	8.7638
EEU	0.0000	0.0000	0.0000	0.8986	11.8101
FSU	0.0000	0.0000	0.0000	0.8986	11.8101
MDE	24.8571	51.5000	0.0000	1.3459	21.8098
CAM	4.5714	69.0000	0.0000	1.2548	22.1552
SAM	4.5714	69.0000	0.0000	1.2548	22.1552
SAS	16.3462	0.0000	0.2500	1.3879	16.5094
SEA	3.2727	6.0000	0.4286	1.3729	20.0541
CHI	0.0000	11.0000	0.0000	1.2399	8.3072
NAF	24.8571	51.5000	0.0000	1.3459	21.8098
SSA	3.6940	293.7500	0.0000	1.3301	21.5857
SIS	4.5714	69.0000	0.0000	1.2548	22.1552

Table A4.22 Parameters of the Monte Carlo analysis (μ: expected value; σ: standard deviation; M: mode; L: lower bound; U: upper bound)

Parameter	Distribution			
Methane emissions	Normal	μ = Table CH4	σ = 6.83/yr	
Nitrous oxide emissions	Normal	μ = Table N2O	σ = 0.0059/yr	
Climate sensitivity	Gamma	M = 2.85	σ = 1.00	
Sea level sensitivity	Gamma	M = 0.31	σ = 0.15	
Life time methane	Triangular	L = 8.00	M = 8.60	U = 16.00
Life time nitrous oxide	Triangular	L = 100	M = 120	U = 170
Response time temperature	Triangular	L = 25	M = 50	U = 100
Response time sea level	Triangular	L = 25	M = 50	U = 100
Life time carbon dioxide	Trunc. normal	μ = 363.00	σ = 90.75	L = 0.00
Life time carbon dioxide	Trunc. normal	μ = 74.00	σ = 18.50	L = 0.00
Life time carbon dioxide	Trunc. normal	μ = 17.00	σ = 4.25	L = 0.00
Life time carbon dioxide	Trunc. normal	μ = 2.00	σ = 0.50	L = 0.00
Baseline loss biodiversity	Trunc. normal	μ = 0.003	σ = 0.002	L = 0.000
Sensitivity biodiversity	Trunc. normal	μ = 0.001	σ = 0.001	L = 0.000
Share biodiversity	Triangular	L = 0.00	M = 0.05	U = 1.00
Water technology rate	Trunc. normal	μ = 0.005	σ = 0.005	L = 0.000
Population growth	Normal	μ = Table P	σ = 0.0048/yr	
Income growth	Normal	μ = Table Y	σ = 0.0026/yr	
Energy efficiency	Normal	μ = Table AEEI	σ = 0.0005/yr	
Decarbonisation	Normal	μ = Table ACEI	σ = 0.0009/yr	
Land use emissions	Normal	μ = Table CO2F	σ = 0.20/yr	
Ecosystem value	Trunc. normal	μ = 50	σ = 50	L = 0
Anchor income	Trunc. normal	μ = 30,000	σ = 10,000	L = 0
Value of a statistical life	Trunc. normal	μ = 200	σ = 100	L = 0
Value of a year diseased	Trunc. normal	μ = 0.8	σ = 1.2	L = 0
Sensitivity malaria	Trunc. normal	μ = 0.0794	σ = 0.0575	L = 0.0000
Non-linearity malaria	Trunc. normal	μ = 1.0	σ = 0.5	L = 0.0
Sensitivity dengue fever	Trunc. normal	μ = 0.3534	σ = 0.0614	L = 0.0000
Non-linearity dengue fever	Trunc. normal	μ = 1.0	σ = 0.5	L = 0.0
Sensitivity schistosomiasis	Trunc. normal	μ = -0.1149	σ = 0.0614	U = 0.0000
Non-linearity schistosomiasis	Trunc. normal	μ = 1.0	σ = 0.5	L = 0.0
Income elasticity vector-borne diseases	Trunc. normal	μ = -2.65	σ = 0.69	U = 0.00
Income elasticity diarrhoea mortality	Trunc. normal	μ = -1.58	σ = 0.23	U = 0.00
Income elasticity diarrhoea morbidity	Trunc. normal	μ = -0.42	σ = 0.12	U = 0.00
Non-linearity diarrhoea mortality	Trunc. normal	μ = 1.14	σ = 0.51	L = 0.00

Non-linearity diarrhoea morbidity	Trunc. normal	μ = 0.70	σ = 0.26	L = 0.00
Cardiovascular and respiratory mortality	Normal	Table HC	Table HC	
Change in baseline cardiovascular disease	Trunc. normal	μ = 0.0259	σ = 0.0096	L = 0.0000
Change in baseline respiratory disease	Trunc. normal	μ = 0.0016	σ = 0.0005	L = 0.0000
Change in population above 65	Trunc. normal	μ = 0.25	σ = 0.08	L = 0.00
Maximum increase cardiovascular & respiratory disease	Trunc. normal	μ = 0.05	σ = 0.02	L = 0.00
Sensitivity water	Normal	Table EFW	Table EFW	
Income elasticity water	Trunc. normal	μ = 0.85	σ = 0.15	U = 0.00
Non-linearity water	Trunc. normal	μ = 1.00	σ = 0.50	U = 0.00
Sensitivity forestry	Normal	Table EFW	Table EFW	
Income elasticity forestry	Trunc. normal	μ = 0.31	σ = 0.20	U = 0.00
Non-linearity forestry	Trunc. normal	μ = 1.00	σ = 0.50	U = 0.00
Sensitivity heating	Trunc. normal	Table EFW	Table EFW	
Non-linearity heating	Trunc. normal	μ = 1.00	σ = 0.50	U = 0.00
Sensitivity cooling	Trunc. normal	Table EFW	Table EFW	
Non-linearity cooling	Trunc. normal	μ = 1.00	σ = 0.50	U = 0.00
Agriculture, rate	Trunc. normal	μ =Table A	σ = Table A	U = 0.00
Adaptation time	Trunc. normal	μ = 10.0	σ = 5.0	U = 0.0
Non-linearity	Trunc. normal	μ = 2.0	σ = 0.5	U = 0.0
Agriculture, level	Normal	μ =Table A	σ = Table A	
Agriculture, optimum	Normal	μ =Table A	σ = Table A	
Agriculture, CO2	Trunc. normal	μ =Table A	σ = Table A	U = 0.00
Income elasticity agriculture	Trunc. normal	μ = 0.31	σ = 0.15	U = 0.00
Dryland value	Trunc. normal	μ = 4.0	σ = 2.0	U = 0.0
Adaptation time	Exponential		σ = 0.1	
Wetland value	Trunc. normal	μ = 5.0	σ = 2.5	U = 0.0
Adaptation time	Exponential		σ = 0.1	
Dryland loss	Trunc. normal	μ = Table SLR	σ = Table SLR	U = 0.0
Protection cost	Trunc. normal	μ = Table SLR	σ = Table SLR	U = 0.0
Dryland value	Trunc. normal	μ = Table SLR	σ = Table SLR	U = 0.0
Wetland value	Trunc. normal	μ = Table SLR	σ = Table SLR	U = 0.0
Immigration	Trunc. normal	μ = Table I	σ = Table I	U = 0.0
Immigration cost	Trunc. normal	μ = 0.4	σ = 0.2	U = 0.0
Adaptation time	Trunc. normal	μ = 3.0	σ = 1.0	U = 0.0
Emigration cost	Trunc. normal	μ = 3.0	σ = 1.5	U = 0.0
Adaptation time	Exponential		σ = 0.1	

Figure A4.1
Impacts Module: Loss of Drylands and Wetlands and Protection Costs due to Sea Level Rise

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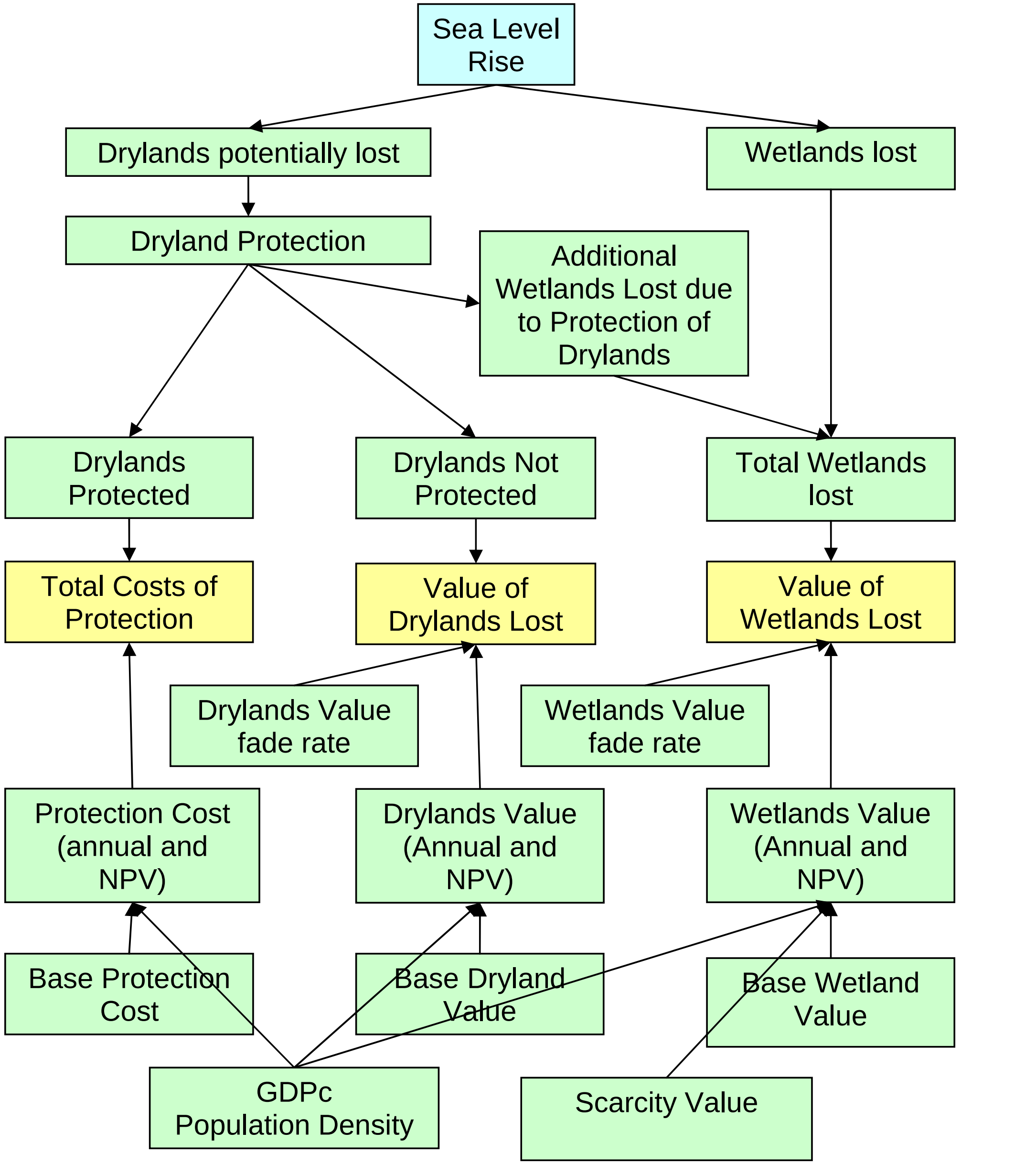
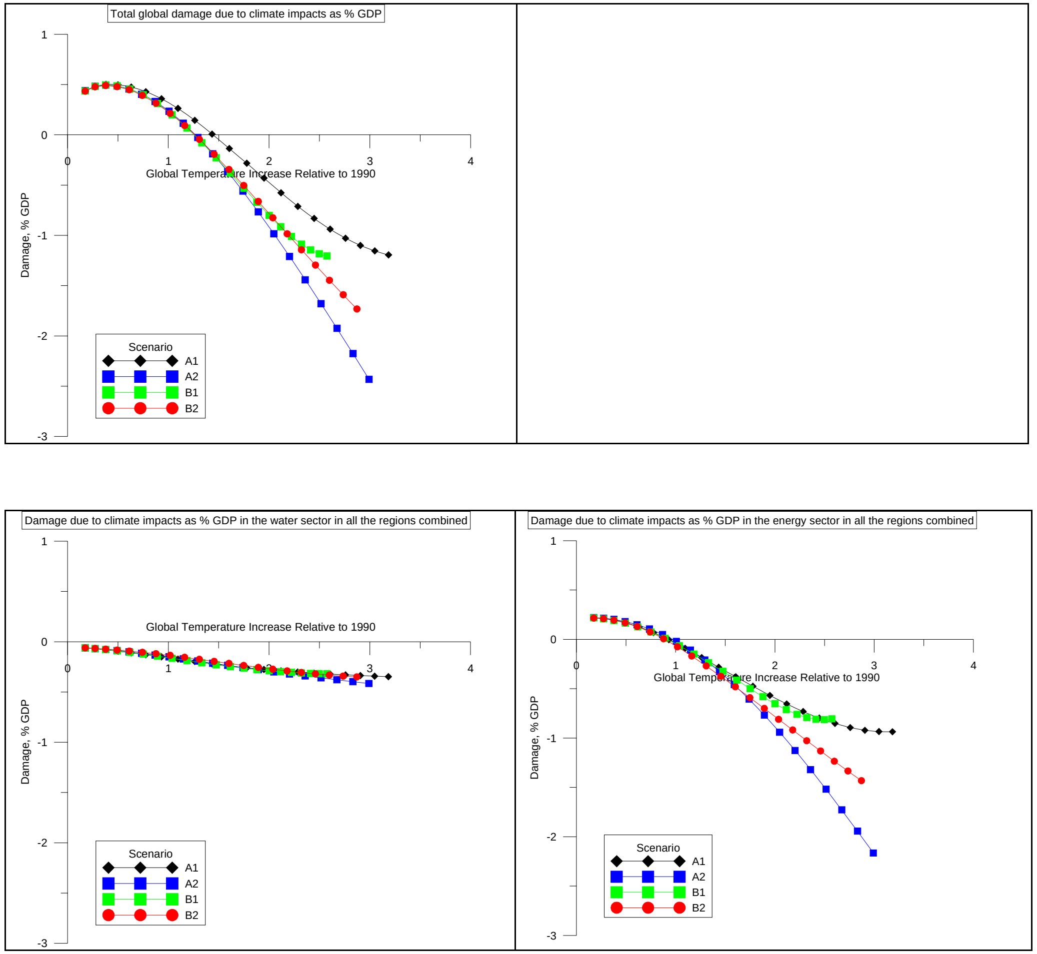


Figure A4.2a FUND-simulated global and sectoral damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 for the major FUND impact sectors for 4 SRES scenarios



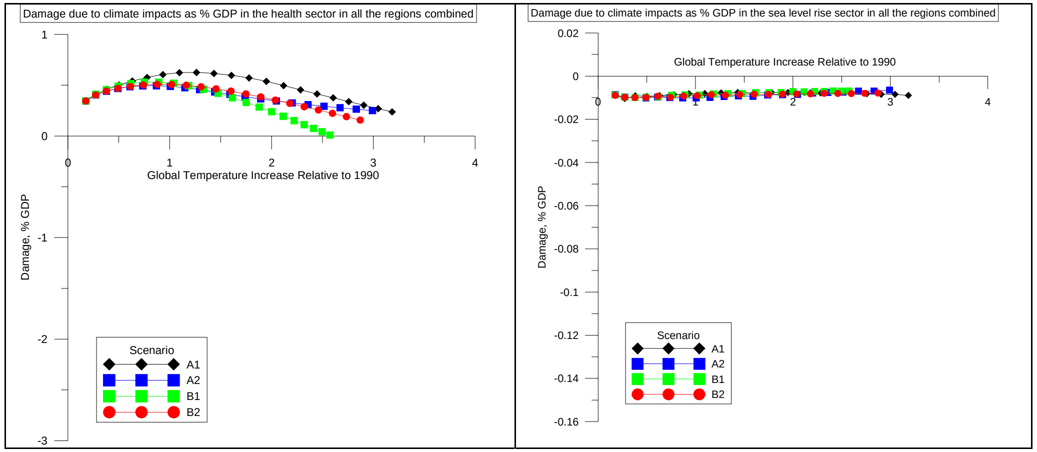


Figure A4.2a cont'd. FUND-simulated global and sectoral damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 for the major FUND impact sectors for 4 SRES scenarios

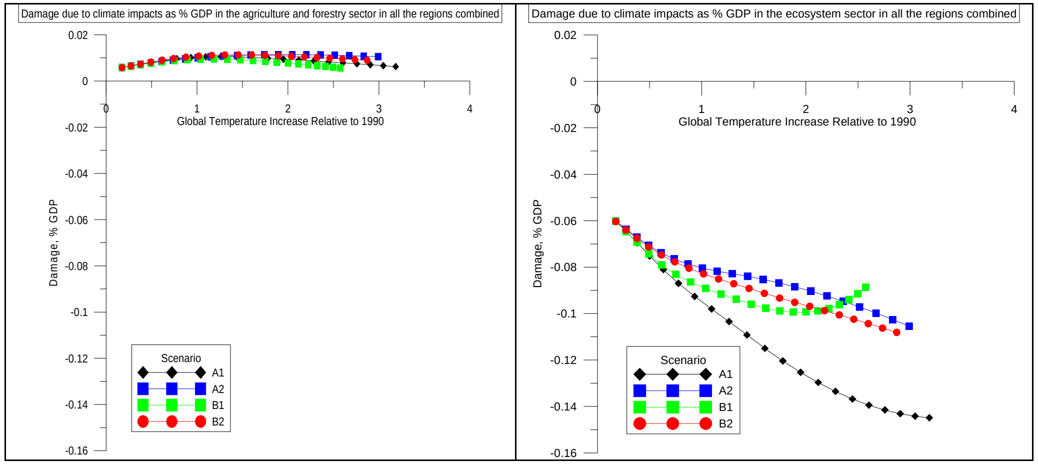
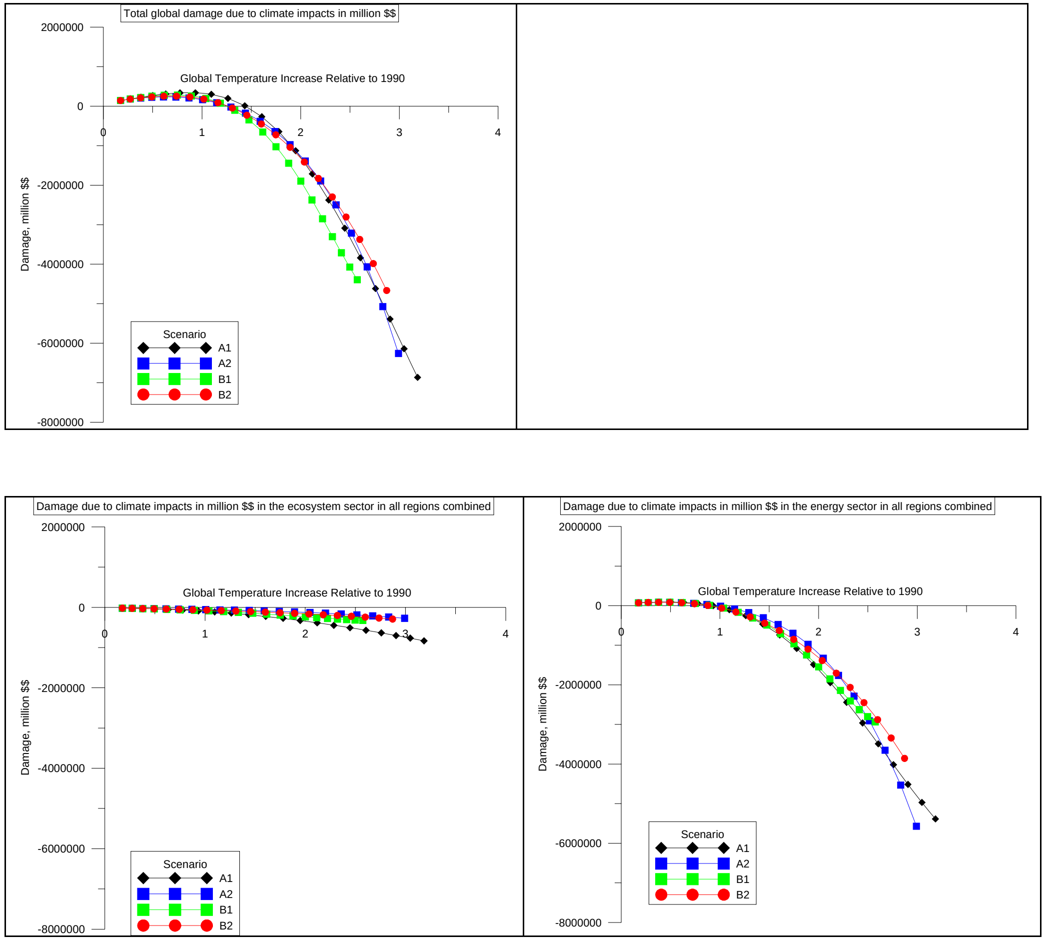


Figure A4.2b FUND-simulated global and sectoral damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 for the major FUND impact sectors for 4 SRES scenarios



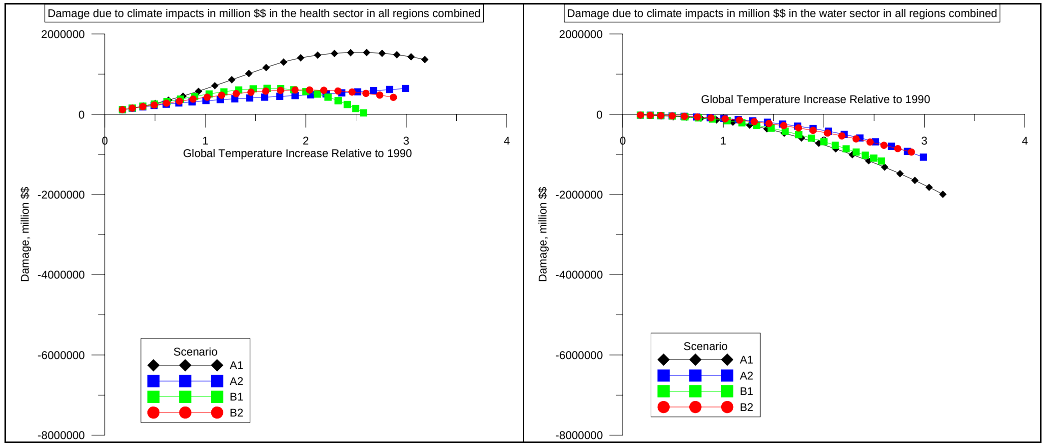


Figure A4.2b cont'd FUND-simulated global and sectoral damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 for the major FUND impact sectors for 4 SRES scenarios

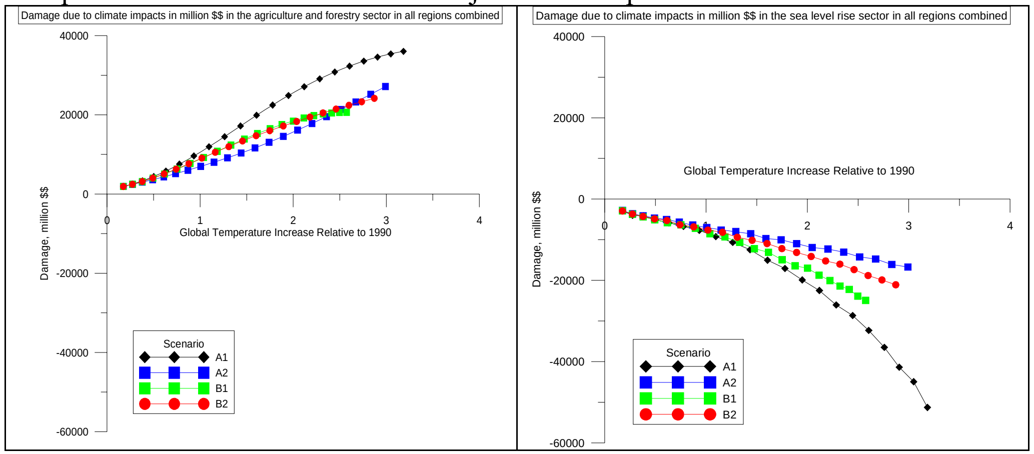
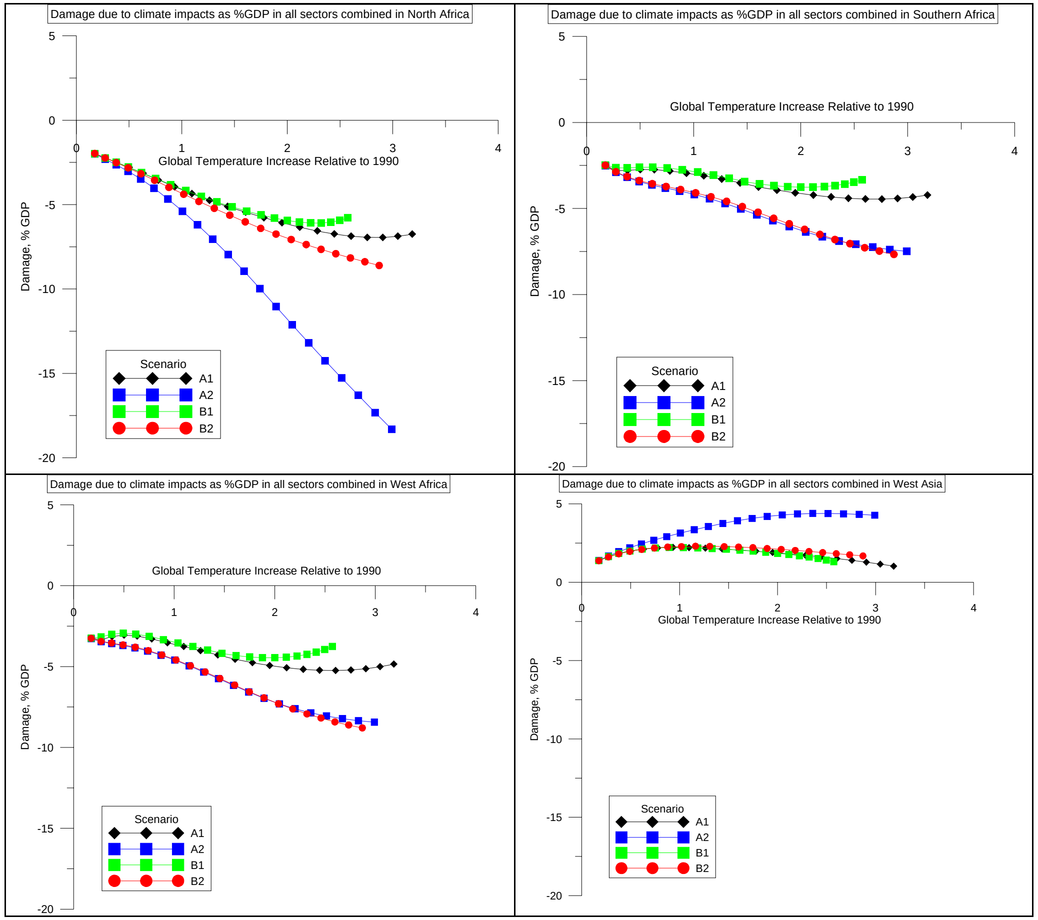
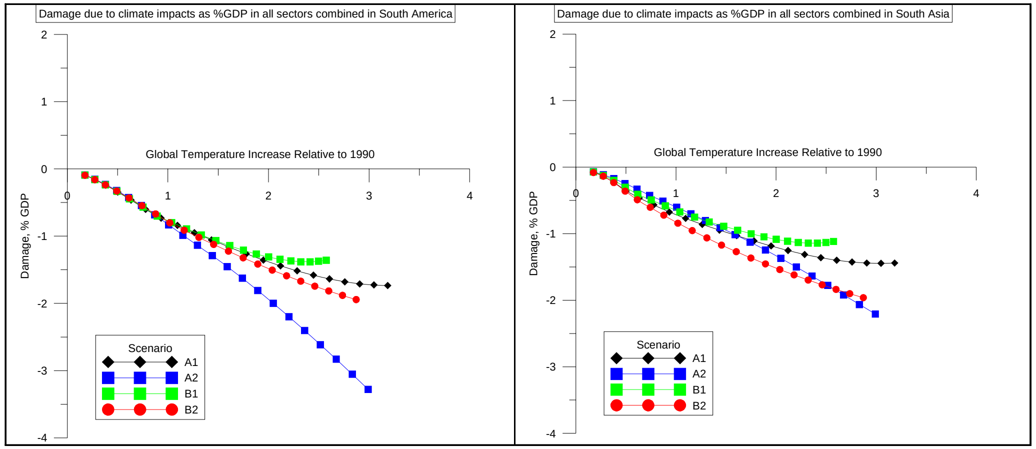


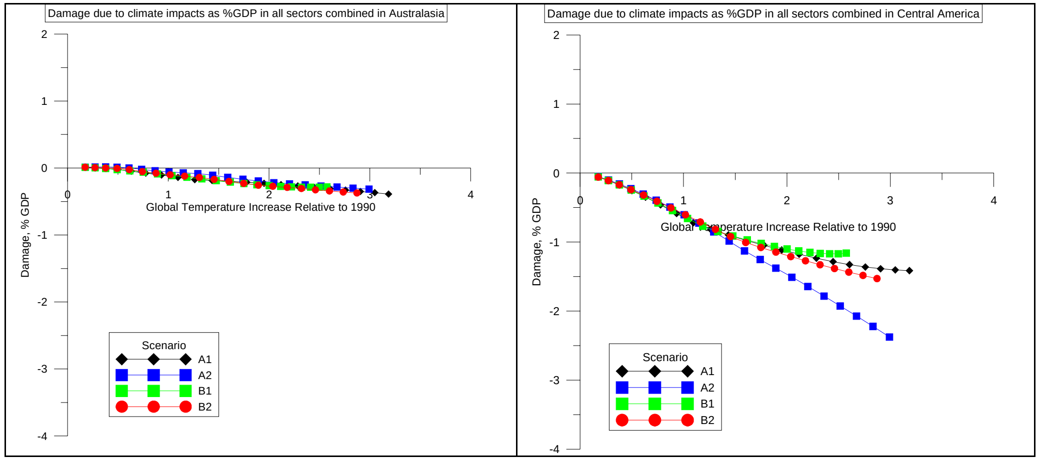
Figure A4.3a FUND-simulated regional damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 for 4 SRES scenarios





Damage due to climate impacts as %GDP in all sectors combined in South America
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2
Damage due to climate impacts as %GDP in all sectors combined in South Asia
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2

Figure A4..3a cont'd FUND-simulated regional damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 for 4 SRES scenarios



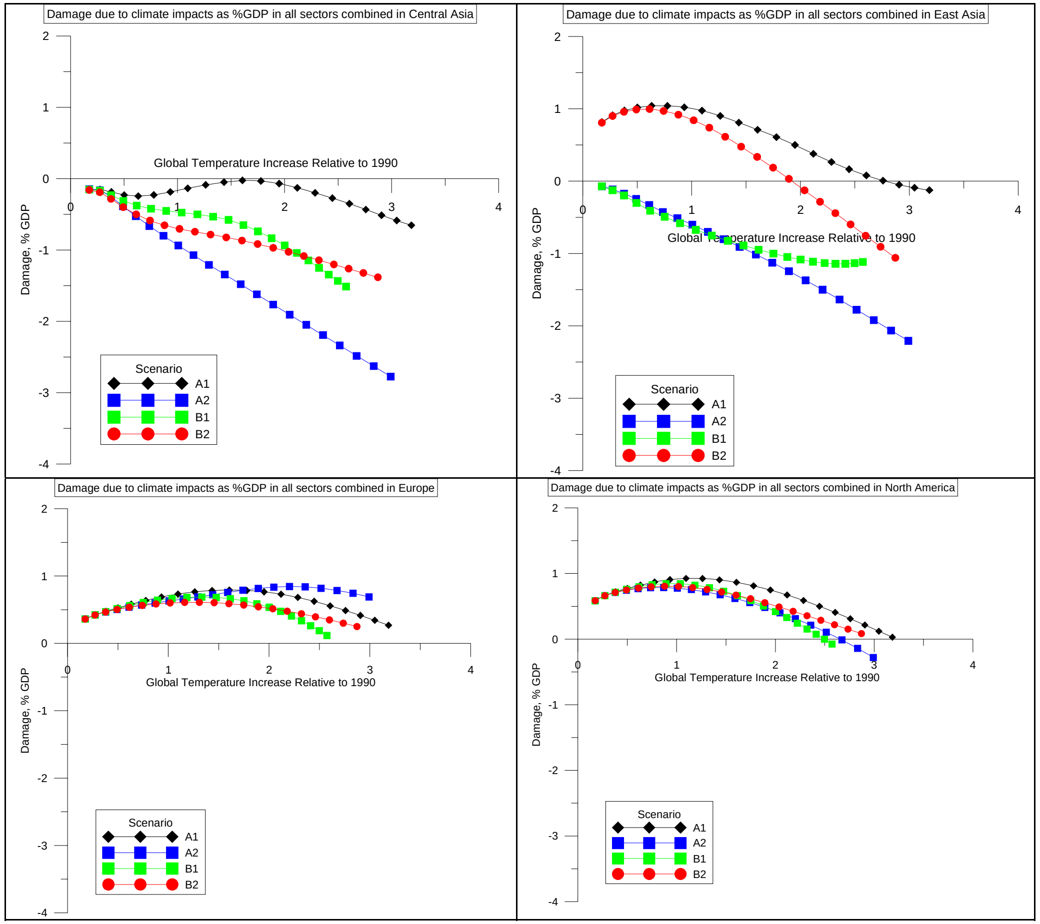
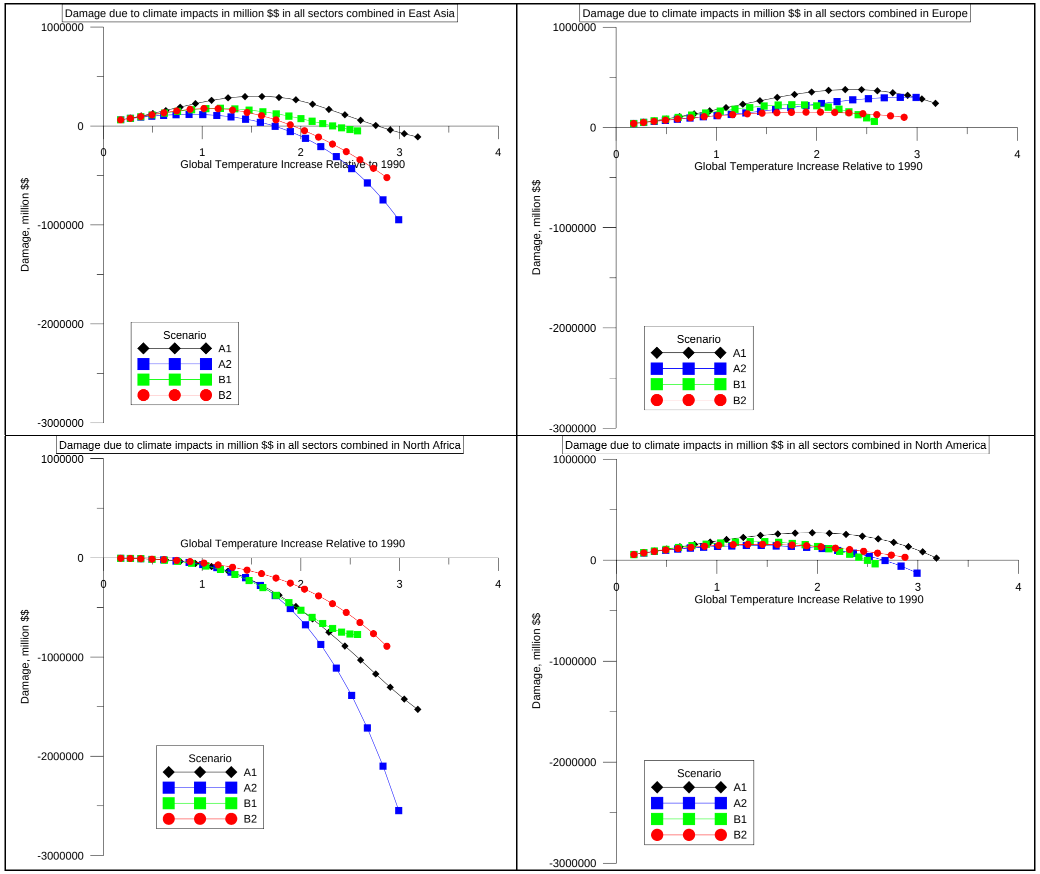
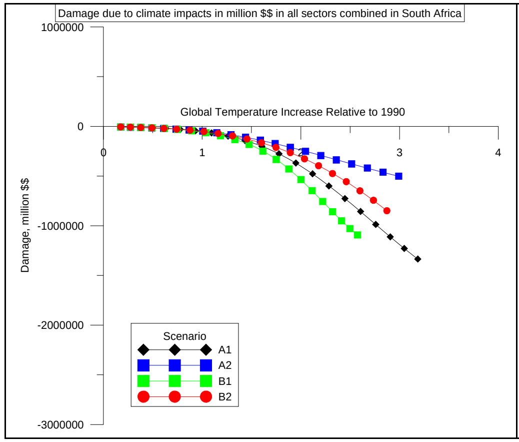


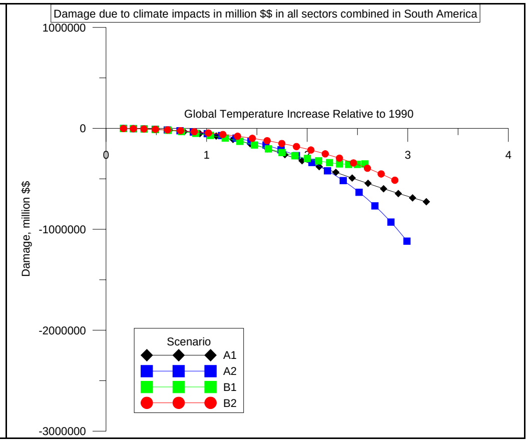
Figure A4.3b FUND-simulated regional damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 for 4 SRES scenarios



Damage due to climate impacts in million $$ in all sectors combined in East Asia
Damage due to climate impacts in million $$ in all sectors combined in Europe
Damage due to climate impacts in million $$ in all sectors combined in North Africa
Damage due to climate impacts in million $$ in all sectors combined in North America
Damage, million $$
Global Temperature Increase Relative to 1990
1000000
0
-1000000
-2000000
-3000000
0
1
2
3
4
Scenario
A1
A2
B1
B2

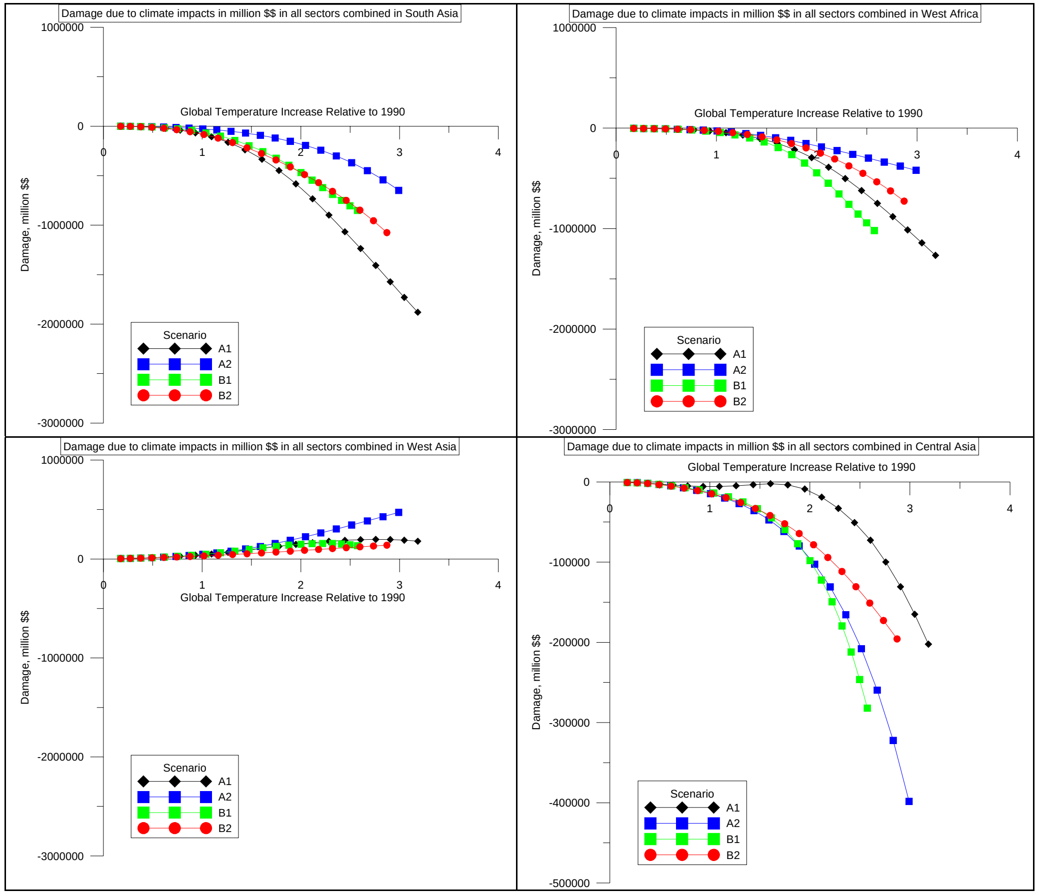


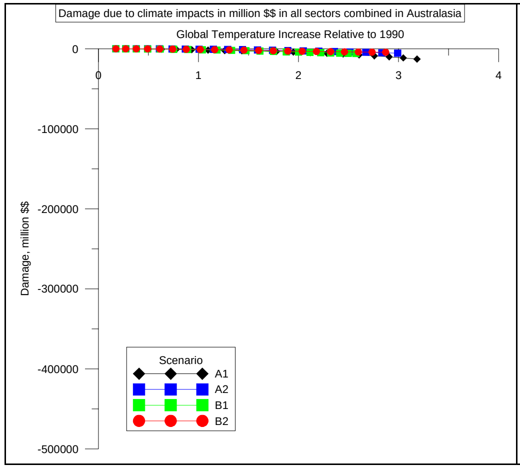
Damage due to climate impacts in million $$ in all sectors combined in South Africa
Global Temperature Increase Relative to 1990
Damage, million $$
1000000
0
-1000000
-2000000
-3000000
0
1
2
3
4
Scenario
A1
A2
B1
B2



Damage due to climate impacts in million $$ in all sectors combined in South America
Global Temperature Increase Relative to 1990
Damage, million $$
1000000
0
-1000000
-2000000
-3000000
0
1
2
3
4
Scenario
A1
A2
B1
B2

Figure A4.3b cont'd. FUND-simulated regional damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 for 4 SRES scenarios




Damage due to climate impacts in million $$ in all sectors combined in Australasia
Global Temperature Increase Relative to 1990
0
1
2
3
4
0
-100000
-200000
-300000
-400000
-500000
Damage, million $$
Scenario
A1
A2
B1
B2

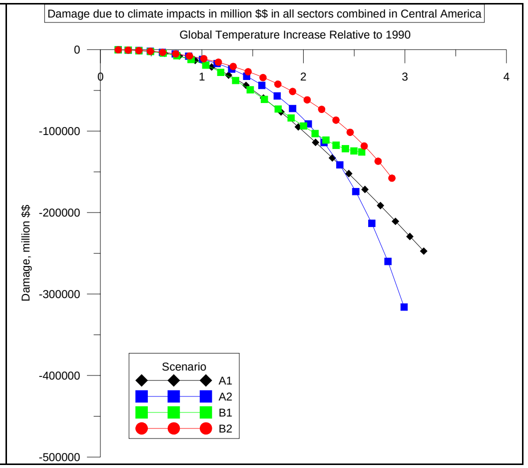
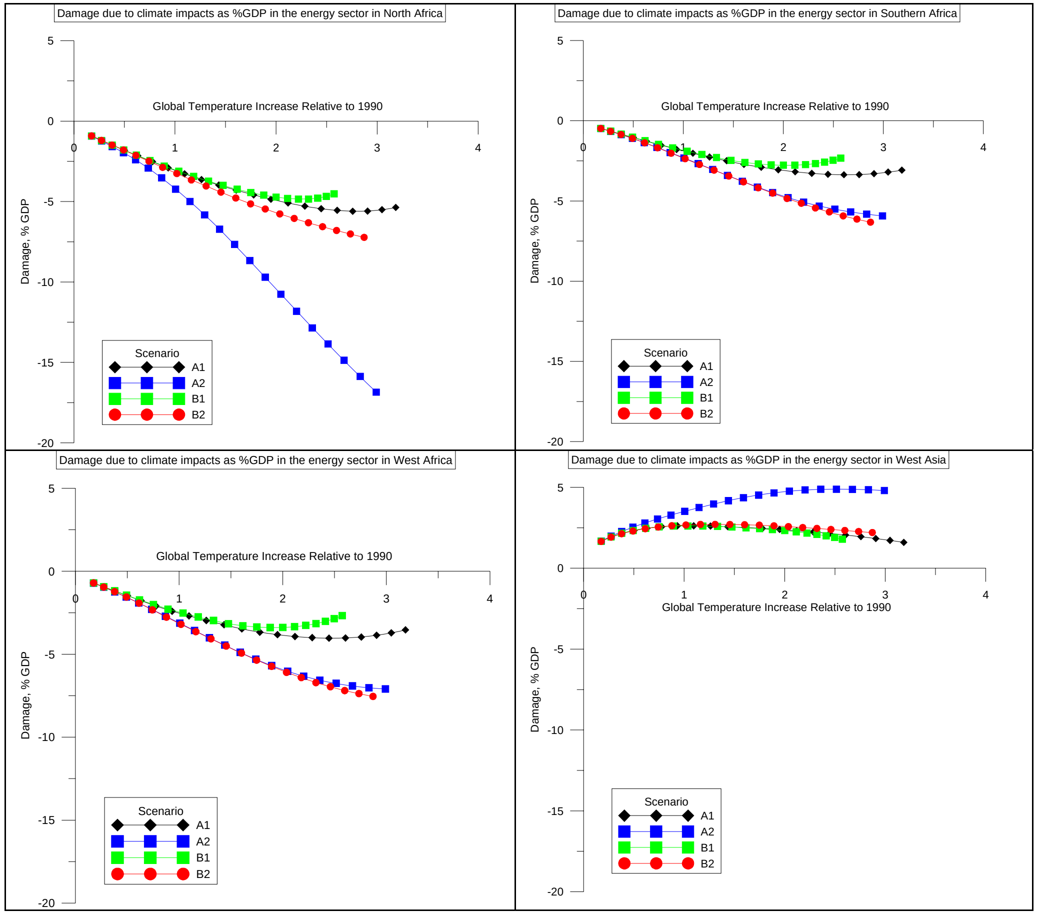

Damage due to climate impacts in million $$ in all sectors combined in Central America
Global Temperature Increase Relative to 1990
0
1
2
3
4
0
-100000
-200000
-300000
-400000
-500000
Damage, million $$
Scenario
A1
A2
B1
B2

Figure A4.4a FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the energy sector for 4 SRES scenarios



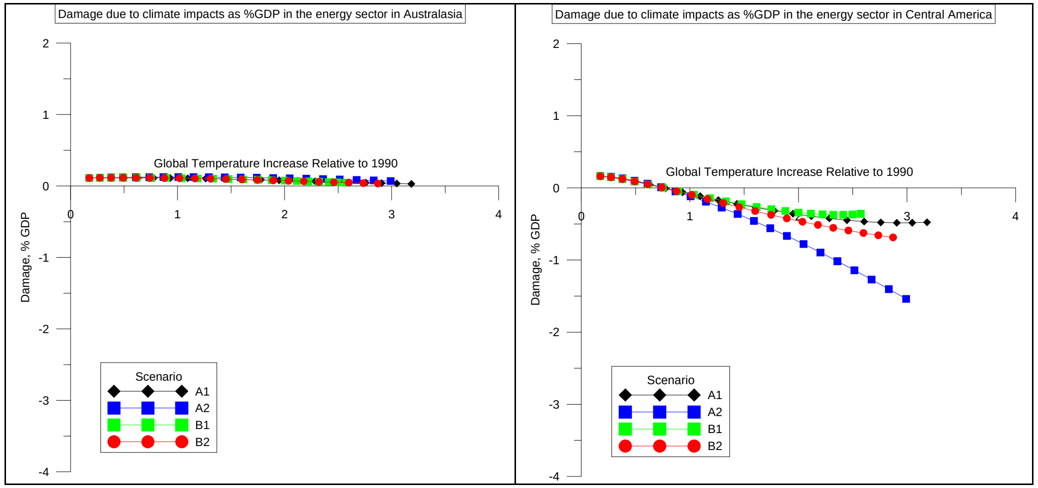
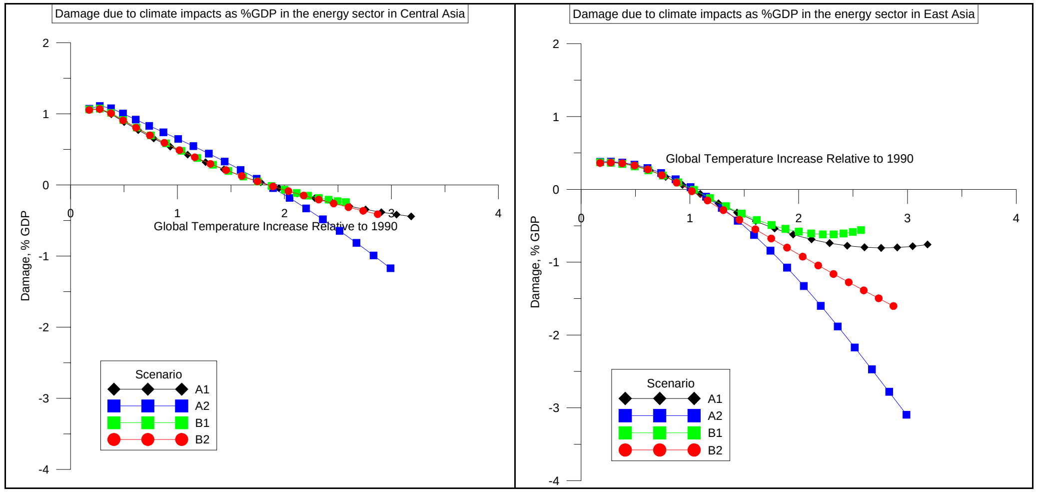


Figure A4.4a cont'd. FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the energy sector for 4 SRES scenarios



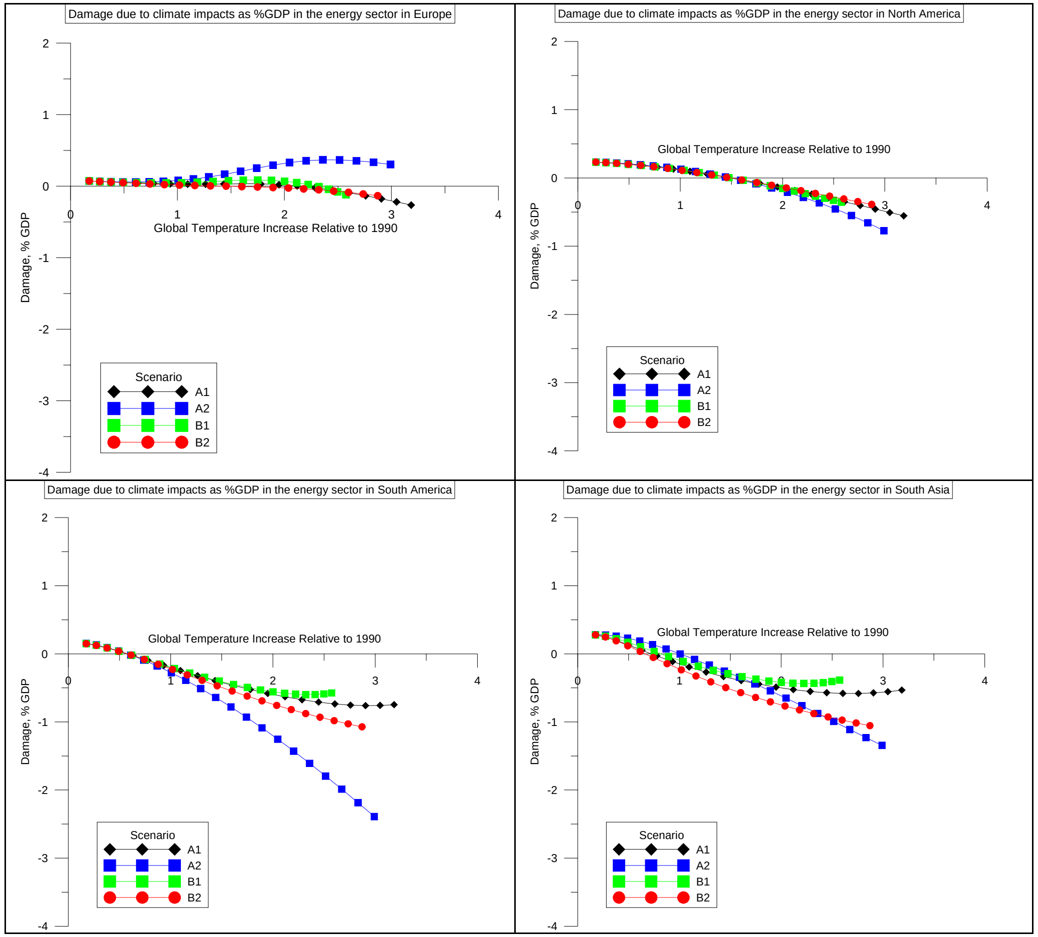
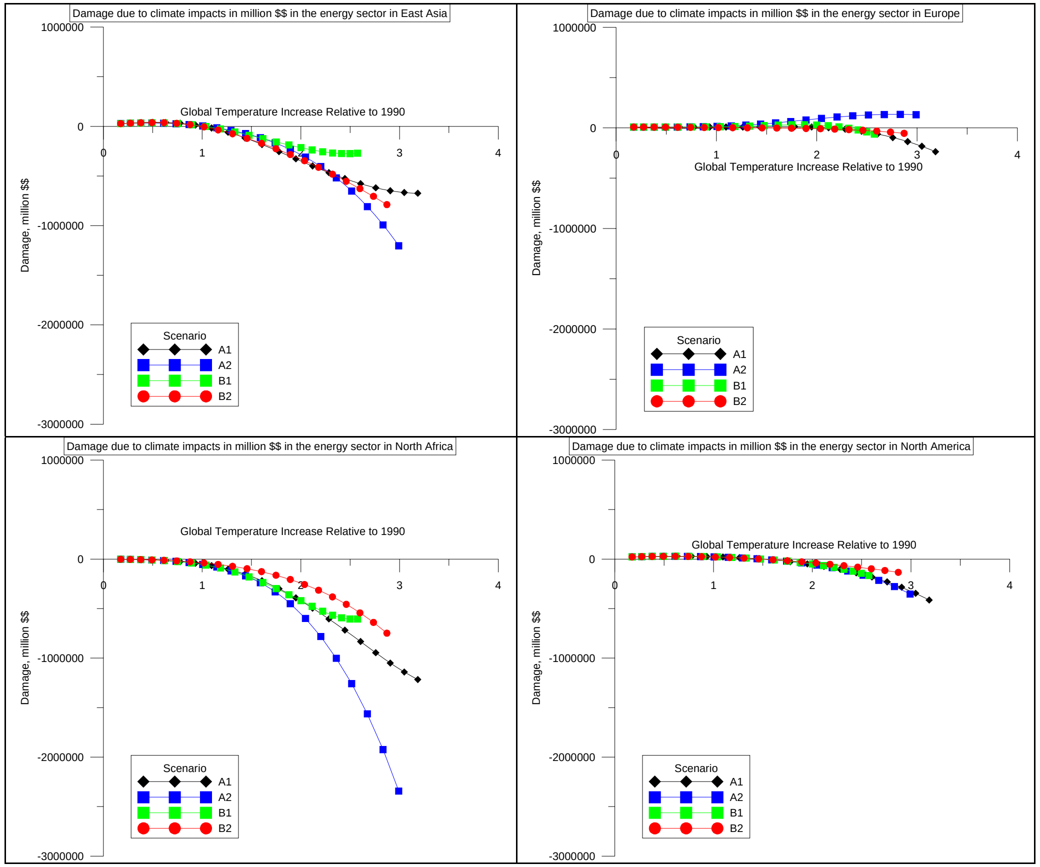


Figure A4.4b FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the energy sector for 4 SRES scenarios



Damage due to climate impacts in million $$ in the energy sector in East Asia
Global Temperature Increase Relative to 1990
Damage, million $$
1000000
0
-1000000
-2000000
-3000000
0
1
2
3
4
Scenario
A1
A2
B1
B2
Damage due to climate impacts in million $$ in the energy sector in Europe
Global Temperature Increase Relative to 1990
Damage, million $$
1000000
0
-1000000
-2000000
-3000000
0
1
2
3
4
Scenario
A1
A2
B1
B2
Damage due to climate impacts in million $$ in the energy sector in North Africa
Global Temperature Increase Relative to 1990
Damage, million $$
1000000
0
-1000000
-2000000
-3000000
0
1
2
3
4
Scenario
A1
A2
B1
B2
Damage due to climate impacts in million $$ in the energy sector in North America
Global Temperature Increase Relative to 1990
Damage, million $$
1000000
0
-1000000
-2000000
-3000000
0
1
2
3
4
Scenario
A1
A2
B1
B2

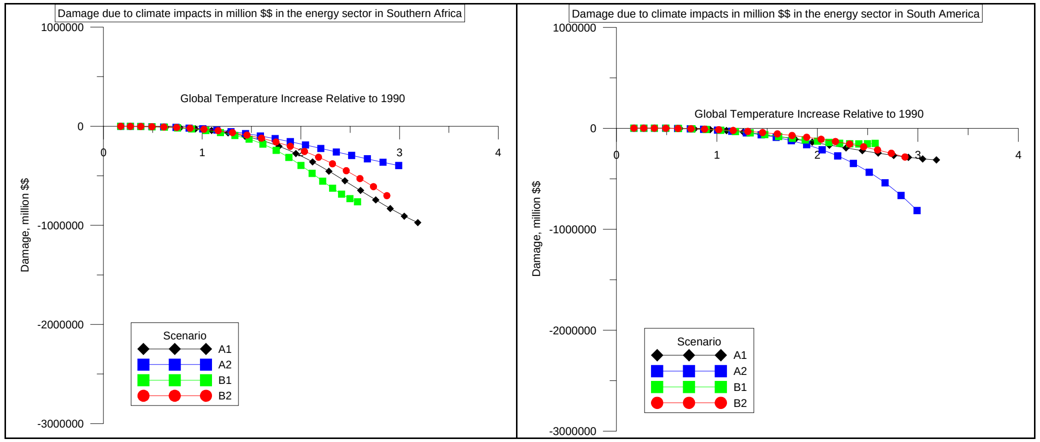
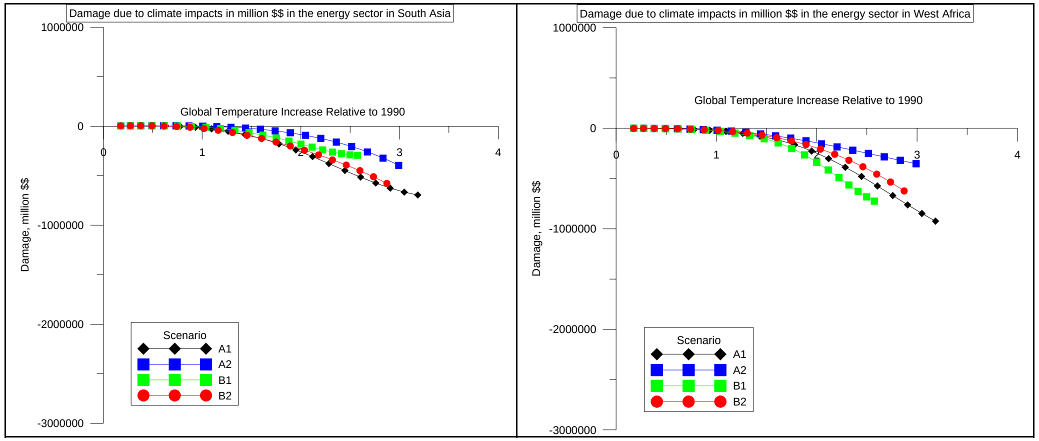


Figure A4.4b cont'd. FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the energy sector for 4 SRES scenarios



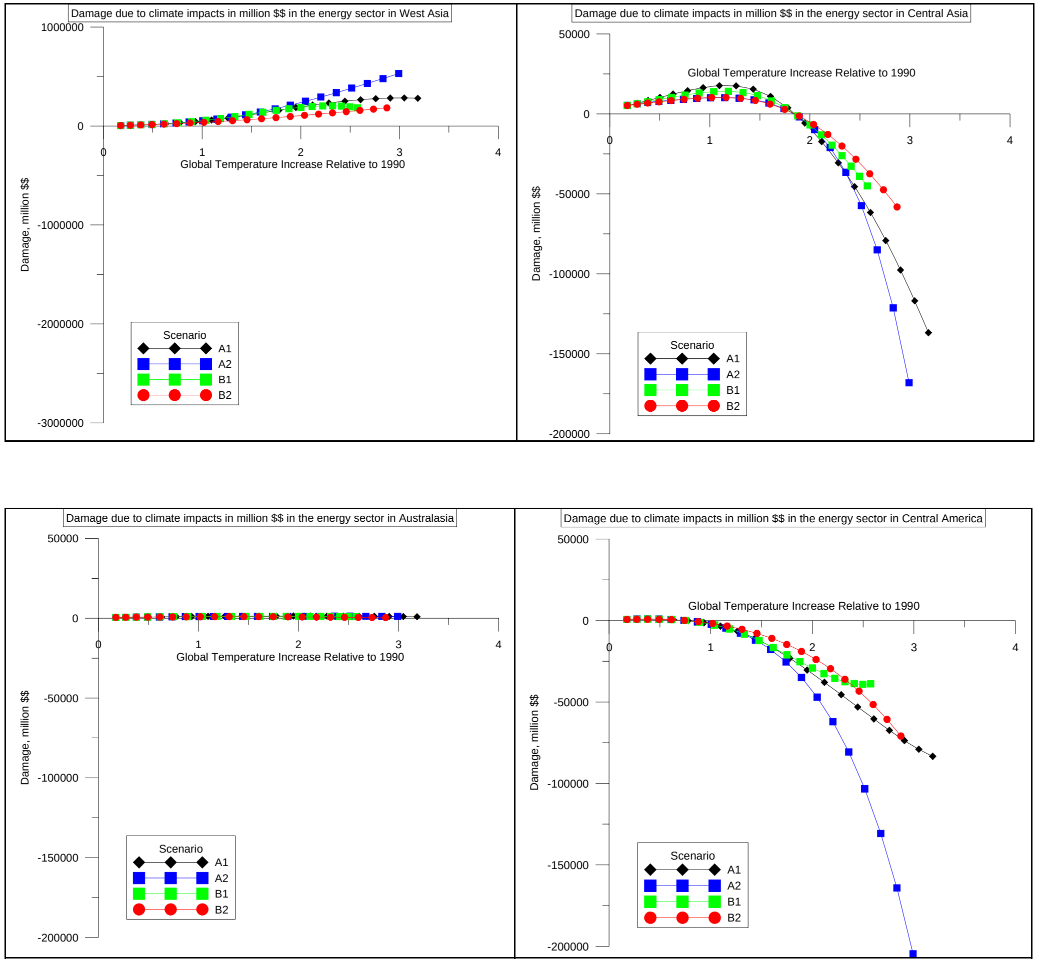
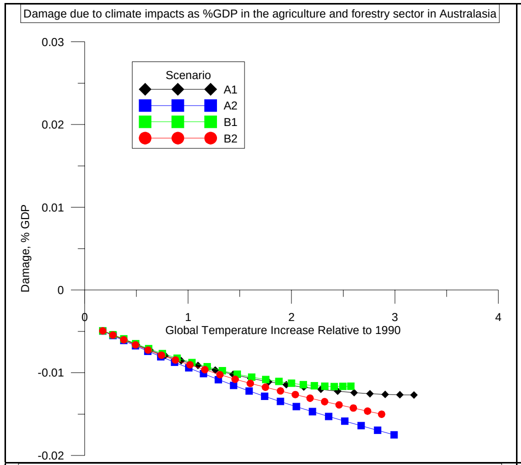
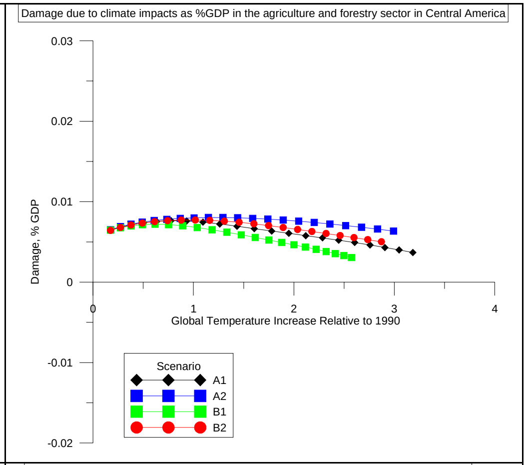
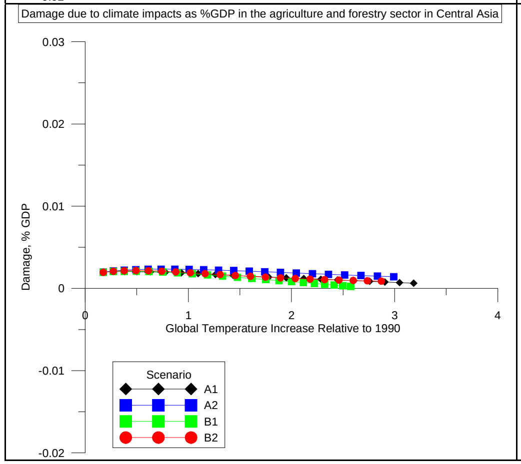
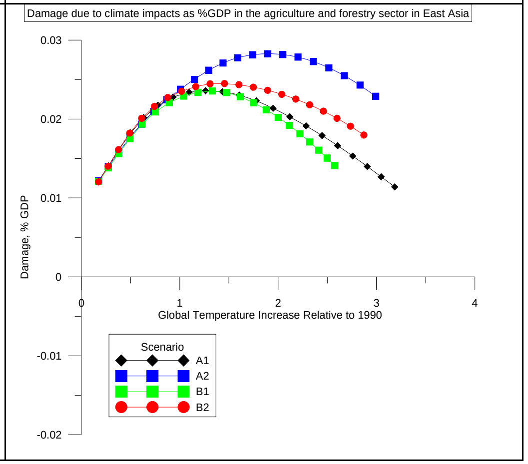


Figure A4.5a FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the agriculture and forestry sector for 4 SRES scenarios


Damage due to climate impacts as %GDP in the agriculture and forestry sector in Australasia
Damage, % GDP
Global Temperature Increase Relative to 1990
0.03
0.02
0.01
0
-0.01
-0.02
0
1
2
3
4
Scenario
A1
A2
B1
B2


Damage due to climate impacts as %GDP in the agriculture and forestry sector in Central America
Damage, % GDP
Global Temperature Increase Relative to 1990
0.03
0.02
0.01
0
-0.01
-0.02
0
1
2
3
4
Scenario
A1
A2
B1
B2


Damage due to climate impacts as %GDP in the agriculture and forestry sector in Central Asia
Damage, % GDP
Global Temperature Increase Relative to 1990
0.03
0.02
0.01
0
-0.01
-0.02
0
1
2
3
4
Scenario
A1
A2
B1
B2


Damage due to climate impacts as %GDP in the agriculture and forestry sector in East Asia
Damage, % GDP
Global Temperature Increase Relative to 1990
0.03
0.02
0.01
0
-0.01
-0.02
0
1
2
3
4
Scenario
A1
A2
B1
B2

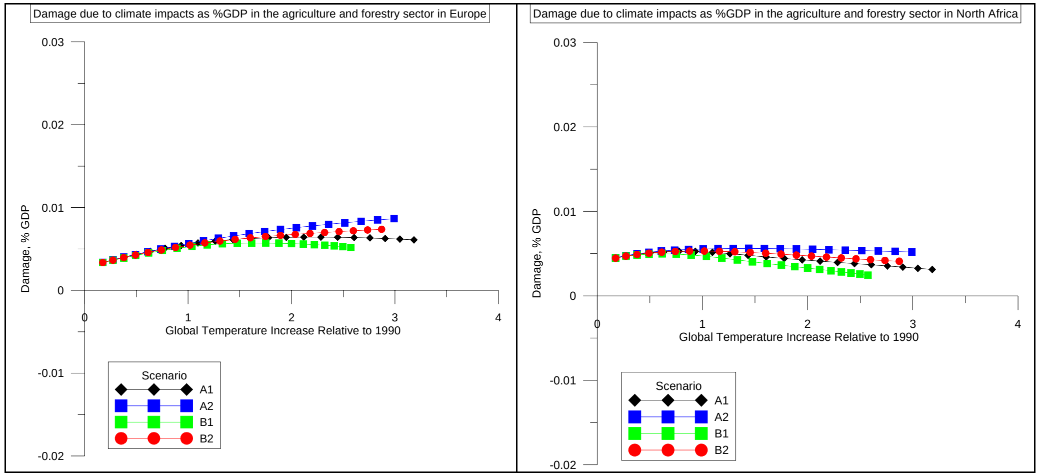
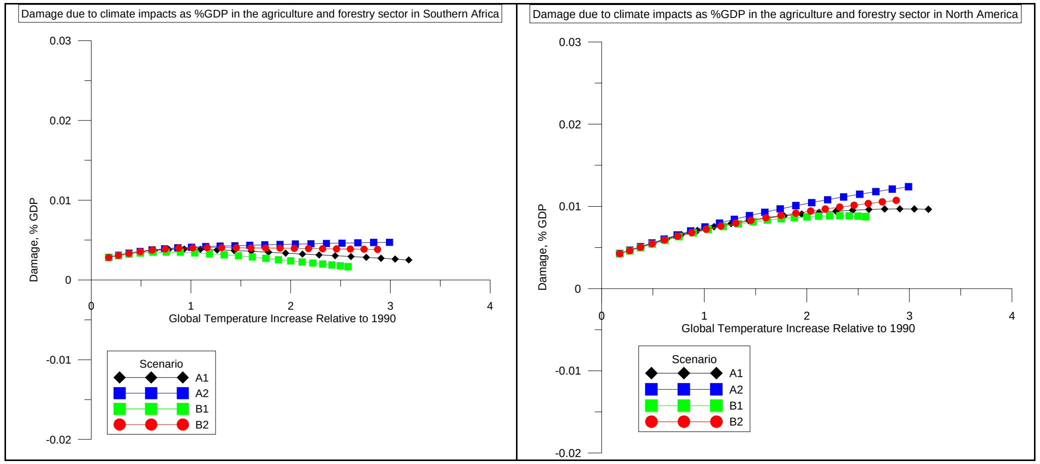


Figure A4.5a cont'd. FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the agriculture and forestry sector for 4 SRES scenarios



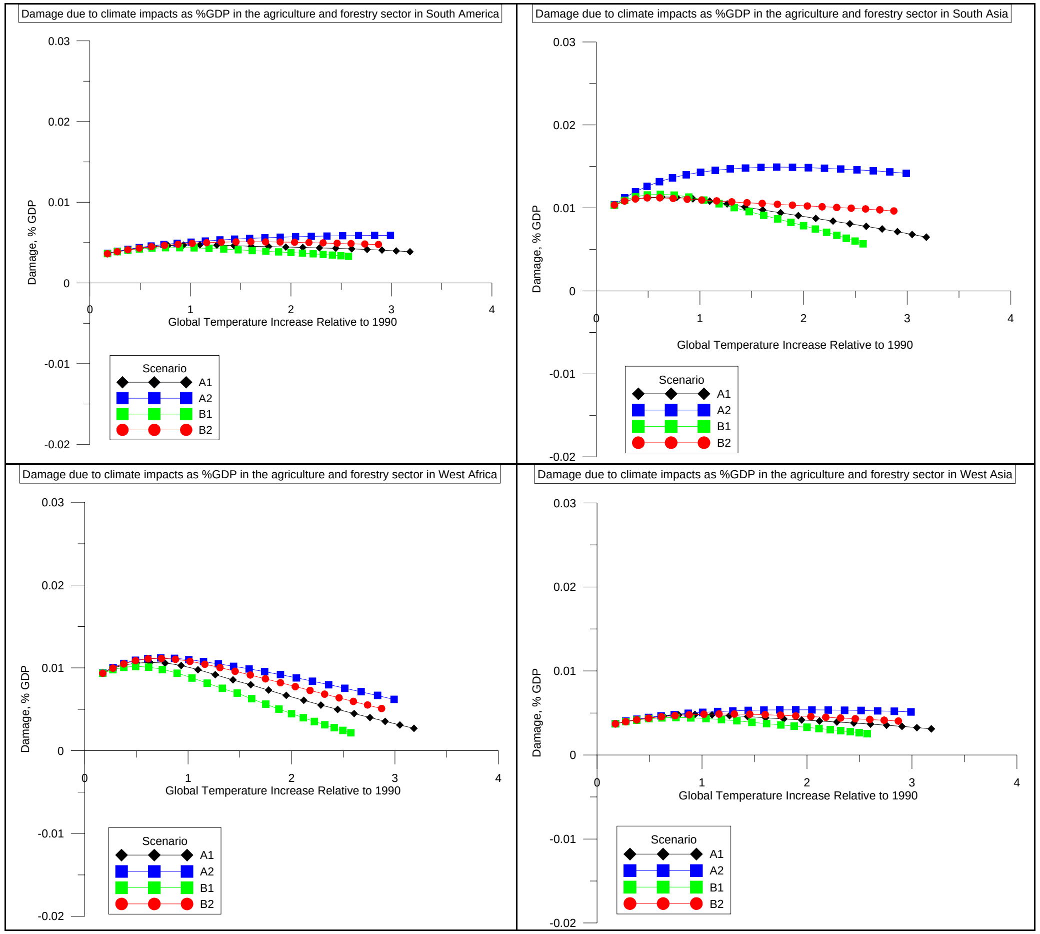
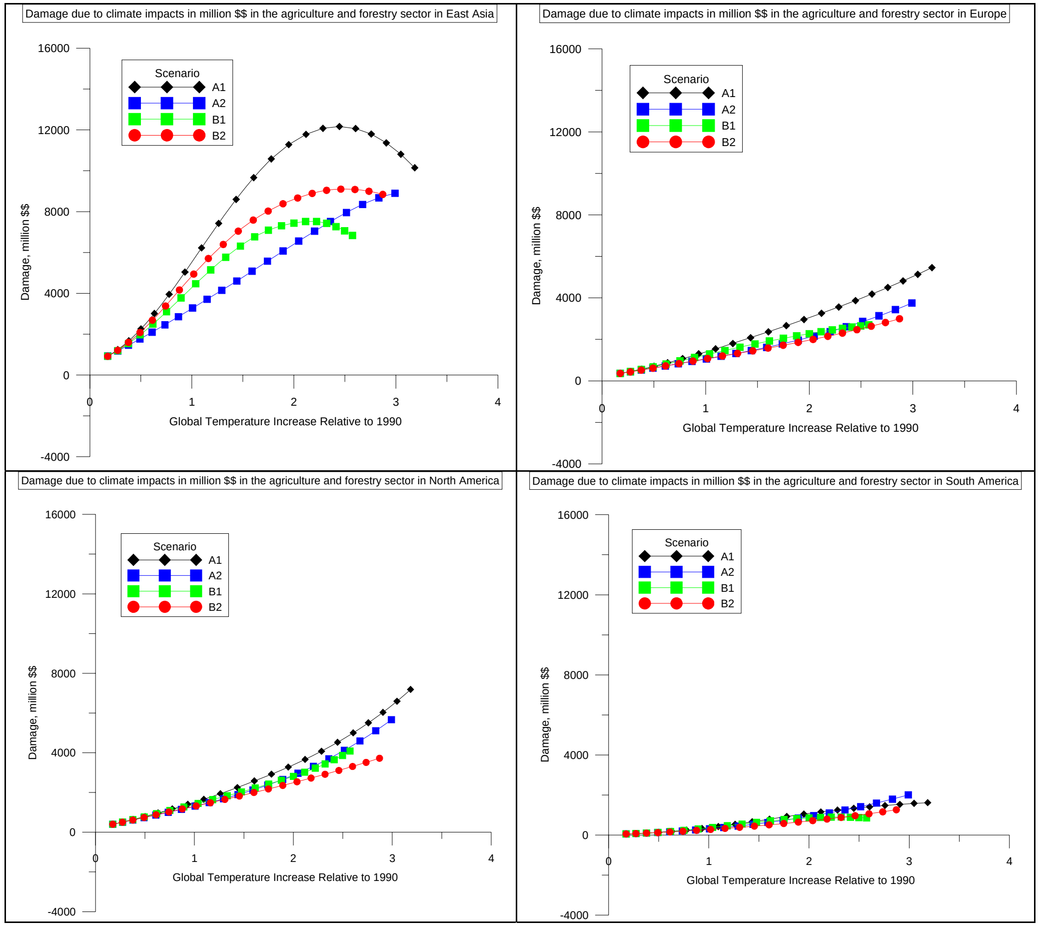


Figure A4.5b FUND-simulated damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 in the agriculture and forestry sector for 4 SRES scenarios


Damage due to climate impacts in million $$ in the agriculture and forestry sector in East Asia
Damage due to climate impacts in million $$ in the agriculture and forestry sector in Europe
Damage due to climate impacts in million $$ in the agriculture and forestry sector in North America
Damage due to climate impacts in million $$ in the agriculture and forestry sector in South America
Scenario
A1
A2
B1
B2
Damage, million $$
Global Temperature Increase Relative to 1990
16000
12000
8000
4000
0
-4000
0
1
2
3
4

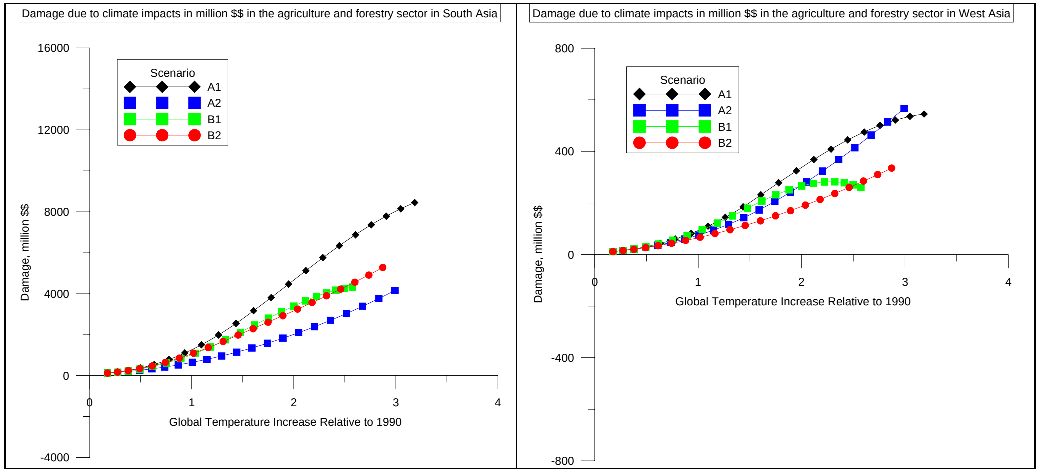
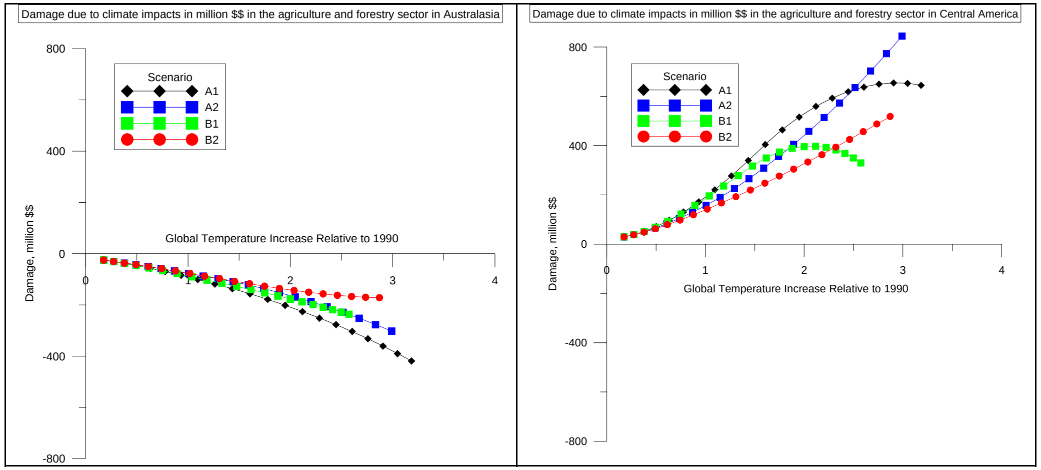


Figure A4.5b cont'd. FUND-simulated damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 in the agriculture and forestry sector for 4 SRES scenarios



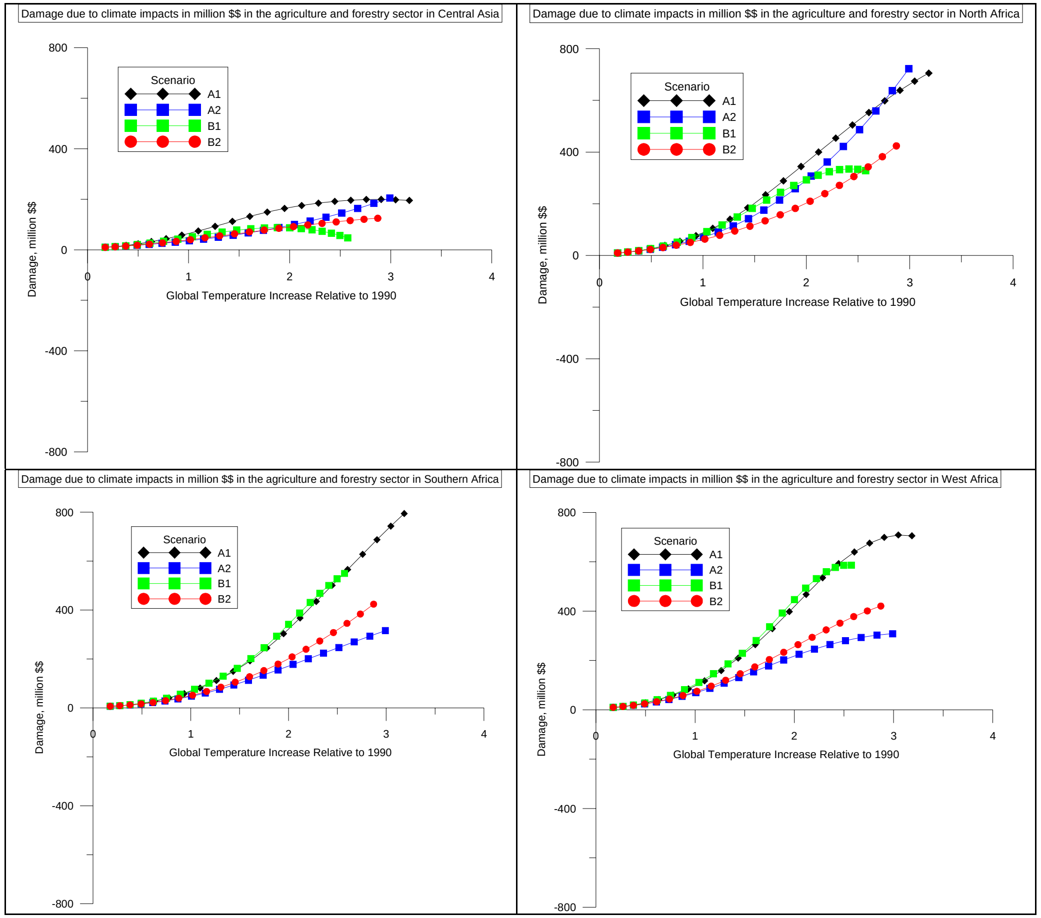
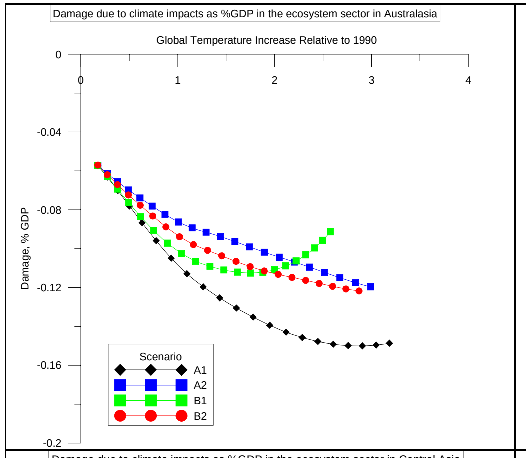
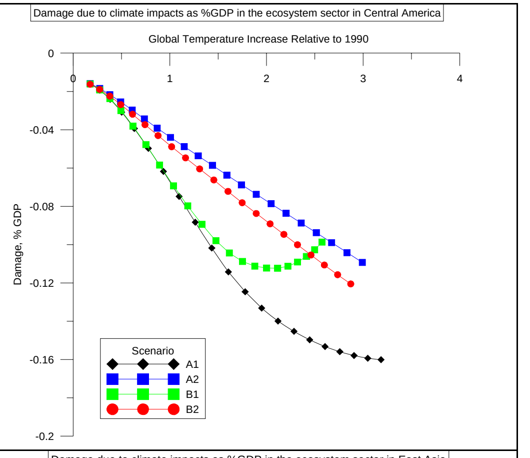


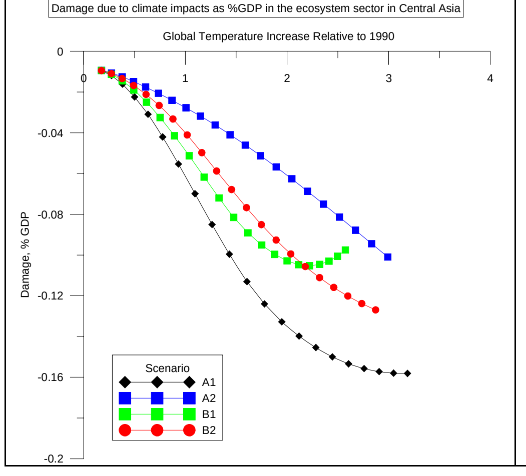
Figure A4.6a FUND-simulated damage costs of climate change impacts (% GDP)
as a function of global mean temperature rise above 1990 in the ecosystems sector for 4 SRES scenarios



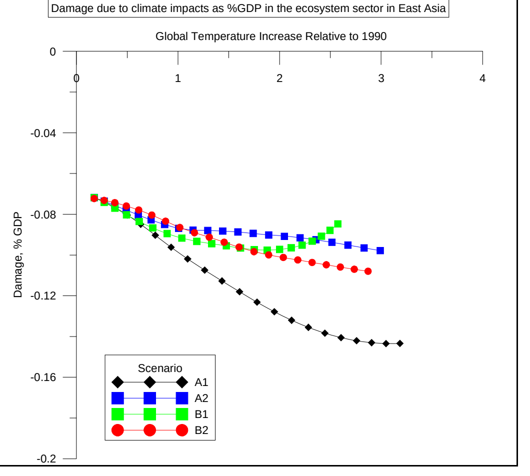
Damage due to climate impacts as %GDP in the ecosystem sector in Australasia
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2



Damage due to climate impacts as %GDP in the ecosystem sector in Central America
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2



Damage due to climate impacts as %GDP in the ecosystem sector in Central Asia
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2



Damage due to climate impacts as %GDP in the ecosystem sector in East Asia
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2

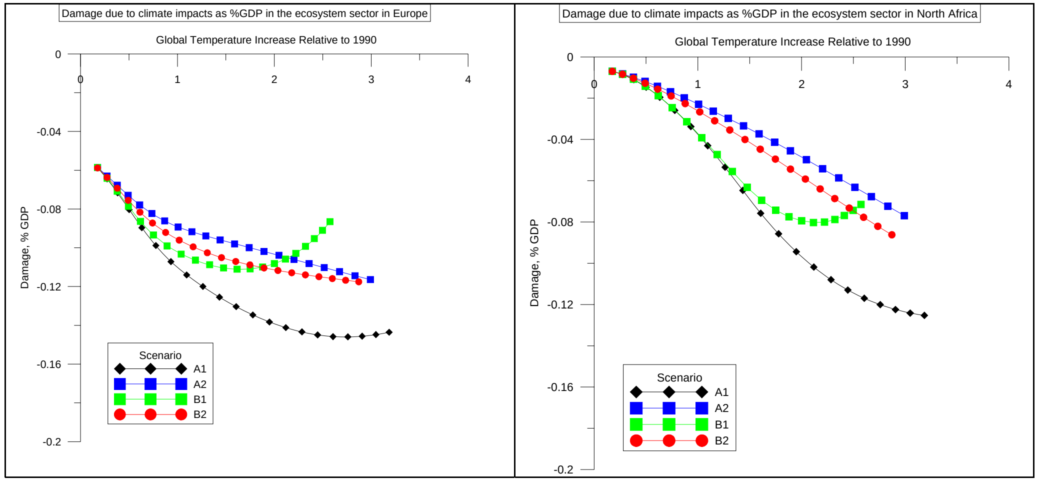
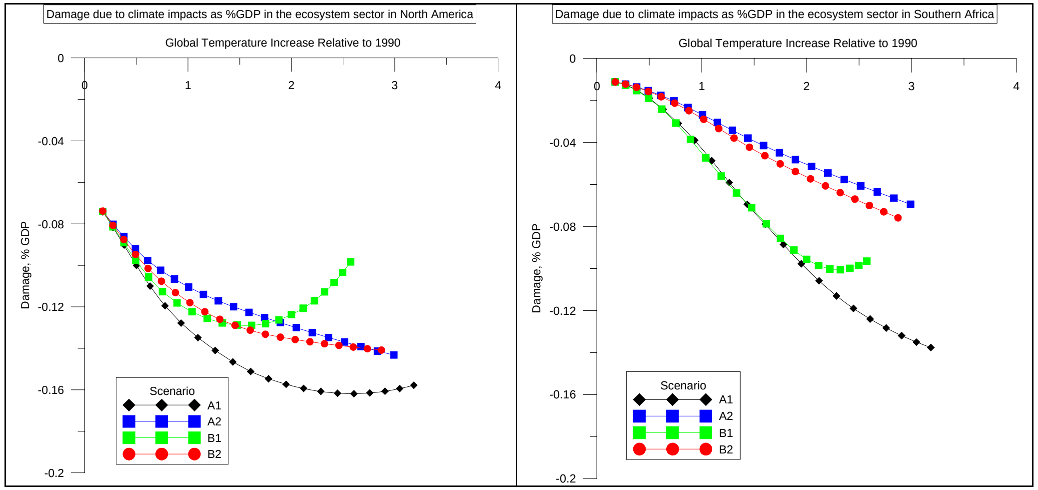


Figure A4.6a cont'd. FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the ecosystems sector for 4 SRES scenarios



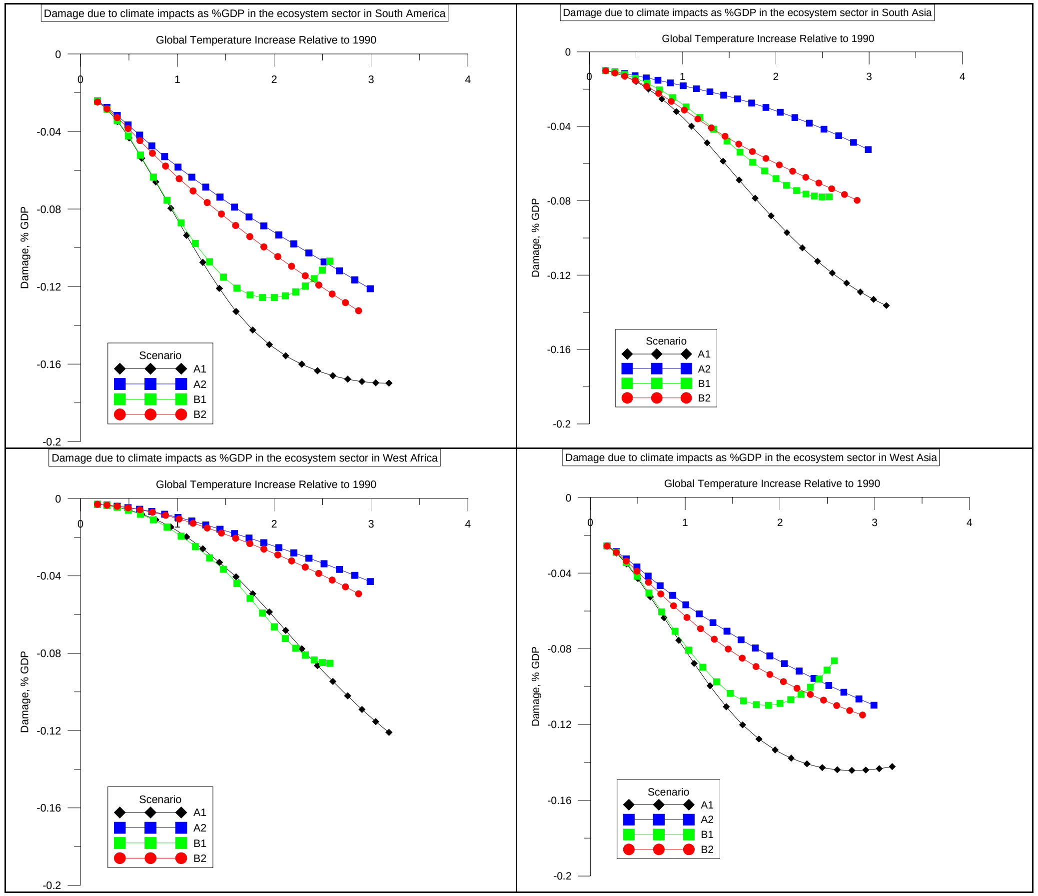
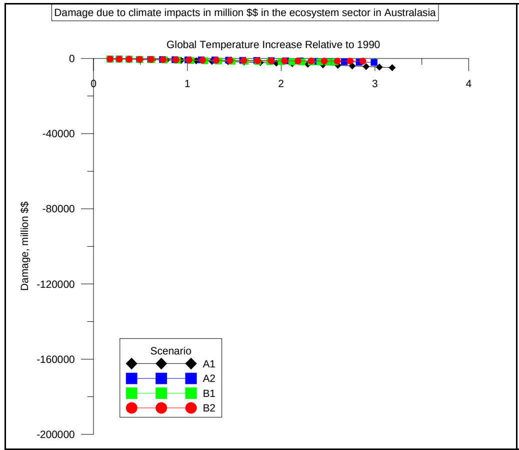
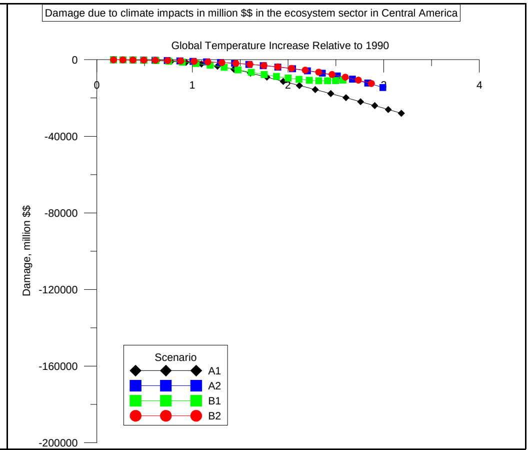
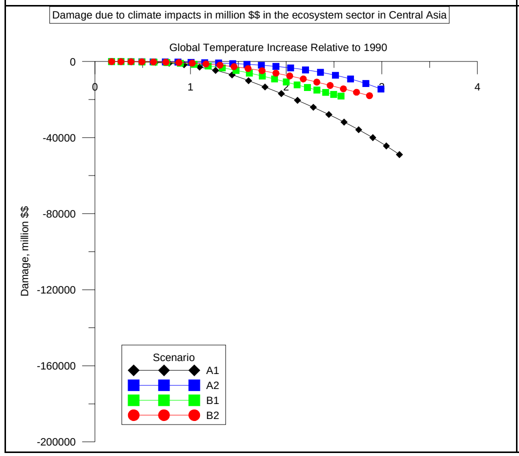
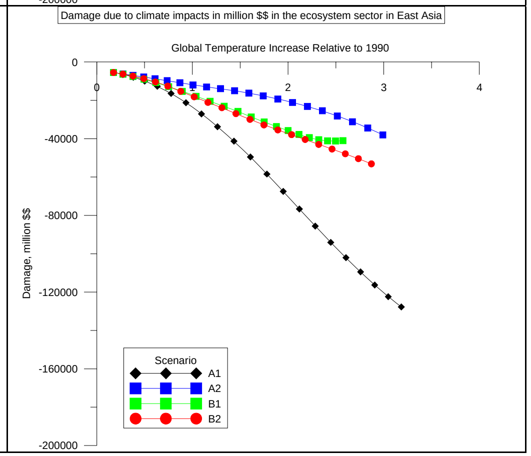


Figure A4.6b FUND-simulated damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 in the ecosystems sector for 4 SRES scenarios


Damage due to climate impacts in million $$ in the ecosystem sector in Australasia
Global Temperature Increase Relative to 1990
0
1
2
3
4
0
-40000
-80000
-120000
-160000
-200000
Damage, million $$
Scenario
A1
A2
B1
B2


Damage due to climate impacts in million $$ in the ecosystem sector in Central America
Global Temperature Increase Relative to 1990
0
1
2
3
4
0
-40000
-80000
-120000
-160000
-200000
Damage, million $$
Scenario
A1
A2
B1
B2


Damage due to climate impacts in million $$ in the ecosystem sector in Central Asia
Global Temperature Increase Relative to 1990
0
1
2
3
4
0
-40000
-80000
-120000
-160000
-200000
Damage, million $$
Scenario
A1
A2
B1
B2


Damage due to climate impacts in million $$ in the ecosystem sector in East Asia
Global Temperature Increase Relative to 1990
0
1
2
3
4
0
-40000
-80000
-120000
-160000
-200000
Damage, million $$
Scenario
A1
A2
B1
B2

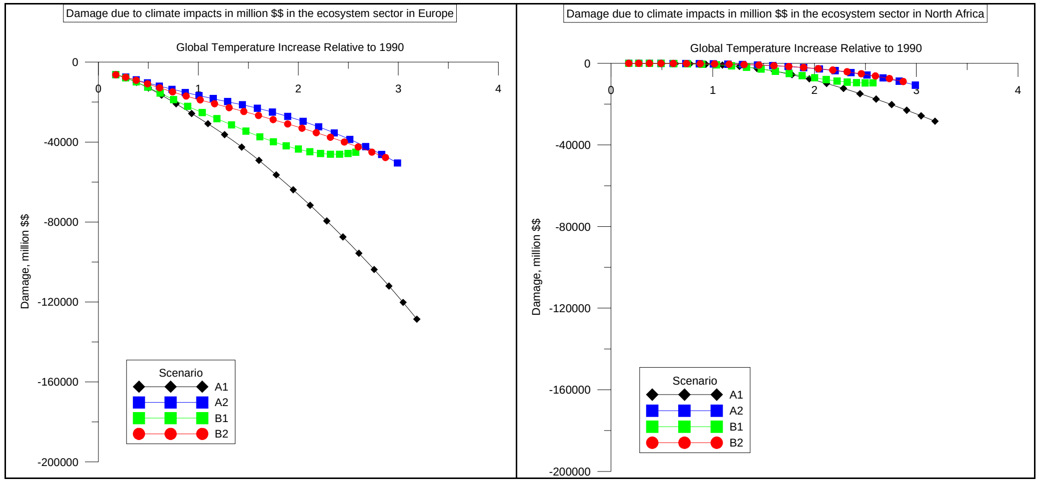
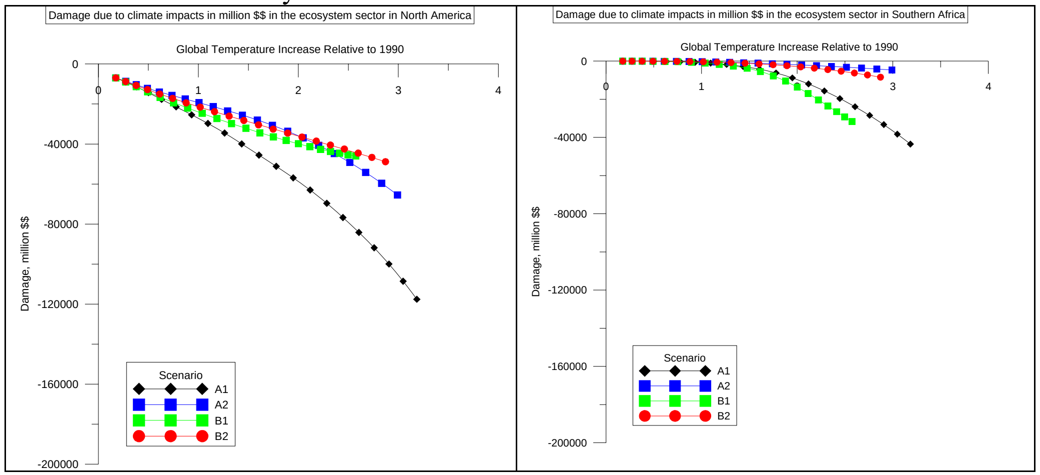


Figure A4.6b cont'd. FUND-simulated damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 in the ecosystems sector for 4 SRES scenarios



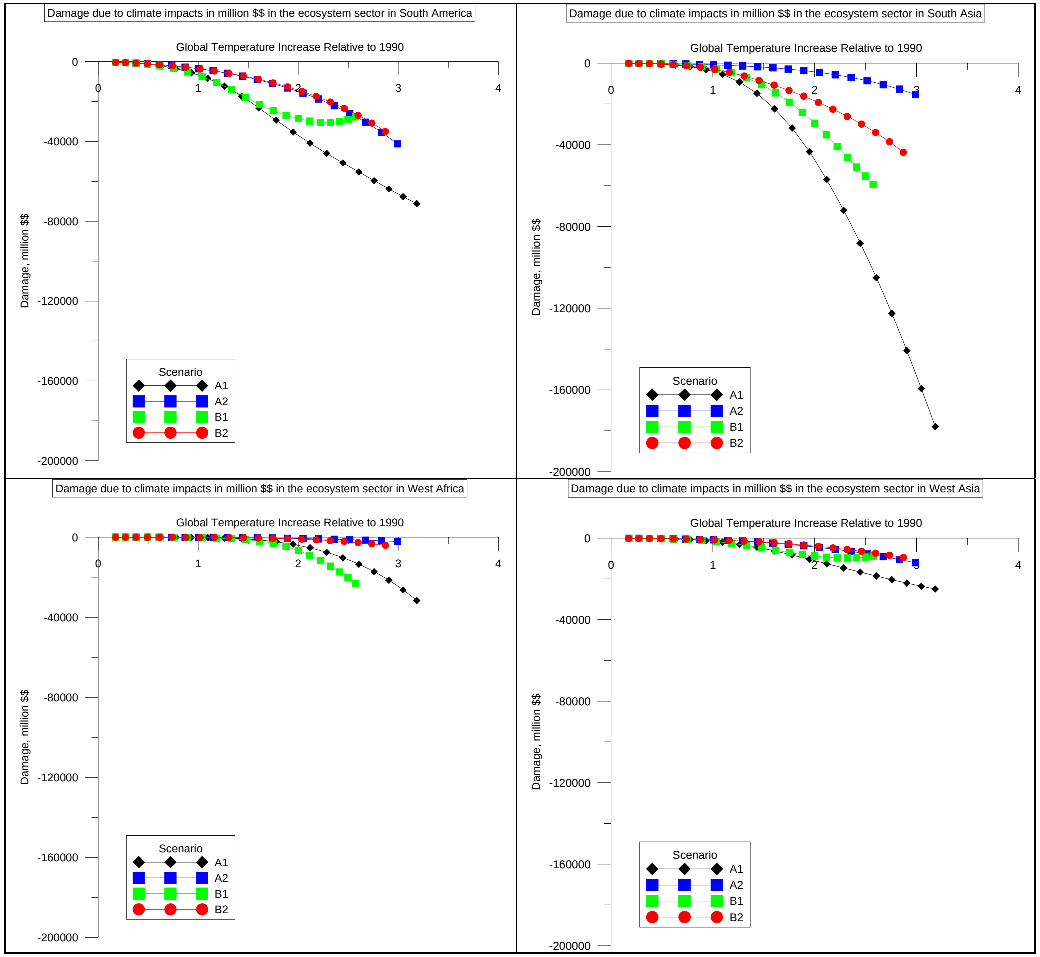
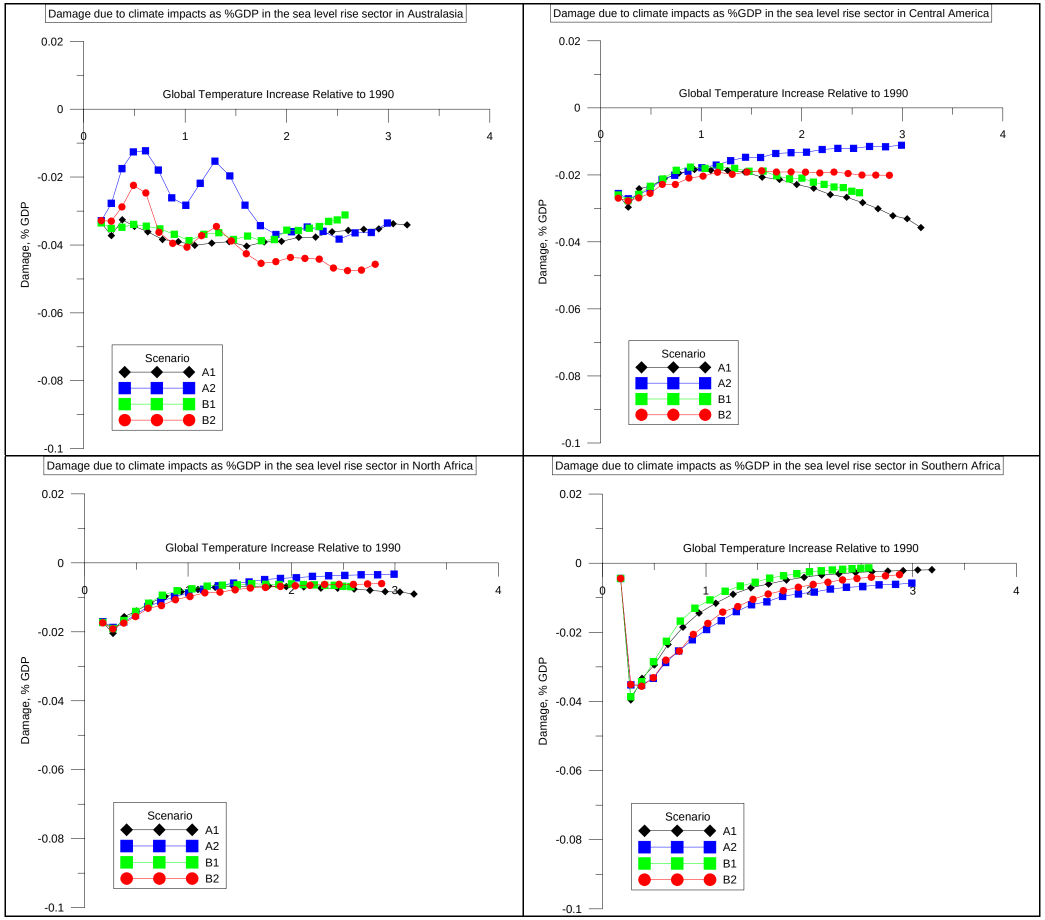


Figure A4.7a FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the sea level rise sector for 4 SRES scenarios



Damage due to climate impacts as %GDP in the sea level rise sector in Australasia
Global Temperature Increase Relative to 1990
Damage, % GDP
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
0
1
2
3
4
Scenario
A1
A2
B1
B2
Damage due to climate impacts as %GDP in the sea level rise sector in Central America
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2
Damage due to climate impacts as %GDP in the sea level rise sector in North Africa
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2
Damage due to climate impacts as %GDP in the sea level rise sector in Southern Africa
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2

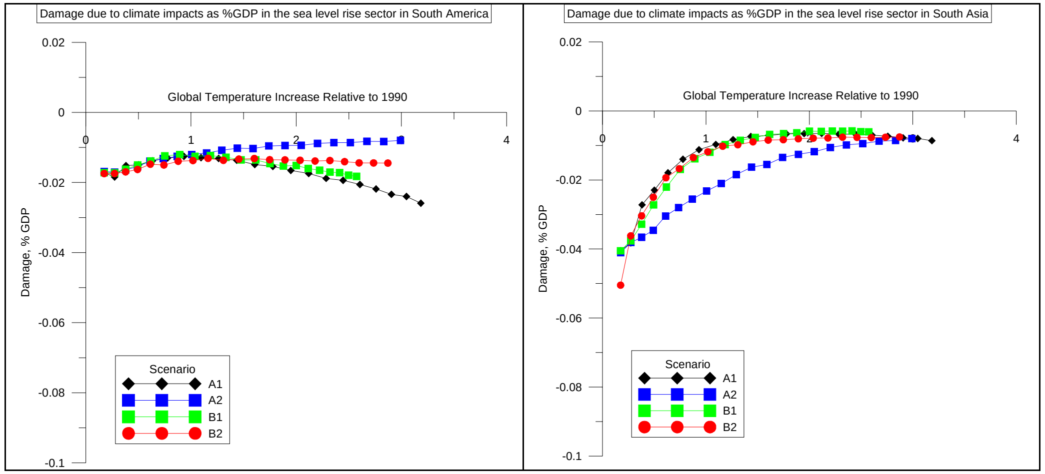
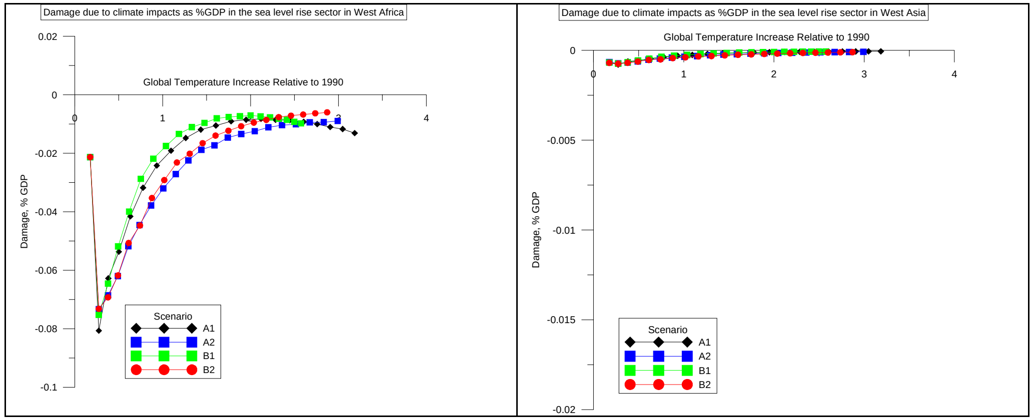


Figure A4.7a cont'd. FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the sea level rise sector for 4 SRES scenarios



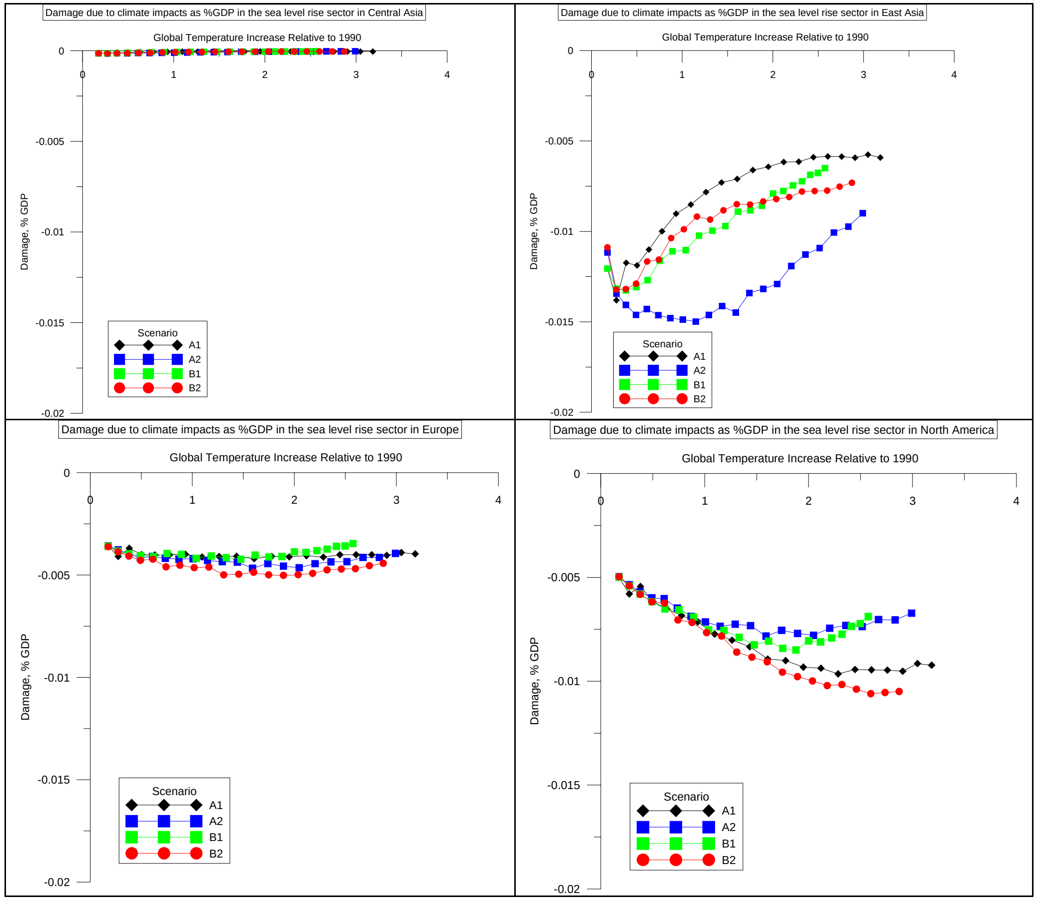
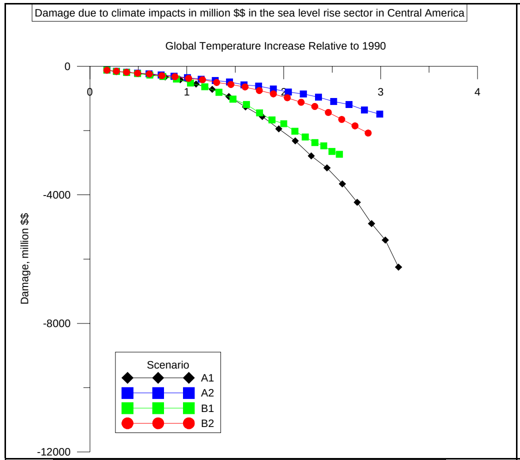
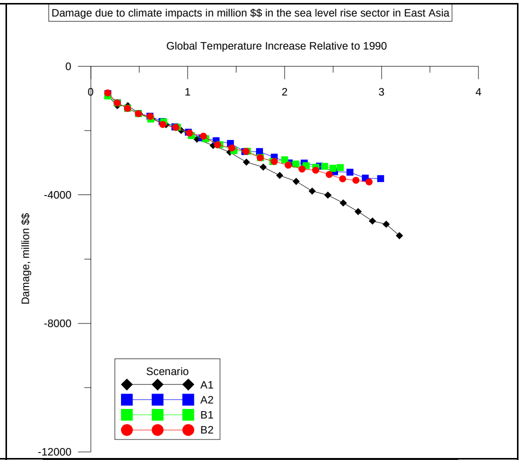
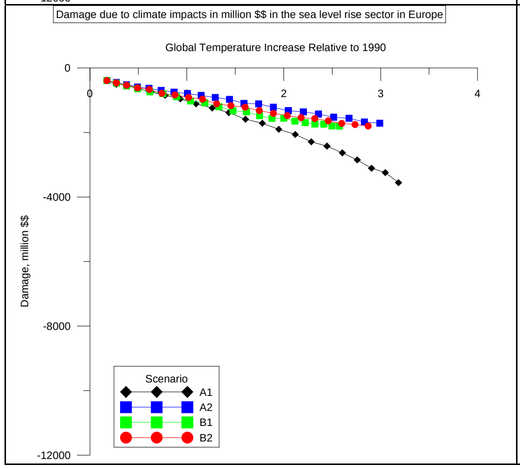
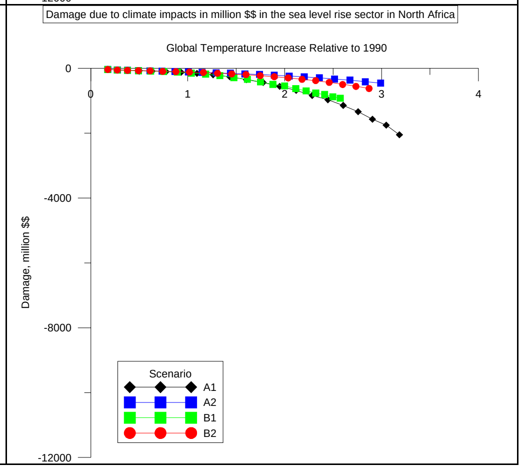


Figure A4.7b FUND-simulated damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 in the sea level rise sector for 4 SRES scenarios


Damage due to climate impacts in million $$ in the sea level rise sector in Central America
Global Temperature Increase Relative to 1990
Damage, million $$
0
-4000
-8000
-12000
0
1
2
3
4
Scenario
A1
A2
B1
B2


Damage due to climate impacts in million $$ in the sea level rise sector in East Asia
Global Temperature Increase Relative to 1990
Damage, million $$
0
-4000
-8000
-12000
0
1
2
3
4
Scenario
A1
A2
B1
B2


Damage due to climate impacts in million $$ in the sea level rise sector in Europe
Global Temperature Increase Relative to 1990
Damage, million $$
0
-4000
-8000
-12000
0
1
2
3
4
Scenario
A1
A2
B1
B2


Damage due to climate impacts in million $$ in the sea level rise sector in North Africa
Global Temperature Increase Relative to 1990
Damage, million $$
0
-4000
-8000
-12000
0
1
2
3
4
Scenario
A1
A2
B1
B2

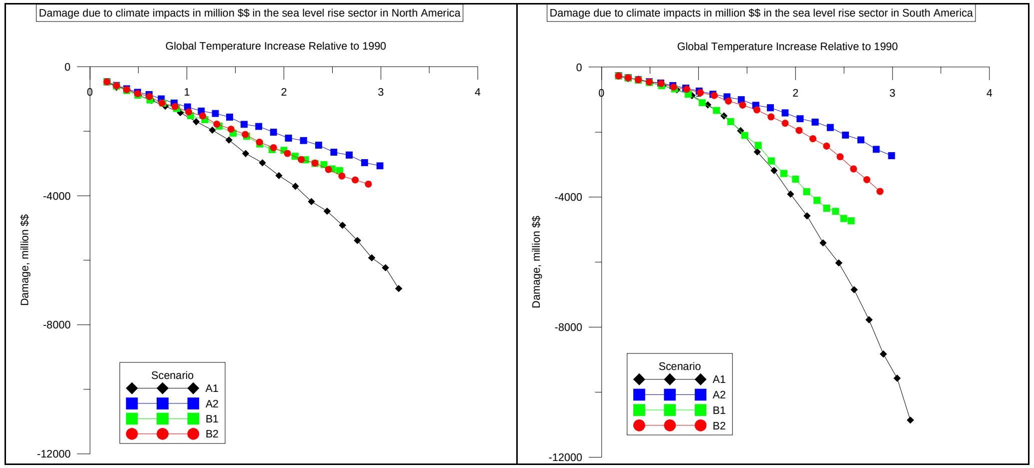
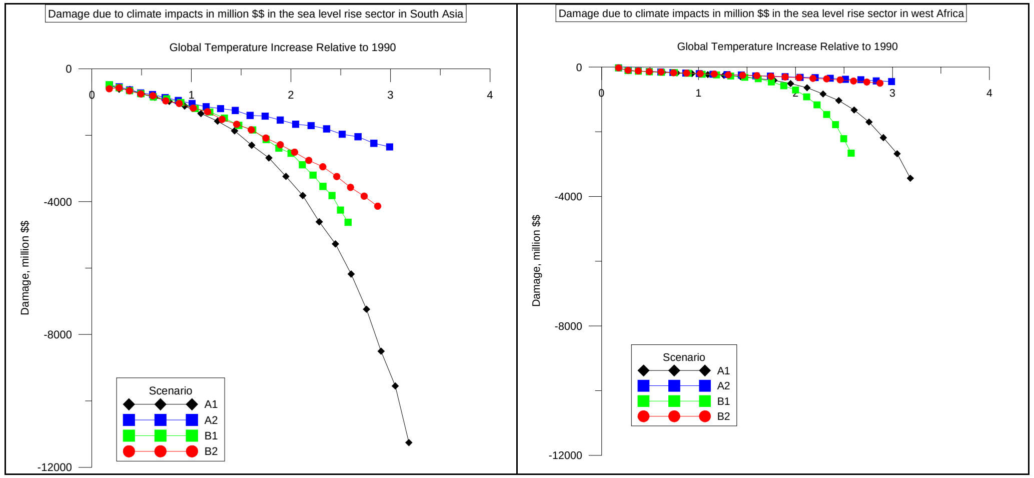


Figure A4.7b cont'd. FUND-simulated damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 in the sea level rise sector for 4 SRES scenarios



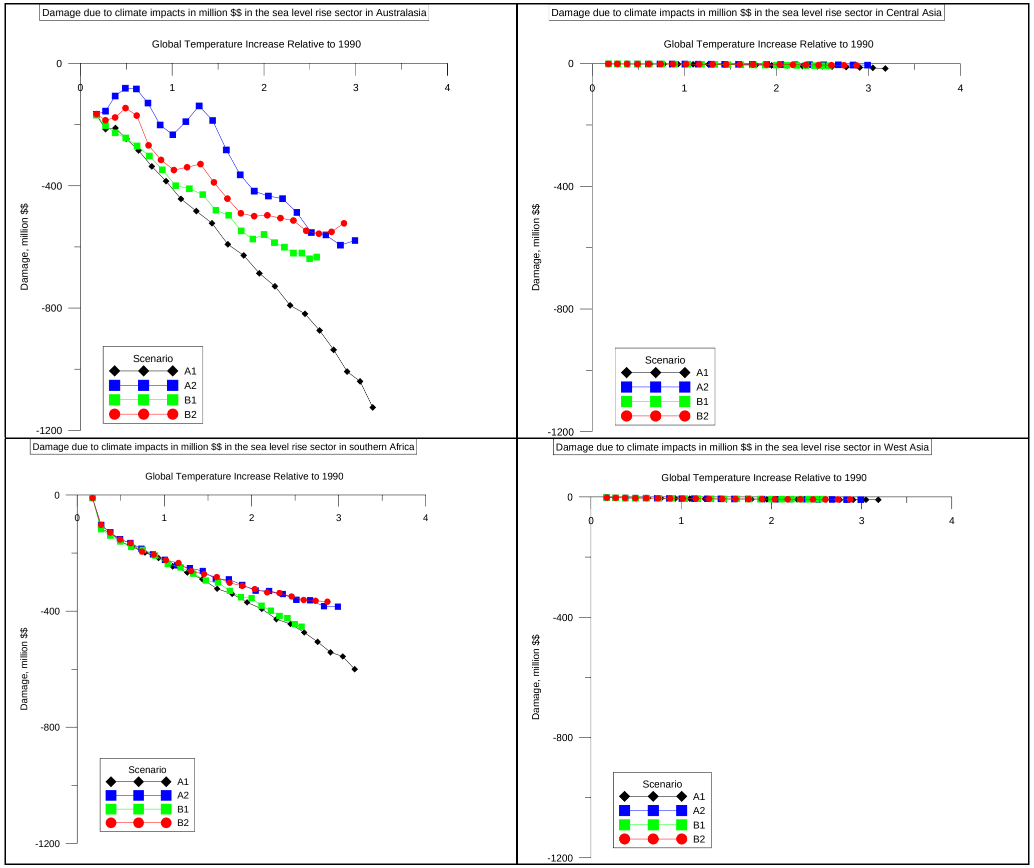
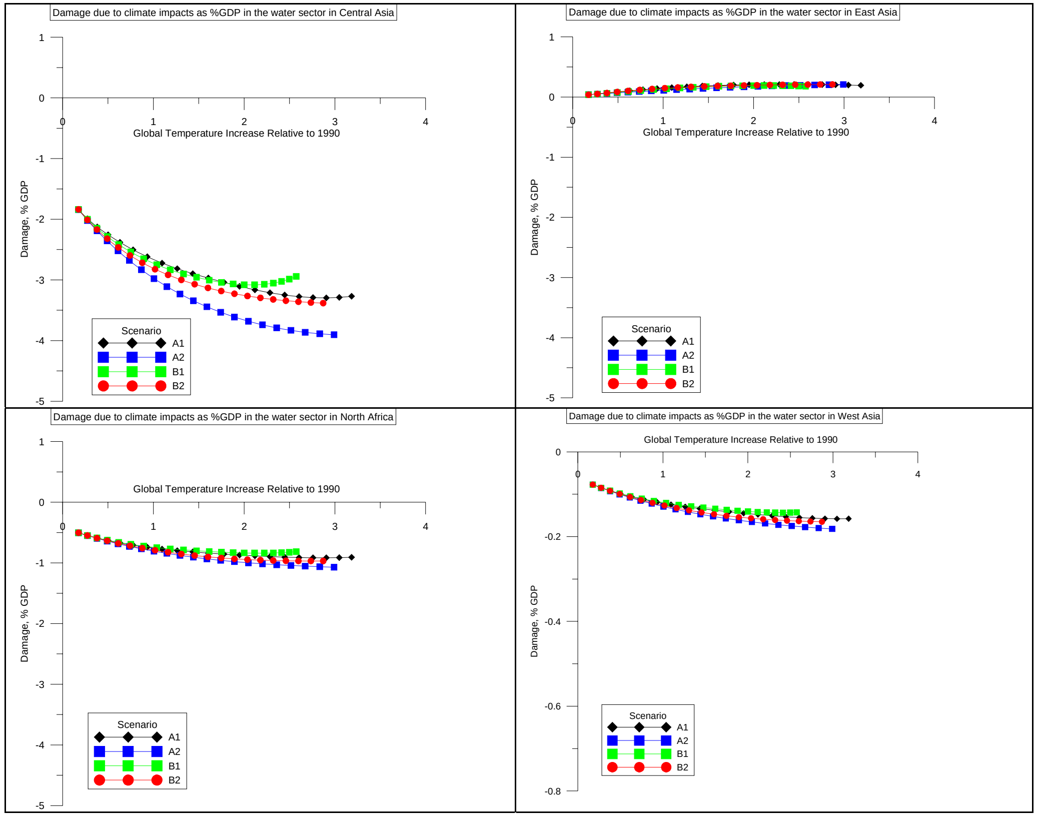
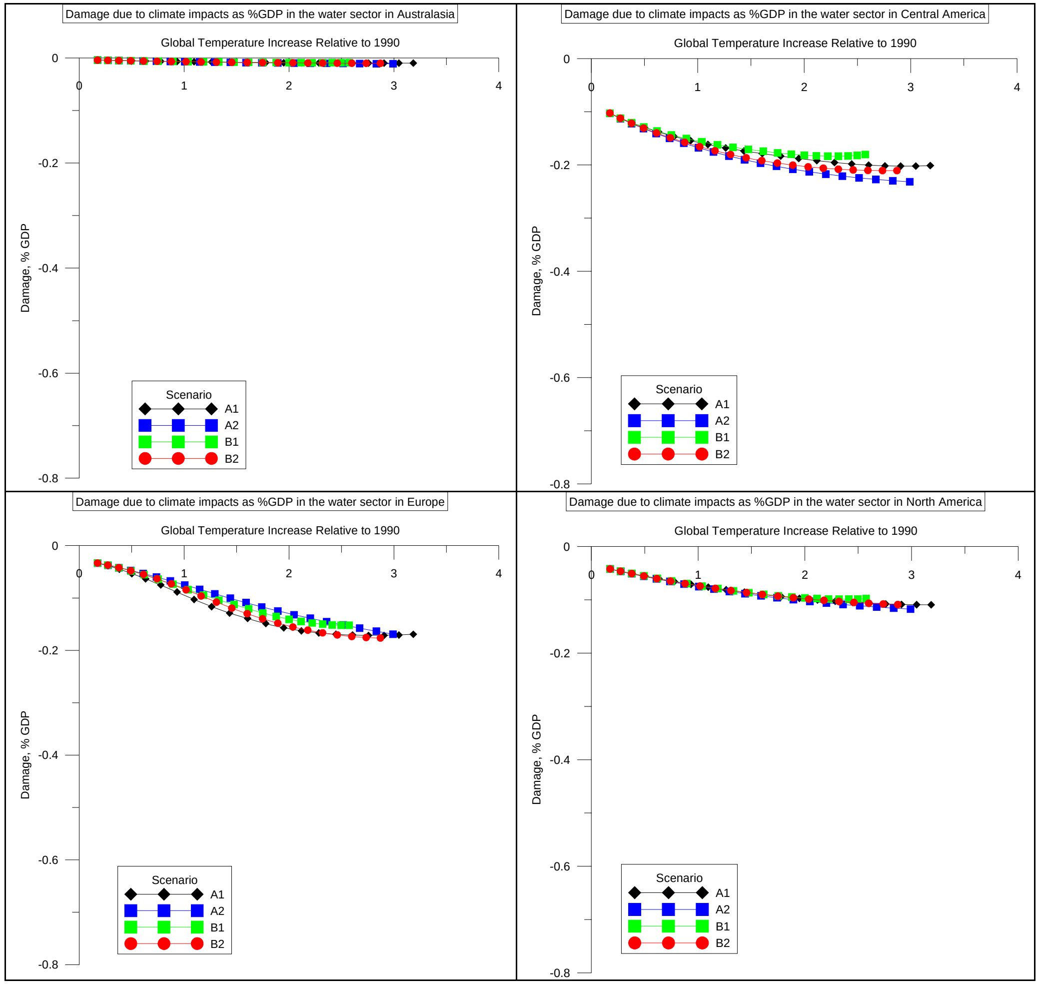


Figure A4.8a FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the water sector for 4 SRES scenarios


Damage due to climate impacts as %GDP in the water sector in Central Asia
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2
Damage due to climate impacts as %GDP in the water sector in East Asia
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2
Damage due to climate impacts as %GDP in the water sector in North Africa
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2
Damage due to climate impacts as %GDP in the water sector in West Asia
Global Temperature Increase Relative to 1990
Damage, % GDP
Scenario
A1
A2
B1
B2


Damage due to climate impacts as %GDP in the water sector in Australasia
Global Temperature Increase Relative to 1990
Damage, % GDP
0
-0.2
-0.4
-0.6
-0.8
0
1
2
3
4
Scenario
A1
A2
B1
B2
Damage due to climate impacts as %GDP in the water sector in Central America
Global Temperature Increase Relative to 1990
Damage, % GDP
0
-0.2
-0.4
-0.6
-0.8
0
1
2
3
4
Scenario
A1
A2
B1
B2
Damage due to climate impacts as %GDP in the water sector in Europe
Global Temperature Increase Relative to 1990
Damage, % GDP
0
-0.2
-0.4
-0.6
-0.8
0
1
2
3
4
Scenario
A1
A2
B1
B2
Damage due to climate impacts as %GDP in the water sector in North America
Global Temperature Increase Relative to 1990
Damage, % GDP
0
-0.2
-0.4
-0.6
-0.8
0
1
2
3
4
Scenario
A1
A2
B1
B2

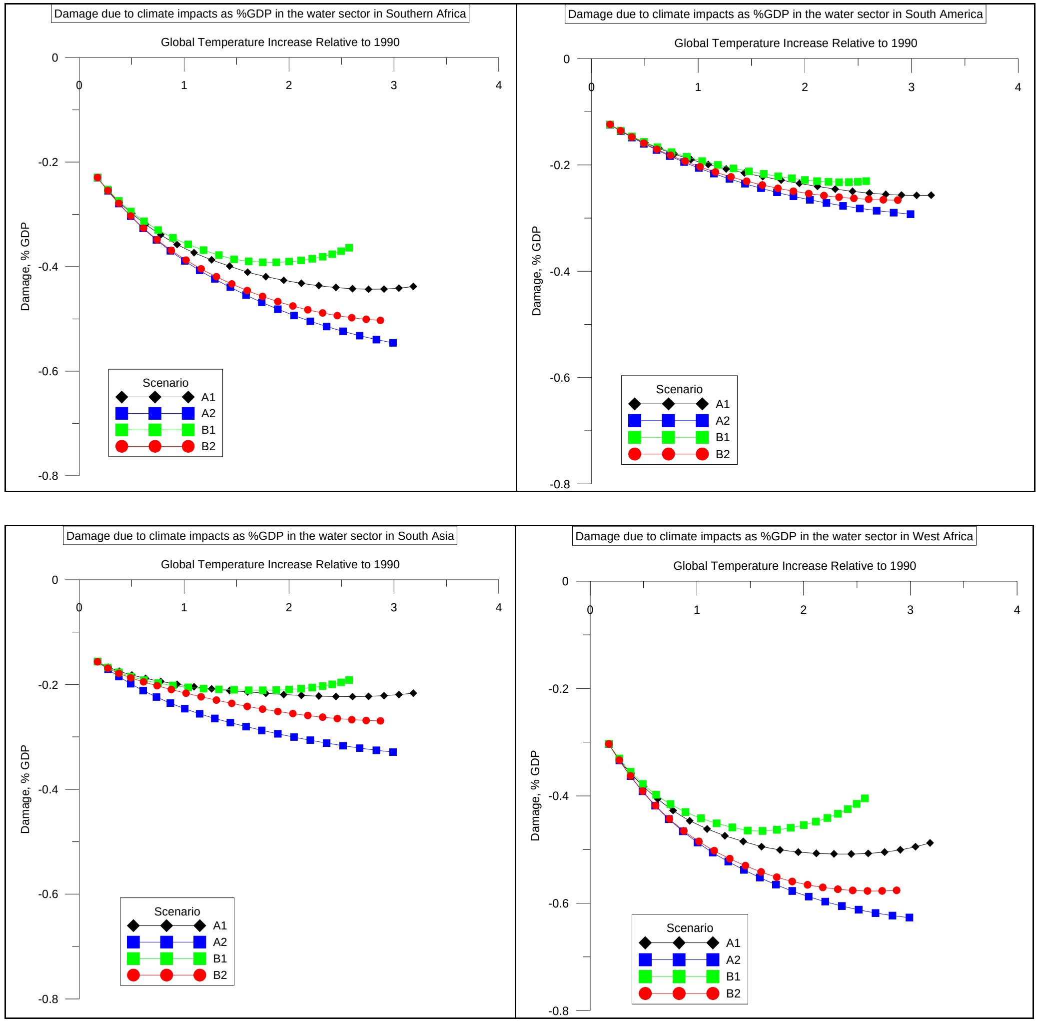
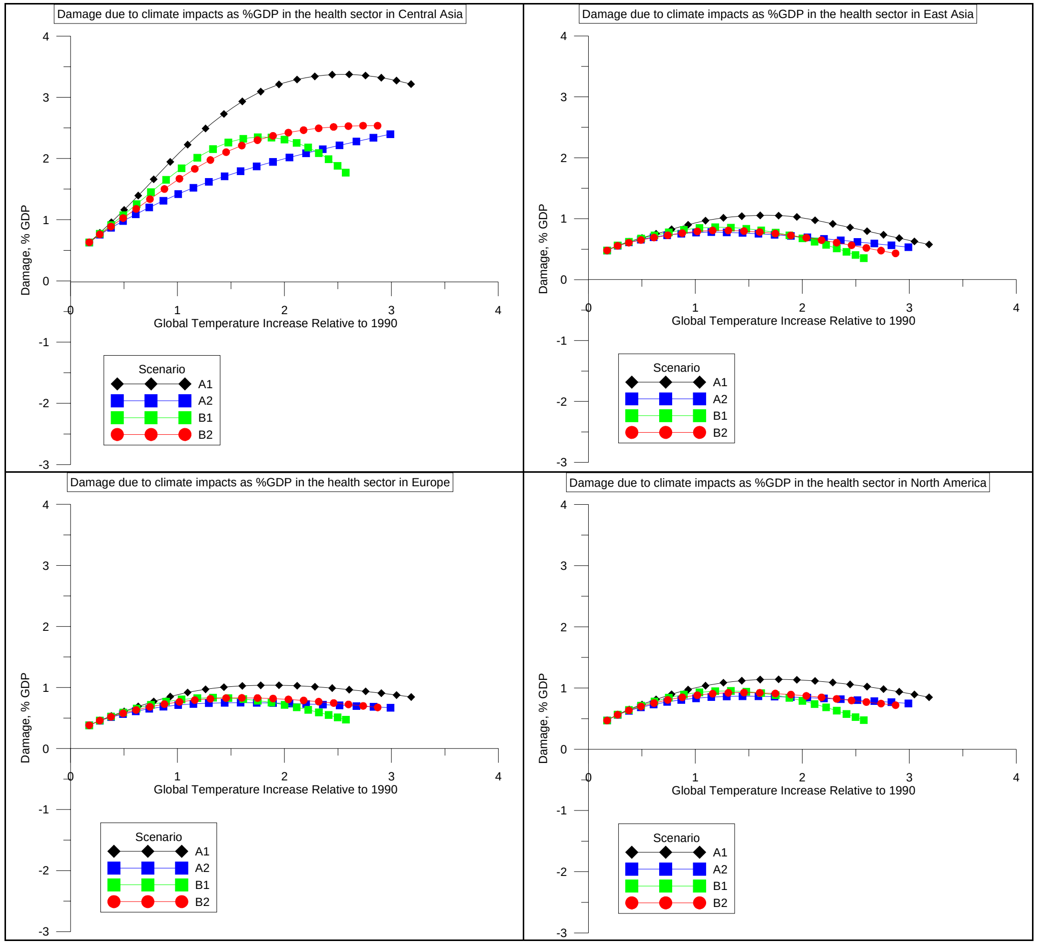


Figure A4.9a FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the health sector for 4 SRES scenarios



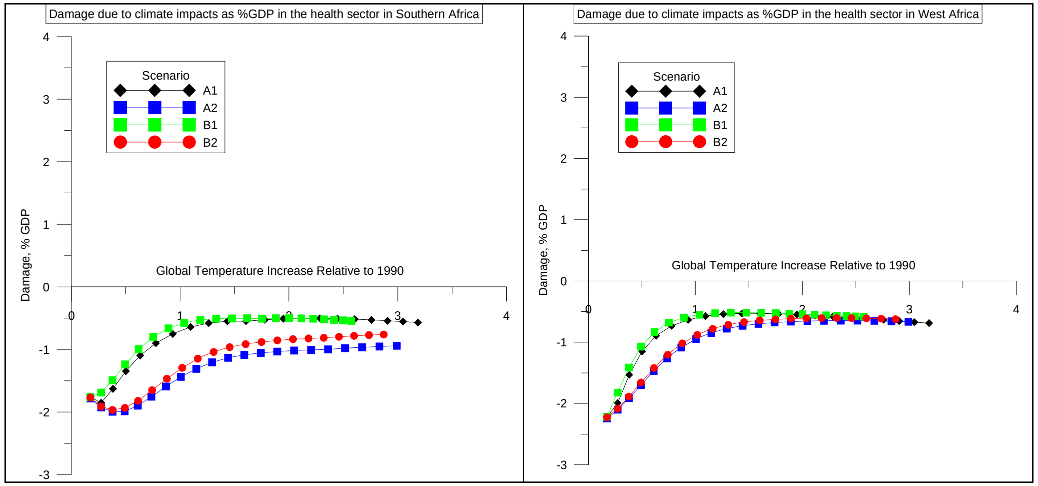
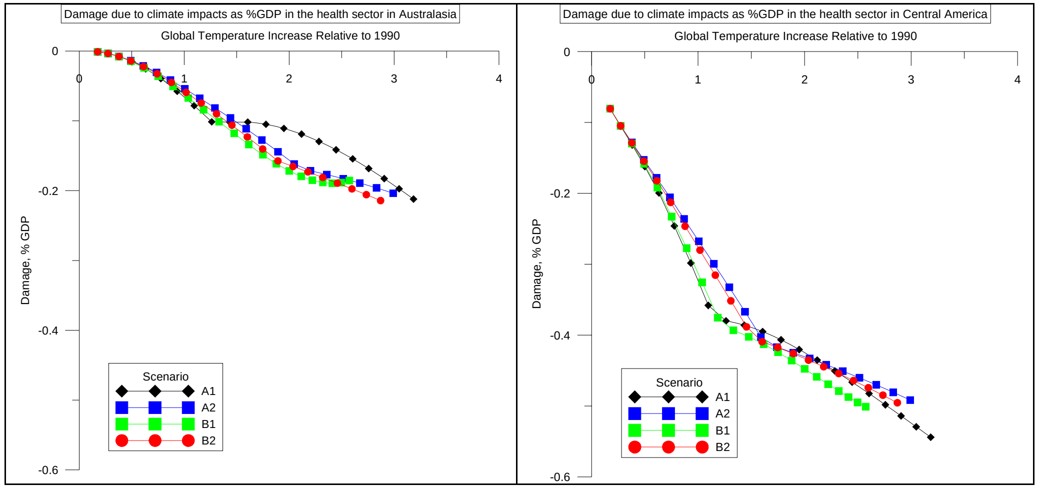


Figure A4.9a cont'd. FUND-simulated damage costs of climate change impacts (% GDP) as a function of global mean temperature rise above 1990 in the health sector for 4 SRES scenarios



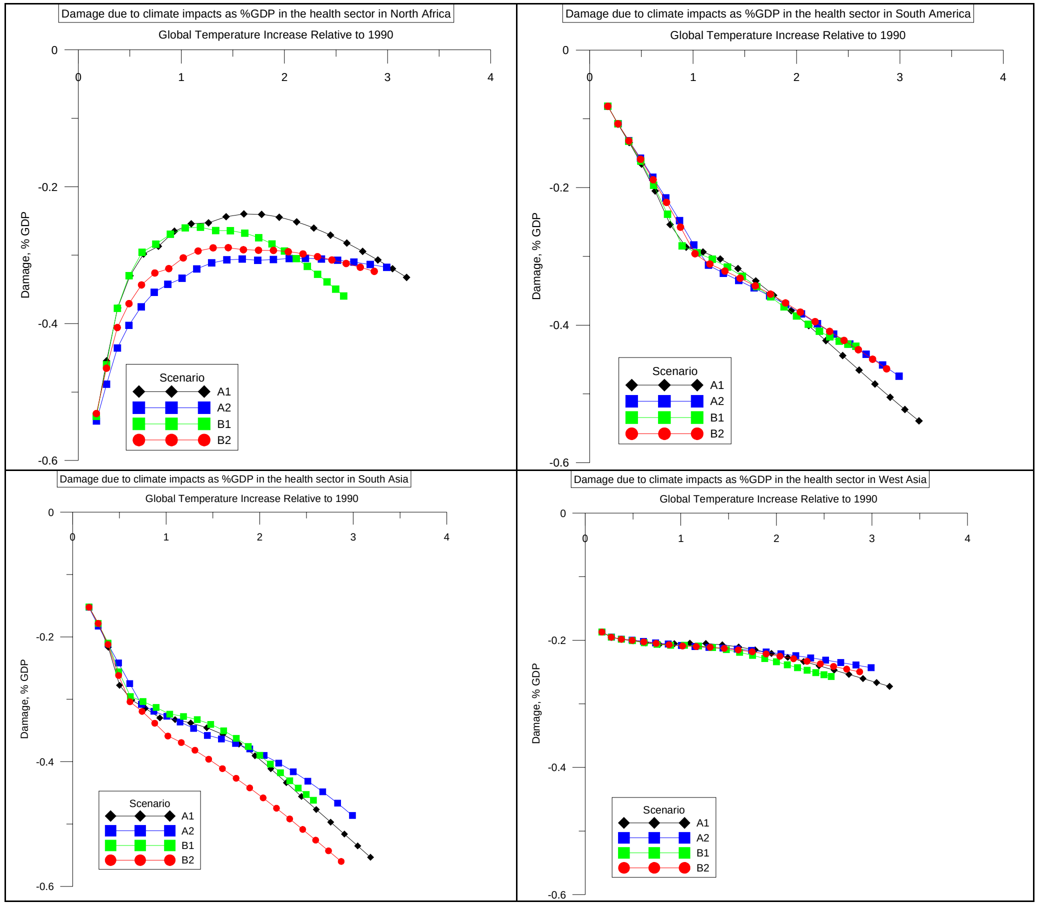
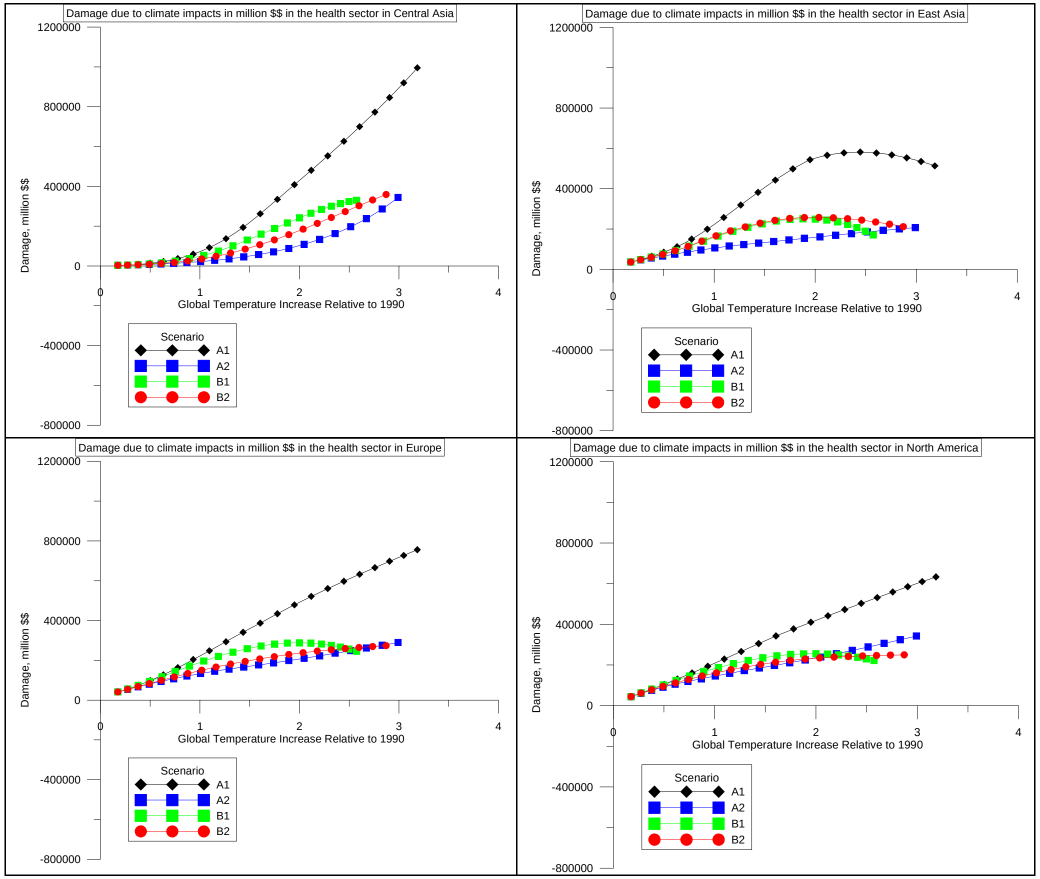


Figure A4.9b FUND-simulated damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 in the health sector for 4 SRES scenarios


Damage due to climate impacts in million $$ in the health sector in Central Asia
Damage, million $$
Global Temperature Increase Relative to 1990
1200000
800000
400000
0
-400000
-800000
0
1
2
3
4
Scenario
A1
A2
B1
B2
Damage due to climate impacts in million $$ in the health sector in East Asia
Damage, million $$
Global Temperature Increase Relative to 1990
Scenario
A1
A2
B1
B2
Damage due to climate impacts in million $$ in the health sector in Europe
Damage, million $$
Global Temperature Increase Relative to 1990
Scenario
A1
A2
B1
B2
Damage due to climate impacts in million $$ in the health sector in North America
Damage, million $$
Global Temperature Increase Relative to 1990
Scenario
A1
A2
B1
B2

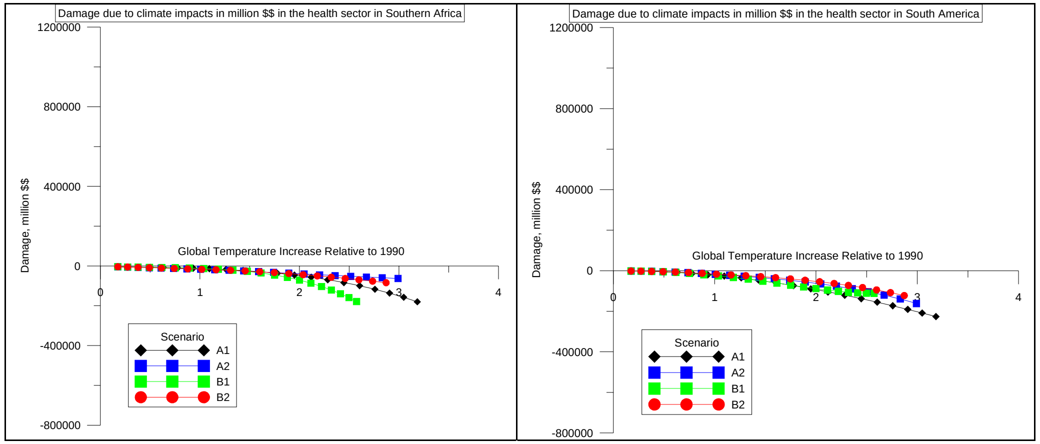
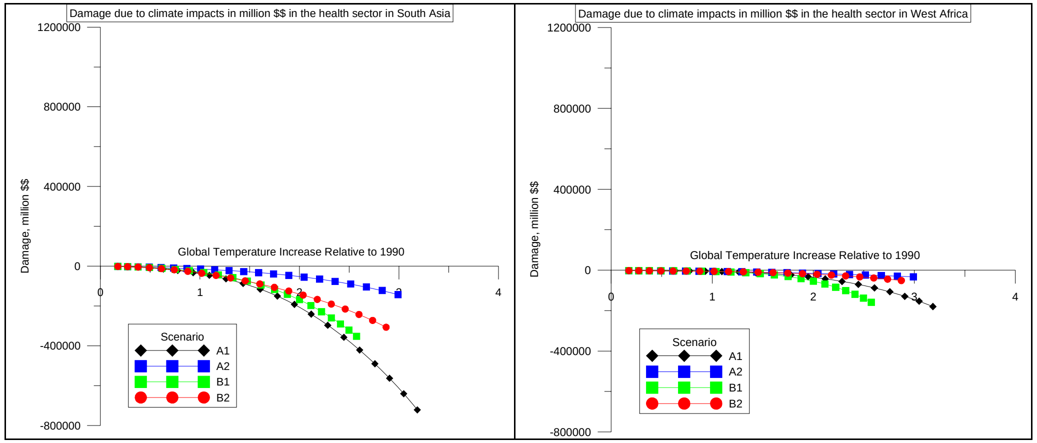
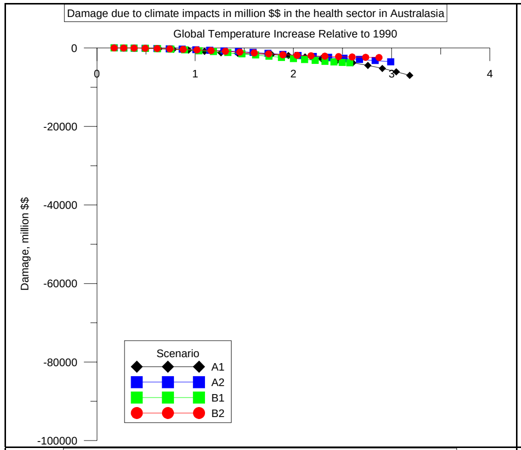
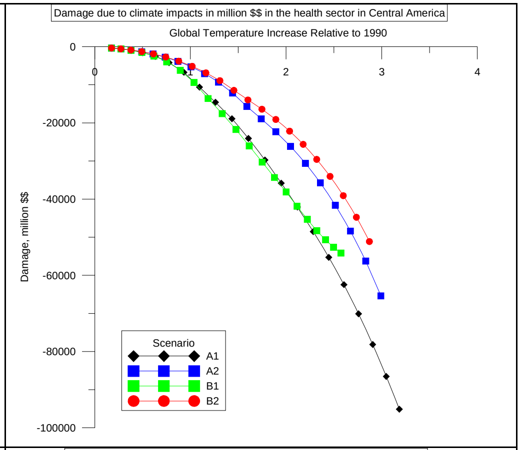


Figure A4.9b FUND-simulated damage costs of climate change impacts (million $$) as a function of global mean temperature rise above 1990 in the health sector for 4 SRES scenarios

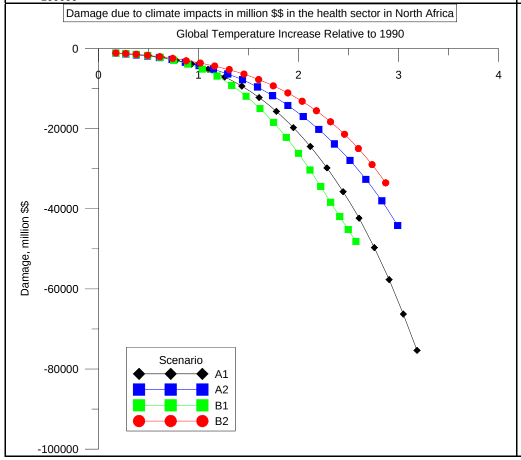




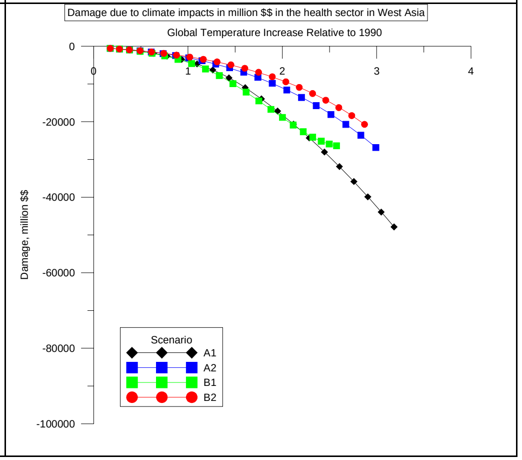
Damage due to climate impacts in million $$ in the health sector in Australasia
Global Temperature Increase Relative to 1990
Damage, million $$
Scenario
A1
A2
B1
B2



Damage due to climate impacts in million $$ in the health sector in Central America
Global Temperature Increase Relative to 1990
Damage, million $$
Scenario
A1
A2
B1
B2



Damage due to climate impacts in million $$ in the health sector in North Africa
Global Temperature Increase Relative to 1990
Damage, million $$
Scenario
A1
A2
B1
B2



Damage due to climate impacts in million $$ in the health sector in West Asia
Global Temperature Increase Relative to 1990
Damage, million $$
Scenario
A1
A2
B1
B2

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