CICERO Report 2010:01

Impacts of climate change to the global economy in the ENSEMBLES +2 °C scenario E1

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March 2010

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Tittel:	**Title**: Impacts of climate change to the global economy in the ENSEMBLES +2 °C scenario E1
Forfatter(e):	**Author(s):** Taoyuan Wei and Asbjørn Aaheim
CICERO Report 2010:01	CICERO Report 2010:01 16 pages
Finansieringskilde:	**Financed by:** European Commission's 7th Framework programme
Prosjekt:	**Project:** ENSEMBLES
Prosjektleder:	**Project manager:** Asbjørn Aaheim
Kvalitetsansvarlig:	**Quality manager:** Nathan A. Rive
Nøkkelord:	**Keywords:** Climate change, impacts and adaptation, macroeconomic modeling
Sammendrag:.	**Abstract:** This report summarises impacts to the global economies of the ENSEMBLES E1 scenario, which exhibits a path for the emissions of greenhouse gases limiting the increase in global mean annual temperature to + 2°C. The results indicate the economic impacts are generally modest, although unevenly distributed across world regions. Rich and fast growing regions are expected to gain from the impacts described in this report, while the poorest regions bear the largest relative losses. In Africa and south Asia reduction in value added amounts to more than 3.5 percent in 2100. However, the overall impact to the global economy is generally positive. This is due to positive impacts of climate change in resource based sectors, and to a decline in the demand for energy. The value added in sectors which are not directly, or only modestly affected by climatic changes, such as manufacturing industries and services, increases by nearly 1 percent by the end of the century. It is also demonstrated that adaptation and resulting market responses plays an important role in assessing the impacts to sectors as well as to regions. The immediate impacts may turn from positive to negative or from negative to positive as a result of a change of prices in the wake of climate change**.**
Språk:	**Language of report:** English

Rapporten kan bestilles fra: CICERO Senter for klimaforskning P.B. 1129 Blindern 0318 Oslo	The report may be ordered from: CICERO (Center for International Climate and Environmental Research – Oslo) PO Box 1129 Blindern 0318 Oslo, NORWAY
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1 Introduction

Even though it may be fair to say that the basic driver behind climate policy is the concerns about the impacts of climate change and, moreover, that the costs of mitigation will have to be evaluated in the light of avoided negative impacts of climate change, there are relatively few studies of the economic impacts of climate scenarios. There are many reasons for this, such as uncertainty or ignorance about the consequences of climate change and difficulties in quantifying them in economic terms. Even the criteria for comparisons of the costs and benefits of climate change are being subject to controversies. This became apparent after the release of Stern Review (Stern, 2006), which once again brought the old controversy among economists about the appropriate choice of discount rate up to the surface. Some claimed that the aggressive emission cuts recommended by the Review were based on an unrealistically low discount rate (Nordhaus, 2007, Dasgupta, 2007). Others argued that the risk aspect ought to be emphasised more strongly than the cost-benefit approach applied in the Review allows for (Neumayer, 2007, and Barker, 2008).

Another reason why studies of the impacts of climate change on the economy are sparse is that it takes time to develop appropriate tools. The first well-known contribution in this respect was Nordhaus (1991) in his model based cost-benefit analysis of whether aggressive emission cuts could be defended in the short term, or if actions should be delayed. He found no reasons for aggressive cuts in the short term. Later studies based on his DICE model (see e.g. Nordhaus and Boyer, 2000) arrive at the same conclusion: the benefits of massive reductions in the emissions of greenhouse gases in the short run do not pay in terms of avoided damages in the future. Over the past 20 years, impacts of climate change have been integrated in other models, such as PAGE (Hope, 2006), which was used in the Stern Review, FUND (Tol, 2007) and WIAGEM (Kempfert, 2005). In all these models, the impacts of climate change are represented as a single estimate of the accumulated damage cost to the economy. The estimate is the based on an economic evaluation of all impacts of climate change at a given point of reference, say when the concentrations of greenhouse gases in the atmosphere is 550 ppmv. A more or less arbitrary choice of functional form helps estimate damages at other levels of concentrations.

A slightly different branch of integrated models include the impacts of climate change from models of natural systems, for example by means of ecological models. These are coupled to a more or less sophisticated economic model, which allows for an evaluation of the economic impacts. In most cases, only a selection of impacts are represented in these models. IMAGE (Bouwman et al., 2006) has been coupled with models for sea-level rise, and is also used to estimate land-use chang, such that consequences for forestry and agriculture can be derived. ISGM (Reilly et al., 2007) integrates economic and terrestrial models. Moreover, there are many partial models (e.g. sector models) which address the relationships between certain natural systems and selected economic sectors, such as forestry (see Aaheim et al., 2010, for a review).

Hence, while some integrated models emphasise the relationship between economic activities and natural systems, while selective in their representation of impacts, integrated models with comprehensive representations of impacts separate impacts from economic decision making. Responses to the impacts of climate change are thereby decoupled from how economic agents respond to similar changes in technologies and endowments for any other than climatic reasons. In other words, economic models have the potential of modelling adaptation to climate change, which is not being fully utilized. An exception is the ICES model (Bosello et al. 2007), which address energy demand, human health, tourism and sea-level rise. The ICES model applies separate relationships between climatic indicators and the demand and supply for impacted economic activities.

A similar approach is chosen in the model Global Responses to Anthropogenic Changes in the Environment (GRACE) (Aaheim et al. 2009, Aaheim and Rive, 2005) applied in this report. The objective of this study is to assess the economic impacts to the global economy of a climate scenario, called E1. It was developed for the ENSEMBLES (2009) project and predicts an increase in global mean temperature at +2 °C in 2100. GRACE is a computable general equilibrium model where the impacts of climate change affect specified activities, such as the productivity of land in agriculture and forestry, the productivity of oceans in the fisheries, or the demand for energy for heating purposes. For example, the growth of biomass in forests may change as a result of climate change. The immediate economic effect is a change of the endowment of natural resources in the forestry sector. This affects the shadow price of the natural resources, which makes agents in the sector adapt by changing the composition of input factors in forestry. This response has repercussions thoughout the economy, which are addressed by general equilibrium models. The process of adaptation can thereby be considered in two stages. First, the adaptation individual agents make in response to a shifting environment, and second, the market effects. Adaptation to climate change is thereby made consistent with ordinary economic behaviour.

This report do not present further policy analysis of the E1 scenario. The pupose is only to examine the economic impacts of climate change, and study the extent to which adaptation follows as a result of market behaviour. The impacts are represented by separate impacts functions, which are presented in Section 2. Section 3 gives a brief presentation of the E1 scenario, presents the main results.

2 Impacts of climate change by world region

The GRACE model is a computable general equilibrium model with eight regions (Europe, Russia and Western Asia, India, China, Africa and South mainland Asia, East Asia and Oceania, North America, Latin America) and eleven sectors (Agriculture, Forestry, Fisheries, Manufacturing, Transport, Other services, Crude oil, Coal, Gas, Electricity, Refined oil), with national account data provided by GTAP (Dimaranan, 2006). The production structure is based on CES-trees, calibrated under a choice of elasticities of substitution, and the trade between world regions are represented by Armington functions. GRACE calculates the the global static equilibrium in time intervals of five years, where economic growth is determined by exogenous assumptions on saving rates (so-called dynamic recursive model). The savings in each reagion are put in a global bank, which allocates investments to the regions in accordance with to their rates of return, while the return is transfered back to its origin. The diversity of return rates across regions in the base year is leveled out over time.

The impacts of climate change are represented by relationships between climate indicators and the economic activities of the model. As for other integrated models, there is a lot of uncertainty connected to the impacts estimates, as the knowledge about these relationships are generally weak. The functional forms are chosen mainly on intuition to illustrate certain general properties of climate change impacts, for example increasing marginal costs of restoring capacity in the wake of an extreme event. While most integrated models aggregate all impacts into one estimate and represent all impacts by one aggregated damage cost function, the GRACE model has nine impacts functions – one for each activity supposed to be affected by climate change. The calibration of these functions are based on interpretations of a collection of studies, which are used to estimate the impacts at a given level of change in a chosen set of climatic parameters, usually mean temperature (see Aaheim et al., 2009).

The advantage of applying a more detailed description of impacts is related to the analytical properties of the model, as adaptation to climate change becomes consistent with economic behaviour. The disadvantage is related to the numerical signficance of the model results, as all the uncertainties about the impacts are spread out in the model. The relatively detailed description of impacts may give the impression that the knowledge about the relationships between economic activities and climate are much better than they actually are. It cannot be emphasized strongly enough that estimates of impacts of cliamte change are vastly uncertain. The reason for making attempts to assess them is, however, that climate policy has to be related to expectations about impacts, and it is, therefore, worth trying to summarize the present state of knowledge despite the uncertainty. In the context of this study, the estimates on impacts are also necessary to illustrate how expectations about direct impacts change because of market responses, which we know more about.

Impacts of climate change can be divided into sector-related and general impacts. Sector related impacts are those that may be attached directly to a specific activity within a sector because this activity is sensitive to climatic conditions. Resource based activities, such as agriculture, fisheries, forestry and renewable energy production are affected by climate change if the productivity of the natural resources on which they are based are changed. Moreover, the demand for some goods and services, such as the share of energy demand for heating or cooling purposes, is also sensitive to the climate. The general impacts are impacts on economic activities that may affect any sector of the economy, such as sea-level rise, extreme events and health effects. Most of these impacts affect the primary input factors labour or capital in terms of changes in labour supply, demand for health services or material loss of real capital.

Table 1 gives an overview of how the impacts are represented in the different sectors. In the resource based sectors, agriculture, forestry and fisheries, climate change is assumed to affect the productivity of natural resources, which is a primary input factor to the sectors. The productivity of natural resources in agriculture and forestry are subject to changes in temperature and precpitation, but depends also on the present level of temperature. As a result, the impacts of climate change is positive in some regions for small changes, but becomes negative at larger temperature changes. The impacts functions to agriculture are calibrated with reference to the estimates of Cline (2007). For forestry and fisheries, we have used different studies, primarily based on European studies (see Aaheim et al., 2009). The functional relationships between the increase in mean temperature in the regions and rates of change in the sectors are illustrated in Figure 1. Impacts may be positive or negative at 0 °C change because of changes in annual precipitation in the E1 scenario.

Sector/Effect	Activity affected	Indicators
Agriculture	Natural resource	Change in temperature, level of temperature, change in precpitation
Forestry	Natural resource	Change in temperature, deviation from ideal temperature, change in precipitaion
Fisheries	Natural resource	Change in temperature, deviation from ideal tempeature, share of aquaculture
Electricity supply	Natural resource	Change in temperature, change in precipitation, share of renewable
Energy demand	Heating/cooling	Change in temperature, level of temperature
Tourism	Demand in service and transport sector	Change in temperature, level of temperature, change in precpitation
Extreme events	Stock of capital	Change in temperature
Sea-level rise	Stock of capital	Change in temperature
Health	Productivity of labour	Change in temperature, level of temperature.

Table 1. Impacts of climate change and explanatory factors in GRACE

The supply of electricity is sensitive to temperature in thermal electricity plants, and to precipitation in those renewable electricity plants where the bulk of the supply originates from hydro power plants. Wind power is sensitive changes in wind patterns, but ind is not predicted in the scenarios, and possible impacts are therefore diregarded here. Energy demand is subject to temperature. It is reduced with higher temperature in cold regions, and the main effect is on fossil fuels. It increases in warm regions, where electricity demand is affected. Many of the regions include both “warm” countries where higher temperature increases energy demand and “cold” countries where the energy demand is reduced by higher temperature. The impact for the region is an estimated average.

Tourism is included because it is assumed to be affected, although there is very little knowledge about the dependency between climate and tourism. Some studies indicate, however, that the change in destinations may be significant (Berrittella et al. 2006). The functions in the model give positive effects in some regions and negative in others. This implies that tourism on the global scale is more or less unaffected by climate change regardless of how “strong” the climate signal is, but that the choice of destination may change. Tourism is not a separate sector in GRACE, but changes in tourism affect the demand for services and transport. The impacts in the model are estimated on the basis of how tourism is divided into the two sectors and tourism’s share of the activity of each sector.

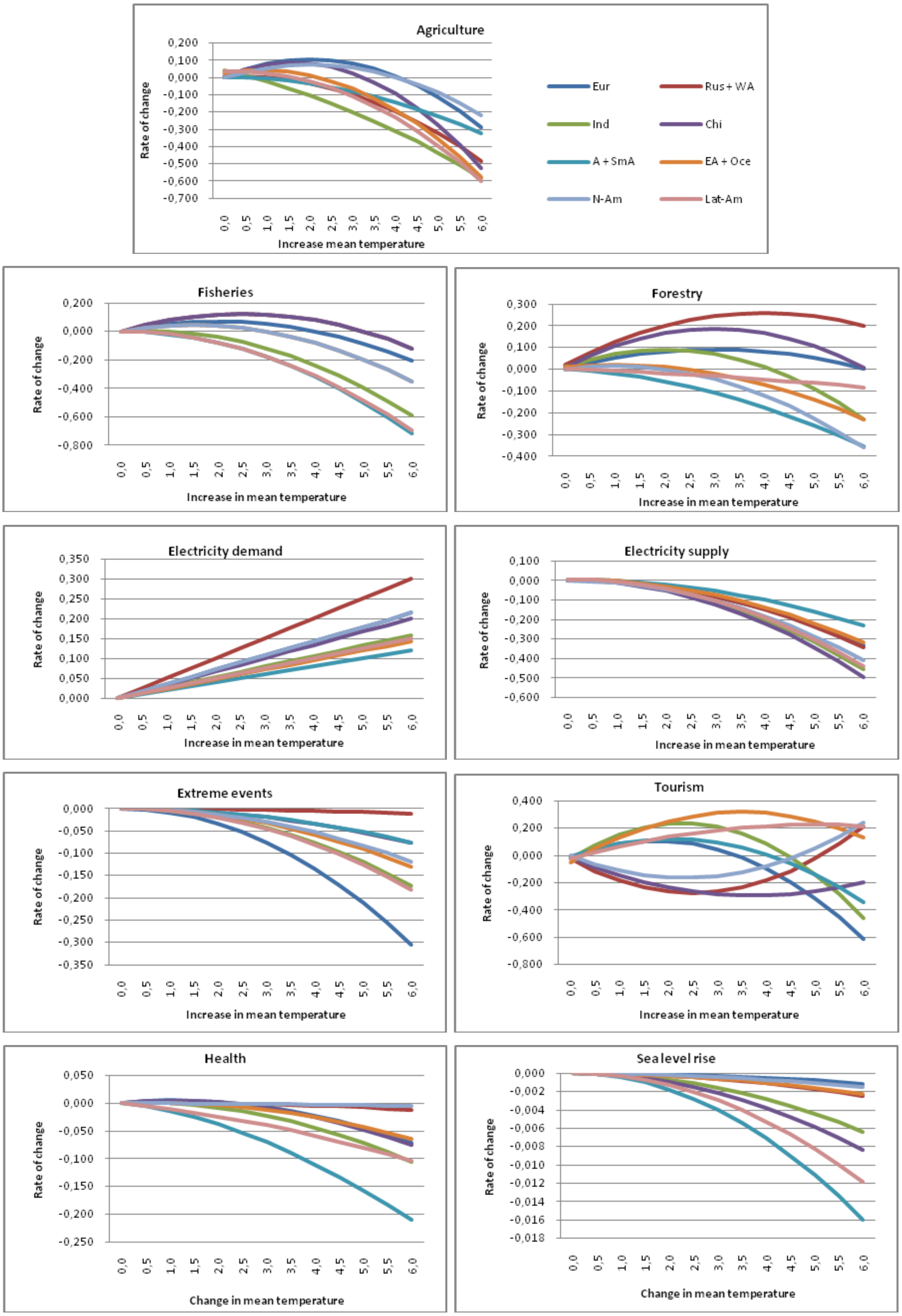

Figure 1. Impacts functions for changes in mean temperature by sector and region in GRAC

Damages of extreme events are expressed in terms of losses in the capital stock in the model. The estimates are based on assessments by the World Bank (2008). Also sea-level rise is assumed to affect the stock of capital, and the estimates are taken from Tol (2002).

Health effects are usually reported as losses of life or number of people affected by selected diseases. In GRACE, the numbers proveded by the World Bank (2008) are translated into estimates of changes in labour productivity. Thus, there are no further evaluations of wider welfare effects on health in the model.

3 The E1 scenario

The E1-scenario is based on a global path for future emissions of greenhouse gases that result in an increase in global mean annual temperature at +2 °C from the period 1961 – 2000 to the period 2070 – 2099. Figure 2 shows how the mean is distributed across the world in the final period. The northern part of the world is most affected, and the annual mean temperature exceeds +5 °C in parts of the Arctic. In the regions around equator and in the southern hemisphere, the increase in temperature varies from less than +1 °C to approximately +2 °C.

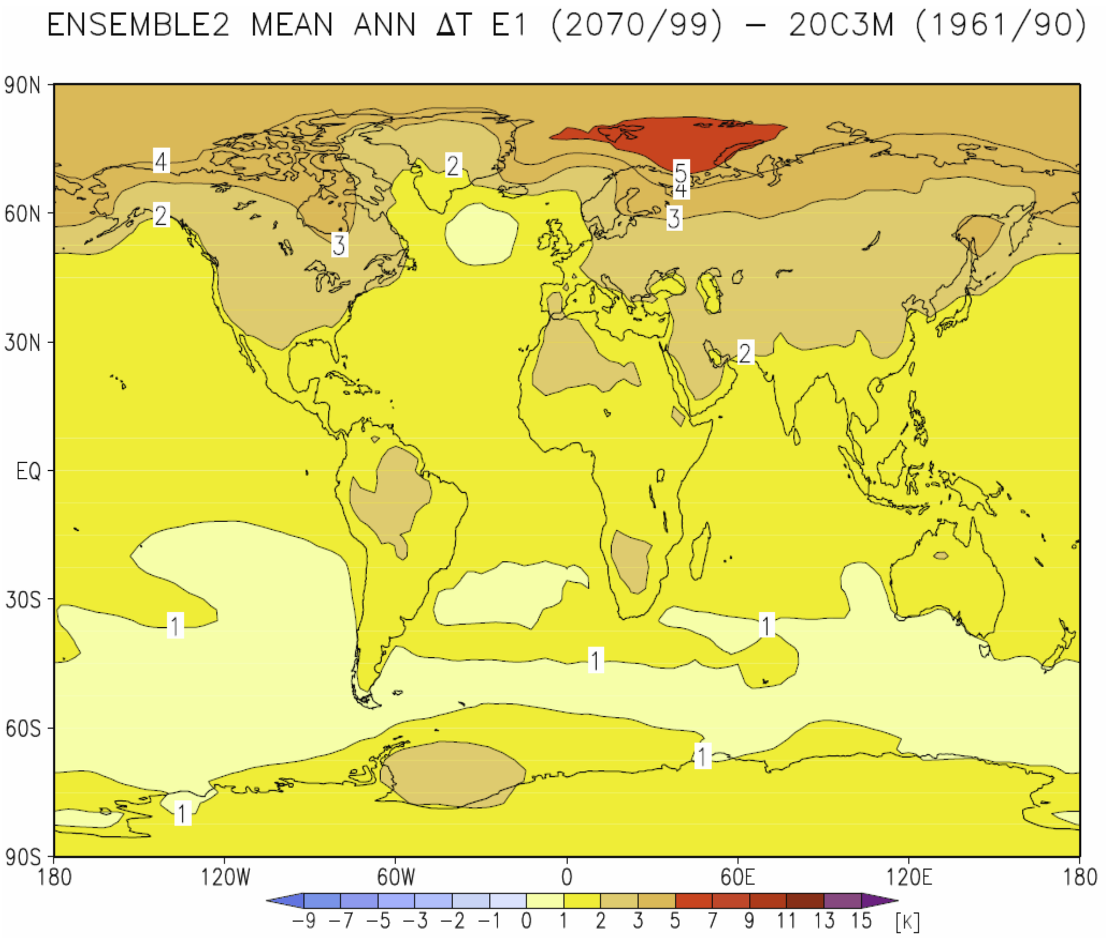

Figure 2. Changes in Global mean temperature in the E1 scenario. Average of 10 GCMs.

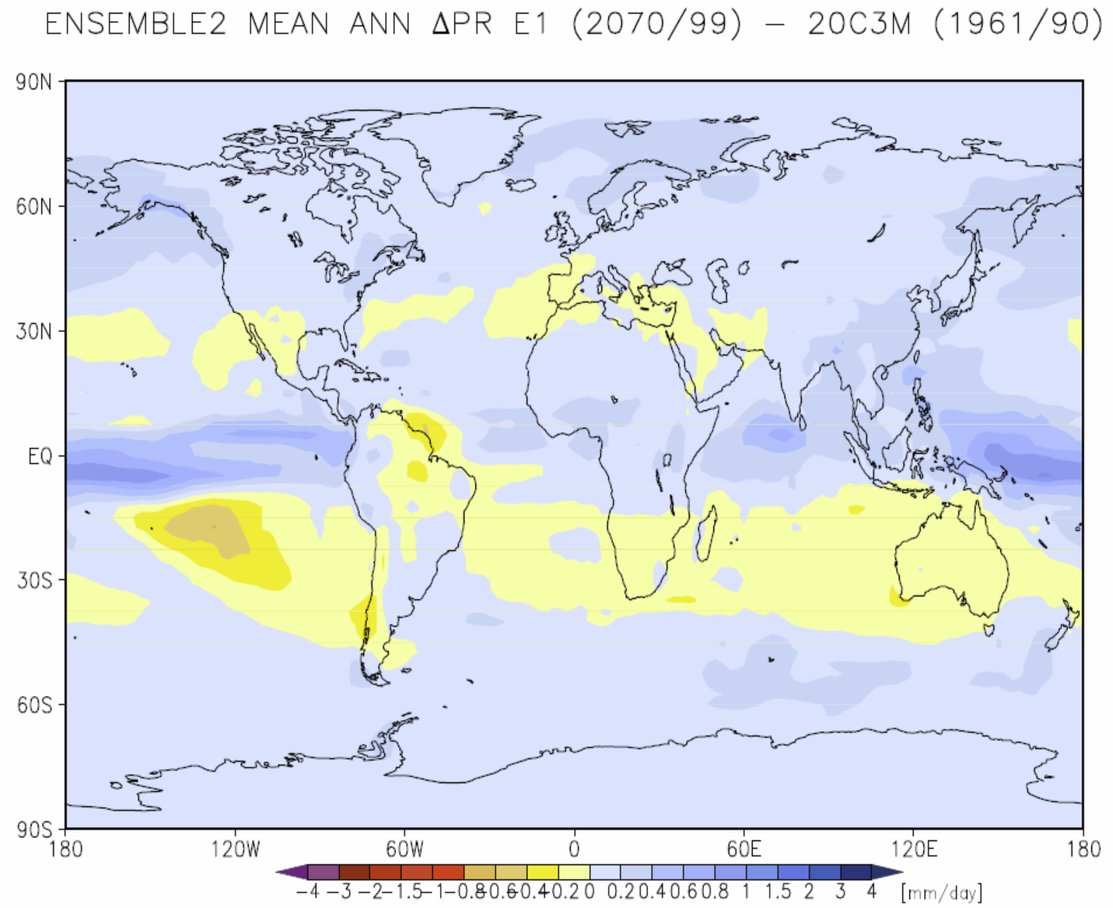

Figure 3. Changes in mean annual precipitation in the E1 scenario. Average of 10 GCMs.

The corresponding changes in mean annual precipitation are shown in Figure 3. With the exeption of the Mediterranian and the Middle Eeast Large the northern hemisphere generally faces a more humid climate. A drier climate is expected in large land-areas in the southern hemisphere. The most significant changes are found in the Pacific, where the himidity will decline by up to 0.6 mm/day in the ocean west of South America, and increase by up to 1 mm/day outside South-East Asia. The GRACE model was run to 2100 with 2004 as base-year. The changes displayed in Figure 1 and Figure 2 were assumed to apply also for this period.

The resulting direct economic impacts of the scenario before adaptation takes place are displayed in Table 2. The figures show percent changes in the affected activity of the model, which is indicated in the second column. The table indicates that the impacts of a relatively moderate climatic change of +2 °C in global mean are noteable. The effects on agriculture vary from -10 percent in India to + 10 percent in Europe. The availability of forest will increase in most regions, whereas fossil energy demand, in particular for gas, will go down as a results of lower demand for heating. The need for cooling, on the other hand, contributes to increase the demand for electricity in all regions. According to the studies underlying the impacts functions of this study, tourism will not change much in total, but destinations will change significantly. It must be emphasised, however, that the material on which all the impacts functions are based is uncertain, indeed. The attempt to synthsise results from many studies into one single impact function moreover adds significantly to this uncertainty. The purpose of this exercise is therefore to illustrate how the world economies will be affected *if* the direct impacts are as described by these functions, rather than to predict the impacts of climate change.

	Affected activity	Europe (EU)	Russia and western Asia (RUS)	India (IND)	China (CHN)	Africa and south mainlad Asia (AFR)	East Asia and Oceania (EOA)	North Ameri ca (NAFT)	Latin America (LAM)
Agriculture	Nat. Res.	10.7	-6.3	-10.3	7.3	-2.4	3	7.1	-4.2
Forestry	Nat. Res.	8.3	22.6	9	17.6	-4.3	1.6	1.1	-2.2
Fisheries	Nat. Res.	6.9	12.3	-4	12.3	-5.7	4.4	4.4	-10.2
El-supply	Nat. Res.	-3.9	-5.8	-4.6	-7.1	-1.4	-1.6	-2.6	-5.9
El. demand	Heat/cool	7.5	12.5	5.3	7.7	3.4	3.8	5.4	5.8
Gas demand	Heat/cool	-40.5	-67.5	-28.4	-41.4	-18.4	-20.6	-28.9	-31.1
Refined oil demand	Heat/cool	-21.6	-36	-15.2	-22.1	-9.8	-11	-15.4	-16.6
Coal demand	Heat/cool	-1.5	-2.5	-1.1	-1.5	-0.7	-0.8	-1.1	-1.2
Tourism	Demand	10.3	-27.5	23.1	-25.4	11.6	20.9	-14.3	15.2
Extreme events	Capital	-3.7	-0.2	-1.9	-1.1	-0.6	-0.9	-0.7	-2.7
Sea-level rise	Capital	0	0	-0.1	-0.1	-0.1	0	0	-0.2
Health	Labour	0.2	-0.1	-0.8	-0.1	-3	-0.1	0	-2.8

Table 2. Immediate impacts by activity of the E1 scenario. Percent.

The impacts displayed in Table 2 represent impacts to the setors before adaptation takes place. In principle, they describe the situation that economic agents face after climate change has take place, but before they have taken any action to adapt. In practice, this is only a part of the story, however, because each of the 11 sectors in GRACE are aggregates of many sub sectors. Some of the adaptation that takes place within each sector should be included in the estimates in Table 2. For example, if climate change leads to a shift from crop yields to livestock in agriculture, this shift ought to be implicit in the impacts estimate because the production function is an expression for the maxium output for the sector aggretate at a given combination of prices.

4 Macroeconomic scenarios

In this study, we compare a set of macroeconomic indicators for the E1 scenario with and without climate change. We first run the E1 scenario without impacts of climate change, henceforth called the *reference scenario*. The economic growth in the reference scenario, which corresponds to IPCC's B2 scenario, varies considerably from region to region. GDP increases by four times in the lowest growing regions East Asia and Northerne America. The fastest growing region is India, where GDP grows by 100. Then, we run the *impacts scenario*, where the impacts function displayed in Figure 1 are implemented

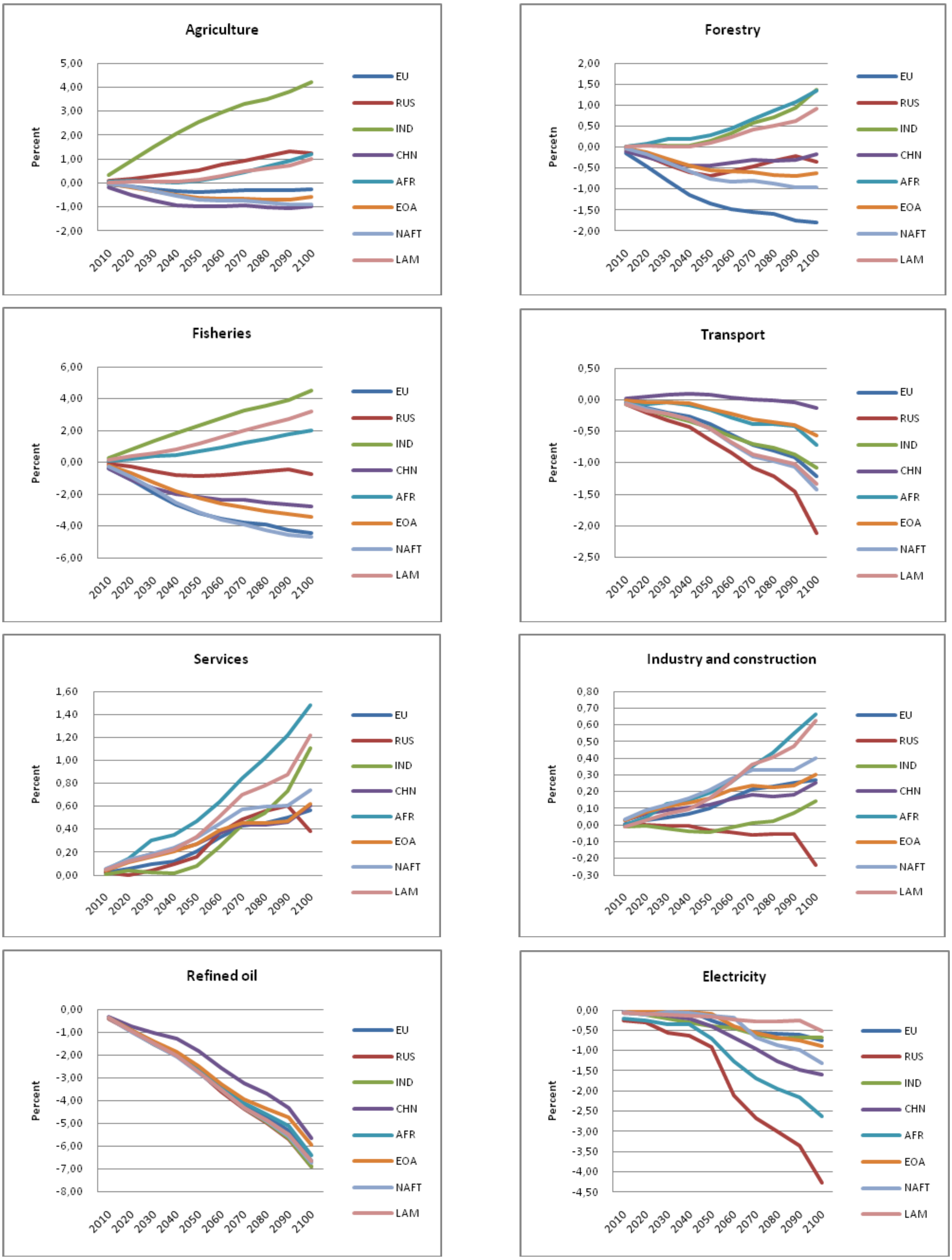

Figure 4. Percent change in price between the reference and the impact scenarios by sector and region 2010 - 2100

Adaptation is driven by changes in market prices spurred by the physical impact of the climate signal. Typically, a reduction in the availability of primary input factors will lead to an increase in the factor price, and thereby reduce the negative economic impact. The economic consequence of an increase the availability of primary input factors will be moderated in a similar manner. To the extent that the demand for goods and services responds directly on climatic changes, market prices will also be affected. The economic implications are not limited to the sectors that are directly affected by climate change, but have implications for all sectors because of market interaction. Figure 4 shows the percent change in prices between the impacts scenario and the reference senario by sector and region over the period 2010 to 2100. The base year is 2004, meaning that there is no difference between the two scenarios this year.

The service sector and the industry and construction sectors are affected directly by climate change through the general impacts to the economy, such as loss of capital because of natural disasters. For the sevice sector, a part, although relatively small, is also due to impacts on tourism. At the same time, these are dominating sectors of the economies in all regions. Even though the differences in prices between the two scenarios is small, the impacts on prices can be interpreted as general indicators to the impacts on the economies. The prices increase in most regions in both sectors. The exeptions are the industry and construction sectors in Russia and west Asia and India, where the prices decline slightly over the first half of the century. In the second half, the prices in Russia and West Asia continue to decline, while increasing slightly India when compared with the reference scenario.

The direct impact on the demand for energy carriers (coal, oil and gas) is generally negative, which leads to a decline in prices, summarized in the path for refined oil in Figure 4. The implications for electricity prices are more complex, being affected directly both on the supply and the demand sides, and indirectly through a change in the price of energy carriers. According to Figure 4, the development of the price differentials is quite different across regions, but nevertheless negative in all regions over the entire century. This indicates that efforts to cut emissions of greenhouse gases may become easier because of climate change itself. However, the price of electriciy declines by 4.5 percent of the century in Russia, while only 0.5 percent in Latin America. The impacts on the price of fuels, together with the impacts on tourism, affect also transport prices. In all regions except China prices are reduced as a consequence of climate change. In China, the change in prices are negligible during the coming century, according to these calculations.

The main impacts of climate change occur in the sectors where natural resources are being utilized. The deviations in product prices of these sectors can, to a certain extent, be predicted by the direct impacts of climate change to the sector in each region. The prices increase in the sectors and regions where the direct impacts are negative, and decrease where it is positive. In the agricultural and forestry sectors, the price increases in regions with negative impacts tend to be stronger than the price decreases in t regions with similar positive impacts. Moreover, the main part of the price differentials occur in the first half of the century in these two sectors.

The impacts on prices in each region make agents adapt to climate change. It may come as a result of an adjustment of the factor combination used to produce a unit of output, but will also come as a result of a change in trade patterns between sectors and regions. As a result, negative impacts in a region may be turned into an economic benefit, depending on the change in relative prices between sectors and regions. Figure 5 shows how the direct impacts of climate change to the resource based sectors change in the regions when the resulting change in trade patterns are taken into account. For Russia and West Asia and India a negative direct impact to agriculture is turned into a positive change in value added, or contribution to GDP, as a result of market responses, including changes in trade. In West Asia and Oceania the effect on agriculture is the opposite: a positive direct impact is turned into a negative change in the value added. In most regions, the direct impact on the productivity of land in agriculture is moderated considerably by the price and trade effects. For example, the increase in the productivity of land in Europe of more than 10 percent nearly diminishes when price and trade effects are taken into account. The exception is Africa and Central Asia, where a negative direct impact in 2100 at 2.4 percent increases to 3.4 percent when the market effects are included.

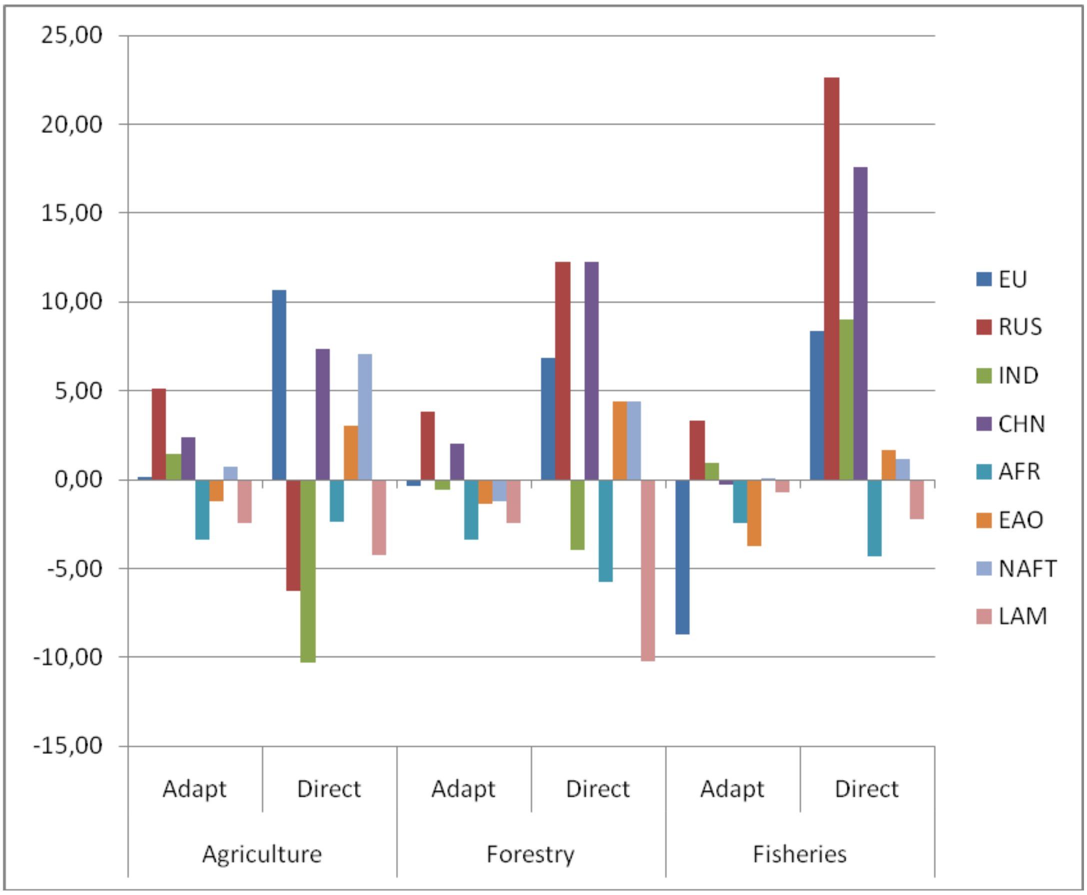

Figure 5. Percent change in value added with and without adaptation in resource based sectors by region in 2100.

In forestry, an increase in the biomass at more than 12 percent in Russia and China is reduced to less than 5 percent, and positiv impacts to the biomass is turned into a reduction in the value added of the sector in Europe, East Asia and Oceania and in North America, where the most significant negative impact on prices are found. In fisheries, where the uncertainties about the direct impacts are much larger than in most other sectors, estimates of substantial positive impacts in four regions are reduced considerably and even turned negative in some regions, in particular in Europe. This can be explained by a relatively large drop in prices in Europe.

The impacts to each sectors, which are being driven by the change in relative prices, are essential to the understanding of the impacts of climate change on the economic aggregates. The percent change in GDP by region is shown in Figure 6. GDP increases in China, North America, Russia with western Asia and Europe as a result of climate change, while, the remaining four regions face a loss. The impacts on GDP range from +2.5 percent in China to nearly – 4 percent in Africa and south Asia. Generally, the estimates confirm previous studies, which show that rich or expanding economes tend to gain from climate change, while poor economies loose. The exeption is India, which is a rapidly expanding economy, but with negative overall impacts throughout the century. However, the negative impact diminishes over the second half of the century, when the Indian economy grows rapidly in the scenario used in this study. In 2100, threre are practially speaking no impact on GDP in India. From Figure 4, we can explain this decline of impact to GDP by a substantial relative increase in the price attributed to cliamte change in the dominating sectors industry, construction and services.

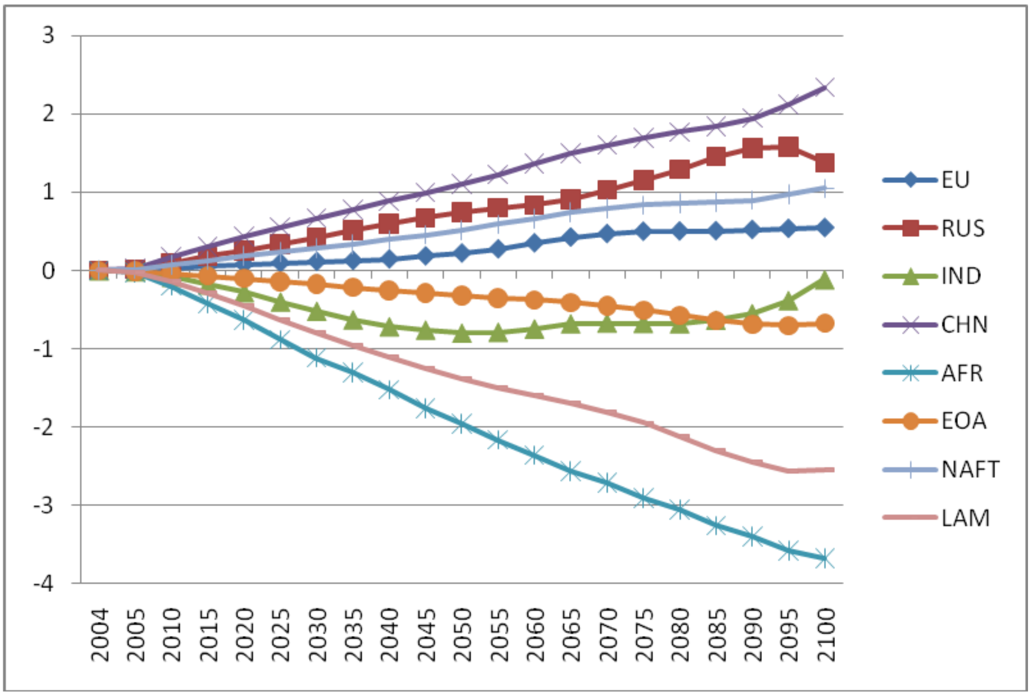

Figure 6. Percent change in GDP between reference and impact scenario by region

Africa and South Asia and Latin America turns out as the most negatively affected regions. In Africa and South Asia, GDP declines by nearly 4 percent under a +2 °C global warming over the coming century. This holds even though the mean temperature increases by less than +2 °C in the region. Also in Latin America the E1 scenario give a lower increase in the mean temperature than the global average, but the impact on the GDP is nevertheless -2.5 percent in the region. The explanations why these two regions are affected more badly than other regions are, to some extent, that an increase in the temperature from the present level is more negative to these warm regions than in many other regions. The most important is, however, that market responses and changes in trade patterns resulting from climate change are most disadvantageous to these regions.

The overall impacts on the world economy can be read from the change in the aggregated value added by sector, shown in Figure 7. First, it may be noted that the value added in manufacturing and services increase on the world scale. This can partly be explained by the pattern of the distribution of impacts between world regions, which suggest overall positive impacts at a modest increase in global mean temperature. The value added in the agrictultural sector also increases towards the end of the century, after a slight decrease in the first part. The main negative impacts are on the energy sectors, because of a lower demand for heating. This applies in particular to the gas sector. The result must, however, be interpreted with caution, because the consumption of gas is relatively small in the baseline scenario. A more realistic scenario may imply a higher share of gas in the baseline scenario, and a less sensitive demand for gas.

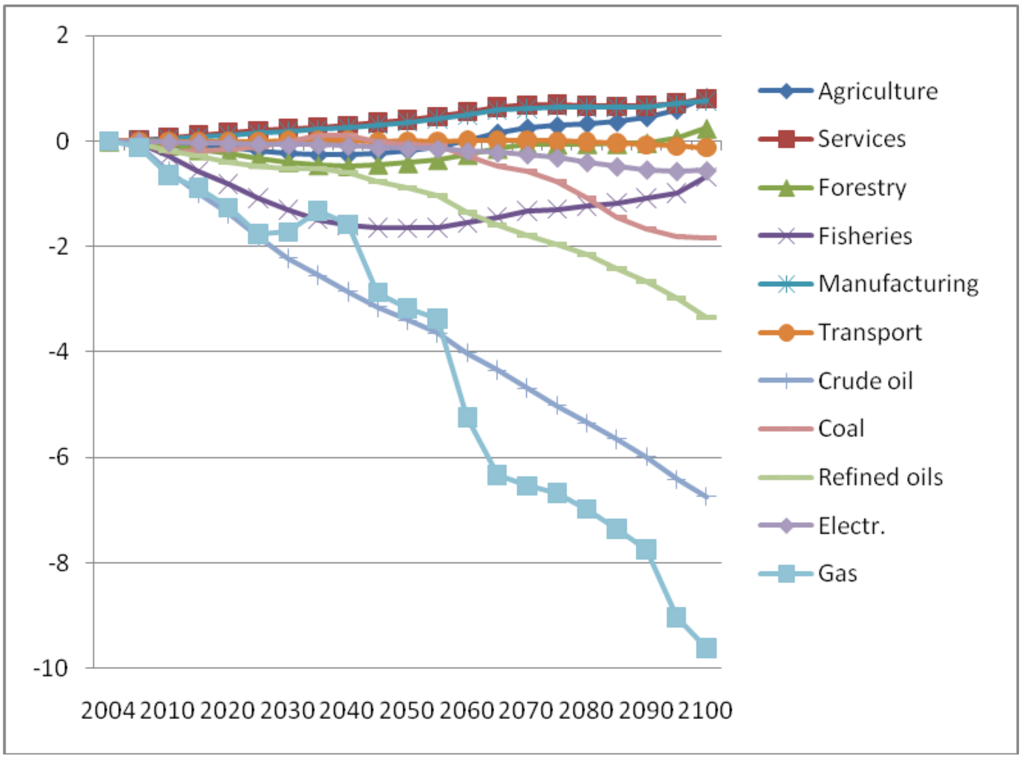

Figure 7. Percent change in world aggregated value added by sector.

The effect of changing market conditions is even more apparent in the forestry and fisheries sector, where a positive immmediate impacts in most regions is burned to negative impact in most regions when adaptation is taken into account. The main explanation is that a positive impact on the availability of the resource leads to a negative shift in prices. In many cases, the quantity effect is insufficient to compensate the price effect, and the value added in the sector therefore declines. Lower prices has a welfare effect though, and allows people to demand commodities and services from other sectors.

On the world scale, the economic impact of a +2 °C global warming scenario is -0.25 percent in 2100, if measured in terms of the world's GDP, according to the cacluations in this study. On the world scale, the term moderate may therefore be defended when talking about the economic impacts of climate change at this level of warming. A closer look at regions and sectors gives a different impression, however. Even for the huge regions addressed here, the negative impacts to some regions, and Africa and Latin America in particular, are notable, while four of the eight world regions experience positive impacts. With a further breakdown of regions, the variety of impacts would increase further, even at this low, and probably unavoidable, level of warming over the coming century. Worth to emphasise is that the region with the lowest income per capita today is the region with the strongest negative impact of climate change in the future.

Even though GDP is the most frequently used measure of welfare, changes in total consumption is usually considered a better one. In 2100 annual total consumption increases in Europe (0.7 percent), India (0.1 percent), China (1 percent), East Asia and Oceania (0.3 percent) and in North America (0.1 percent) in the climate impacts scenario. Consumption declines in Russia (-0.4 percent, Africa and South Asia (-3.4 percent) and Latin America (-2.2

percent). In other words, the pattern from the changes in GDP is somewhat changed because the change in value added is not equally captured by the consumers in terms of price changes in each region. For Russia and western Asia, this means that an increase in the value added is turn to a decline of consumption. In other regions the impacts on consumption is more positive or less negative than the impacts on GDP. This is partly due to the reduction in energy demand in the production sectors, which allows for more production of other goods and services.

5 Conclusions

The E1 scenario is a scenario that represents an acheivement of EUs target to limit climate change in global mean temperature by +2 °C in 2100. This report summarises impacts to the global economies of such a scenario. The basic conclusion is that the impacts are generally modest, although unevenly distributed across world regions. Rich and fast growing regions are expected to gain from the impacts described in this report, while the poorest regions bear the largest relative losses. Africa and south Asia exhibit the largest reduction in value added in 2100. However, the overall impact to the global economy is only slightly negative, when measured as the change in the world’s total GDP. The modest impact is partly due to positive impacts of climate change in resource based sectors, and partly because the demand for energy will decline. This has a positive impact on sectors which are not directly affected by climatic changes. Hence, manufacturing industries and services increase by nearly 1 percent over the next century if the temperature increase is limited to +2 °C. Adaptation and the resulting market responses plays an important role in assessing the impacts to sectors as well as to regions. We show that immediate impacts may turn from positive to negative or from negative to positive as a result of a change of prices in the wake of climate change. Price effects may also have important implications for the welfare effects. In Russia and western Asia, for example, the results indicate that while the value added increases as a result of climate change, consumption declines because of a change in the terms of trade.

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