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Climate Change Impacts: New Estimation and Modeling

By **Francesco Bosello**
Fondazione ENI Enrico Mattei (FEEM),
Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)
francesco.bosello@cmcc.it

Fabio Eboli
Fondazione ENI Enrico Mattei (FEEM),
Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)
fabio.eboli@cmcc.it

Roberta Pierfederici
Fondazione ENI Enrico Mattei (FEEM),
Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)

SUMMARY This report introduces the most recent outcomes of the CMCC/CIP division research activities aimed at constantly updating the input information to the CGE model. Specifically, it presents the results at the country level for all the most important EU economies as well the inclusion of impacts on fishing activity, the estimation of a convex in temperature damage function for adverse impact son crop yields, the estimation of a net loss function for impacts on health, the inclusion of non-market damages.

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Summary

1 INTRODUCTION

Computable General Equilibrium (CGE) models are increasingly used to assess costs and benefits associated with climate change impacts (for a partial list, see e.g. Deke *et al.* (2002), Darwin and Tol (2001), Bosello *et al.* (2007) on sea-level rise; Bosello *et al.* (2006) on health; Darwin (1999), Ronneberger *et al.* (2009) on agriculture; Berrittella *et al.* (2007), Calzadilla *et al.* (2008) on water scarcity; Bosello *et al.* (2009) on sea-level rise, agriculture, health, energy demand, tourism, forestry; Aaheim et al., (2010) on sea-level rise, agriculture, health, energy demand, tourism, forestry, fisheries, extreme events, energy supply; Ciscar, (2009) on sea-level rise, agriculture, tourism, river floods).

The appeal of such tools is the explicit modelling of market interactions between sectors and regions (inter industry and international trade flows are accounted for by databases relying upon input output Social Accounting Matrices). This allows tracing adjustment mechanisms in the whole economic system triggered by a "shock" concerning initially just one part of it (region or sector). Putting it differently, not only direct costs, but higher-order effects as well can be determined.

In this vein the Intertemporal Computable Equilibrium System (ICES) CGE model (Eboli *et al.*, 2010) has been developed and constantly enriched by the CMCC CIP division to analyze climate change impacts in the Mediterranean region. It has been applied in many EU FP 6 and 7 projects (SESAME, CIRCE, CLIMATECOST, MEDPRO, VECTORS) and tenders (DG ENV ClimWatAdapt, DG CLIMA EUAdaptStrat). Exploiting the knowledge originated by these research activities CMCC CIP division is also constantly updating the input information to the model. That is the estimation and then translation into economic terms of climate change impacts. This report introduces the most recent outcomes of this activity presenting results at the country level for all the most important EU economies.

Novelties with respect to the previous work, in addition to the country detail, are: the inclusion of impacts on fishing activity, the estimation of a convex in temperature damage function for adverse impact son crop yields, the estimation of a net loss function for impacts on health, the inclusion of non market damages.

2 IMPACTS ASSESSED, DATA AND SOURCES

The inputs to the CGE exercise derive from the results of a set of bottom-up partial-equilibrium exercises performed within different EU FP projects and other research initiatives referenced in Table 1.

Table 1: Impact types and source studies for the ICES CGE modelling exercise

CC IMPACT	Source Model	Reference project	Reference publication
Sea-level rise	DIVA	CLIMATECOST*	Vafeidis *et al.*, (2008)
Tourism flows	HTM	CLIMATECOST*	Bigano *et al.*, (2007)
Crops' productivity	ClimateCrop	CLIMATECOST*	Iglesias *et al.*, (2009); Iglesias *et al.*, (2010)
Residential energy demand	POLES	CLIMATECOST*	Criqui, (2001); Criqui *et al.*, (2009)
River floods	LISFLOOD	CLIMATECOST*	Van der Knijff *et al.*, (2010); Feyen, (2012)
Health	na	PESETA**	Ciscar et al. (2009)
Fishery		SESAME***	Cheung et al. (2010)
Ecosystem		na	Manne *et al.*, (2005); Warren (2006)

Notes:
* http://www.climatecost.cc/
** http://peseta.jrc.ec.europa.eu/
*** http://www.sesame-ip.eu/

These allow to physically quantify climate change consequences on sea-level rise, energy demand, agricultural productivity, tourism flows, river floods, health, fishery and ecosystem. All the studies, except those on floods and health, have a global coverage. The majority of them is based on a geographic information system. When this is the case, results have been aggregated to match the geographical resolution of the CGE exercise.

The major characteristics of the individual input studies are summarized below. The reader interested in further details is directly addressed to the specific researches.

Estimates of coastal land loss due to sea-level rise, derive from the FP7 project CLIMATECOST (http://www.climatecost.cc/) and are based upon the DIVA model outputs (Vafeidis et al., 2008). DIVA (Dynamic Integrated Vulnerability Assessment) is an engineering model designed to address the vulnerability of coastal areas to sea-level rise. The model is based on a world database of natural system and socioeconomic factors for world coastal areas reported with a spatial resolution of 5°. The temporal resolution is 5-year time steps until 2100 and 100-year time steps from 2100 to 2500. Changes in natural as well as socio-economic conditions of possible future scenarios are implemented through a set of impact-adaptation algorithms. Impacts are then assessed both in physical (i.e. sq. Km of land lost) and economic (i.e. value of land lost and adaptation costs) terms and are available for the regional detail of the ICES CGE model used in this exercise.

Changes in tourism flows induced by climate change derive from the FP7 project CLIMATECOST and stem from simulations based on the Hamburg Tourism Model (HTM) (Bigano et al., 2007). HTM is an econometric simulation model, estimating the number of domestic and international tourists by country, the share of international tourists in total tourists and tourism flows between countries. The model runs in time steps of 5 years. First, it estimates the total tourists in each country, depending on the size of the population and of average income per capita; then it divides tourists between those that travel abroad and those that stay within the country of origin. In this way, the model provides the total number of holidays as well as the trade-off between holidays at home and abroad. The share of domestic tourists in total tourism depends on the climate in the home country and on per capita income. International tourists are finally allocated to all other countries based on a general attractiveness index, climate, per capita income in the destination countries, and the distance between origin and destination.

Changes in average crops' productivity per world region derive from the FP7 project CLIMATECOST and are based upon the ClimateCrop model (Iglesias et al., 2009; Iglesias et al., 2010). Crop response depends on temperature, CO2 fertilisation and extremes. Water management practices are also taken into account. Integrating spatially all these elements the model estimates climate change impacts and the effect of the implementation of different adaptation strategies.

Responses of residential energy demand to increasing temperatures derives from the FP7 project CLIMATECOST and are based upon the POLES model (Criqui, 2001; Criqui et al., 2009). It is a bottom-up partial-equilibrium model of the world energy system extended within CLIMATECOST to include information on water resource availability and adaptation measures. It determines future energy demand and supply according to energy prices trend, technological innovation, climate impacts and alternative mitigation policy schemes. The present version of the model considers both heating and cooling degree-days in order to determine the evolution of demand for different energy sources (coal, oil, natural gas, electricity) over the time-horizon considered.

Data on climate change impacts on river floods derives from the FP7 project CLIMATECOST and are based upon results from the LISFLOOD model (Van der Knijff et al., 2009; Feyen, 2009). This is a spatially distributed hydrological model embedded within a GIS environment. It simulates river discharges in drainage basins as a function of spatial information on topography, soils, land cover and precipitation. This model has been developed for operational flood forecasting at European scale and it is a combination of a grid-based water balance model and a 1-dimensional hydrodynamic channel flow routing model. The LISFLOOD model can assess the economic loss in the EU27 countries per different macro-sectors: residential, agriculture, industry, transport and commerce together with the number of people affected. The role of climate change, and of economic growth in determining the final losses can be disentangled. Differently from other impact studies, LISFLOOD is an EU model, thus the Non-EU regions remain outside the scope of its investigation.

Climate-change induced changes in global catch potential used in this study derive from the FP6 SESAME project and are based upon Cheung et al. (2010). They applied an empirical model (Cheung et al. (2008a)) that predicts maximum catch potential depending upon primary production and distribution range of 1066 species of exploited fish and invertebrates. Distribution of each species on a 30' latitude 30' longitude grid is derived from an algorithm (Close et al. 2006) including the species' maximum and minimum depth limits, northern and southern latitudinal range limits, an index of association with major habitat types and known occurrence boundaries as input parameters. Future changes in species distribution are simulated by using a dynamic bioclimate envelope model (Cheung et al., 2008b, 2010). First, the model identified species' preference profiles with environmental conditions. Then, these are linked to the expected carrying capacity in a population dynamic model. The model assumes that carrying capacity varies positively with habitat suitability of each spatial cell. Finally, aggregating spatially and across species, the related change in total catch potential can be determined.

Health impacts of climate change in the EU derive from the PESETA study (Ciscar et al., 2009). Heat and cold-related (cardiovascular and respiratory) additional or avoided deaths per thousand for different degrees of warming (1 °C, 2.5 °C, 3.9 °C and 4.1 °C above pre industrial levels) in five European regions (British Isles, Northern Europe East, Northern Europe West, Southern Europe East and Southern Europe West) are estimated. The study emphasizes that the decrease in cold related mortality outweighs the increase in heat related mortality however at a diminishing rate with increase in temperature. Therefore the net reduction in mortality is higher in lower temperature increase than in high temperature increase scenarios. To match the PESETA geographical detail with the higher detail of the present study it is assumed that the change in mortality rate remains the same across those countries part of the same PESETA EU macro-region.

Table 2. Heat-related and Cold-related mortality changes - projections for 2 °C and 4 °C temperature increase

	2 °C			4 °C		
	Heat-related	Cold-related	Net effect	Heat-related	Cold-related	Net effect
Austria	13.6	-16.0	-2.4	31.0	-38.0	-7.0
Belgium	9.6	-11.2	-1.6	21.5	-25.5	-4.0
Czech Republic	13.6	-16.0	-2.4	31.0	-38.0	-7.0
Denmark	6.4	-6.4	0	12.0	-12.0	0
Finland	6.4	-6.4	0	12.0	-12.0	0
France	13.6	-16.0	-2.4	31.0	-38.0	-7.0
Germany	9.6	-11.2	-1.6	21.5	-25.5	-4.0
Greece	8.8	-22.4	-13.6	18.0	-50.5	-32.5
Hungary	13.6	-16.0	-2.4	31.0	-38.0	-7.0
Ireland	3.2	-21.6	-18.4	7.5	-52.5	-45.0
Italy	8.8	-22.4	-13.6	18.0	-50.5	-32.5
Netherlands	9.6	-11.2	-1.6	21.5	-25.5	-4.0
Poland	9.6	-11.2	-1.6	21.5	-25.5	-4.0
Portugal	8.8	-22.4	-13.6	18.0	-50.5	-32.5
Spain	8.8	-22.4	-13.6	18.0	-50.5	-32.5
Sweden	6.4	-6.4	0	12.0	-12.0	0
United Kingdom	3.2	-21.6	-18.4	7.5	-52.5	-45.0
RoEU	9.6	-16.8	-7.2	20.5	-38.0	-17.5

Note: change in death rate per 100,000 population per year. Positive sign means a rise in mortality. A negative sign represents a decrease.
Source: Peseta Project (Ciscar et al., 2009)

To estimate the non-market ecosystem loss component, a Willingness To Pay (WTP) approach has been used. In principle, an elicited WTP to avoid a given loss in ecosystems should encompass all their non-market values and therefore reasonably approximate the lost value in case they are not protected1. This is for instance the methodology used in the MERGE model (Manne et al., 2005) where the WTP to avoid - and thus the ecosystem losses related to - a 2.5°C temperature increase above pre-industrial levels is 2% of GDP when per capita income is above $ 40,000 US 1990. The 2% figure was the US EPA expenditure on environmental protection in 1995. The implicit (and heroic) assumptions are that the WTP is reasonably close to what actually paid and that what paid is roughly sufficient to preserve ecosystems and their services in a world warming moderately. Given the focus of the present research, the proxy for WTP/ecosystem damages in the EU is the EU country expenditure on environmental protection (Table 4). This value encompasses activities such as protection of soil and groundwater, biodiversity and landscape, protection from noise, radiation, along with more general research and development, administration and multifunctional activities. Differently from Manne et al., (2005), the present study is slightly more conservative and assumes that the observed expenditure relates to protection against 2°C warming. Then to link average per capita environmental expenditure and per capita income in non EU countries the logistic function proposed by Warren et al. (2006) is used:

[1] In practice the limitations of this approach are well known and many criticisms are raised against WTP and other stated preference approaches. However, the usual response is that in the end, they represent the only viable way to capture existence values.

$$WTP_{n,t|t=2.°C} = \gamma \Delta T^{\varepsilon}{}_{n,t|t=2°C} \frac{1}{1+100e^{(-0.23*GDPn,t|t=2°C/POPn,t|t=2°C)}} \quad (1)$$

To calibrate γ the EU is the reference. γ is thus set to give exactly 0.6% of GDP when per capita income is $28,780 (and ΔT=2°C) which are respectively 2001 total EU environmental expenditure and per capita income.

Table 3. WTP for ecosystems protection related to a temperature increase of 2°C (% of regional GDP)

Austria	0.76
Belgium	0.58
Czech Republic	0.62
Denmark	0.66
Finland	0.58
France	0.54
Germany	0.60
Greece	0.67
Hungary	0.70
Ireland	0.88
Italy	0.86
Netherlands	1.52
Poland	0.30
Portugal	0.57
Spain	0.35
Sweden	0.34
United Kingdom	0.49
RoEU	0.21
RoOECD	0.43
CHIND	0.06
TE	0.10
RoW	0.01

As shown, the reference WTP value used for rich countries crucially determines the final results. For instance Nordhaus and Boyer (2000) estimate an annual willingness to pay to avoid the disruption of settlements and ecosystem associated with a 2.5°C increase in global average temperature to about $67 per household (2006 values). Hanemann (2008) revised Nordhaus and Boyer's estimates for the United States almost doubling them to $120 (in 2006 values). Using the EU values as the benchmark for calculations gives lower damages than in the MERGE model, but anyway higher than in Hanemann (2008) and Nordhaus and Boyer (2000). This also emphasises the large uncertainty when assigning an economic value to non-market impacts.

Table 3 also demonstrates that a WTP approach tends to produce higher evaluations for non-market ecosystem losses in high-income countries, although ecosystem/biodiversity richness is highly concentrated in developing countries.

Among all the above mentioned studies, those deriving from the CLIMATECOST project estimate impacts which are roughly consistent with a +2 °C warming in 2050. The same holds for the impact assessment on fishery performed within the SESAME project. This is indeed the warming estimated in the A1B IPCC SRES scenario, reference for both projects. The Health analysis in PESETA addresses impacts for different degrees of warming: 1 °C, 2.5 °C, 3.9 °C, and 4.1 °C. The ecosystem impact assessment refers originally to a 2 °C warming.

In the present analysis impacts are economically assessed for a 2 °C and 4 °C warming scenarios. For simplicity both are assumed to occur in 2050.

In the case of flooding, sea-level rise, tourism, and health, the respective impact estimations are available also for the 4 °C temperature increase. In the case of ecosystem changes the reduced-form formula used allows a straightforward computation of losses for the 4 °C. Unluckily no information are currently available from the surveyed studies to quantify 4 °C impacts on energy demand and crops productivity. In the first case it is for simplicity assumed that the relation between temperature and energy demand is linear. Therefore impacts double in the 4 °C scenario. Concerning agriculture, it is assumed that when impacts on crops' productivity in the 2 °C scenario are negative, they remain negative also in the 4 °C and perfectly proportional to the temperature increase. When they are positive, they still increase linearly with temperature, but just until a temperature threshold of 3 °C and then, albeit remaining positive, they start to decline. The 3 °C temperature threshold derives from inspection of the literature placing between 2.5 °C and 3 °C the peak CO_2 fertilization effect which can benefit especially crops at the medium-high latitudes, where EU region is by and large located.

3 CLIMATE CHANGE IMPACTS IMPLEMENTATION INTO THE ICES-CGE MODEL

To determine with a CGE model the economic consequences of the different impacts assessed, these need to be firstly translated into changes in economic variables existing in the model.

Therefore:

Land losses to sea-level rise have been modelled as percent decreases in the stock of productive land and capital by country/region. Both modifications concern variables, land and capital stocks, which are exogenous to the model and therefore can be straightforwardly implemented. As information on capital losses are not available, we assume that they exactly match land losses[2].

[2] We could have avoided including capital losses, however they are an important part of sea-level rise costs therefore we prefer to have a rough even though arbitrary estimation of this component rather than none. We are not including displacement costs.

Changes in regional households' demand for oil, gas and electricity are modelled as changes in households' demand for the output of the respective industries.

Changes in tourists' flows are modelled as changes in (re-scaled) households' demand addressing the market services sector, which includes recreational services. In addition, changes in monetary flows due to variations in tourism demand are simulated through a direct correction of the regional incomes.

Impacts on agriculture are modelled through exogenous changes in land productivity. Due to the nature of source data, land productivity varies by region, but is uniform across all crop types present in ICES.

With reference to river floods, to account for economic damages affecting the agricultural sector we impose an equal-value reduction in regional land stock, while, when other sectors are involved, an equal-value reduction in sectoral capital productivity. With regard to people affected, this is accommodated in the model by reduction in labour productivity. This is computed relating people affected to the total regional population and assuming that the average loss of working days is one week.

Changes in labour productivity is also the channel to account for health impacts. Lower mortality translates in an increased labour productivity which is one on one proportional to the change in the total population. The underlying assumption is that health impacts affect active population, disregarding the age characteristic of cardiovascular and respiratory diseases.

Impacts on fishery are modelled as a decreased productivity of the natural resource input used by the fishing sector. In ICES there are four sectors using natural resources as a production factor: coal, oil, gas, timber and fishery.

Impacts on ecosystems are modelled as a loss in the physical capital stock. In ICES the capital stock does not enter directly in the production function, rather capital services do. Nonetheless in the model there is a one on one relation between capital stock and capital services as any change in the former implies an equal change in the latter. The assumption made thus, is that ecosystems offer a set of support services to the production activity which are all embedded in capital services. When ecosystem deteriorates, its production support services deteriorates and thus (through deterioration of the capital stock) capital services deteriorate.

As can be noted, two broad categories of impacts can be distinguished in the abovementioned list. The first, relates to the supply-side of the economic system, affects exogenous variables in the model - stock or productivity of primary factors - and thus can be easily accommodated. Impacts on sea-level rise, agriculture, floods, ecosystems, fishery and human health belong to this category. They do not require any substantial change in the basic structure of the model to be implemented.

The second affects changes in the demand side. Impacts on tourism and on energy consumption are of this kind. This implies to intervene on variables which are endogenous to (i.e. output of) the model. The technicality involved is more complex than in the case of exogenous variables and consists in the following procedure. The computed percentage variations in the demands have been imposed as exogenous shifts in the respective demand equations. The implicit assumption is that the starting information refers to partial equilibrium assessment thus with all prices and income levels constant. The model is then left free to determine the final demand adjustments. Modification in demand structure imposes however to comply with the budget constraint, so we compensated the changed consumption of energy and tourism services with opposite changes in expenditure for all the other commodities.

Tables 5a to 6c summarize the results of all this procedure presenting the computed inputs for the ICES CGE model necessary to run the climate-change simulations.

Table 4a. Demand-side impacts: 2° C temperature increase, ref. year 2050

	Energy			Tourism	
	Gas	*Oil Products*	*Electricity*	*Mserv Demand*	*Expenditure**
Austria	-0.13	0.58	-0.12	1.61	1.70
Belgium	-0.16	0.46	0.15	-0.17	-0.49
Czech Republic	0.16	1.47	-2.62	0.47	0.15
Denmark	-0.48	0.07	2.95	1.12	0.88
Finland	-1.32	-0.17	-0.44	5.15	2.94
France	0.34	1.12	0.14	-0.43	-8.15
Germany	-0.69	-0.07	-0.25	1.26	12.65
Greece	3.48	-0.14	11.42	-2.13	-3.70
Hungary	2.50	3.83	6.92	-0.43	-0.55
Ireland	-0.88	-0.02	1.17	-0.12	-0.12
Italy	-0.19	0.70	15.22	-0.96	-21.69
Netherlands	-0.47	0.36	2.20	0.28	0.55
Poland	-0.30	0.60	-1.67	0.71	0.65
Portugal	-0.17	0.31	10.91	-2.72	-4.08
Spain	-0.40	0.31	17.52	-2.26	-24.71
Sweden	-1.42	-0.27	0.59	4.00	4.95
United Kingdom	-0.49	0.42	0.44	1.28	14.14
RoEU	0.28	1.27	2.17	0.28	0.49
RoOECD	0.88	1.60	6.94	3.04	308.81
CHIND	2.24	2.83	6.52	-2.81	-104.01
TE	0.17	2.18	-2.94	4.66	35.02
RoW	-0.36	0.89	9.32	-2.40	-215.44

Note: *US$ billion

Table 4b. Supply-side impacts (1): 2° C temperature increase, ref. year 2050

	SLR	Fishery	Agriculture	Ecosystems	Health
	Land and K Stock	*Fish Stock*	*Land productivity*	*K Stock*	*L Productivity*
Austria	0	*n.a. -> 0*	7.63	-0.13	0.0024
Belgium	-0.00390	0.21	-3.79	-0.12	0.0016
Czech Republic	0	*n.a. -> 0*	-3.95	-0.10	0.0024
Denmark	-0.00369	7.87	20.35	-0.15	0
Finland	-0.00008	14.86	31.33	-0.11	0
France	-0.01929	0.27	-5.36	-0.11	0.0024
Germany	-0.01706	*n.a. -> 0*	-0.77	-0.12	0.0016
Greece	-0.00145	0.14	-20.88	-0.13	0.0136
Hungary	0	*n.a. -> 0*	3.33	-0.13	0.0024
Ireland	-0.00540	-1.43	-2.11	-0.22	0.0184
Italy	-0.00552	-12.37	-9.27	-0.19	0.0136
Netherlands	-0.13763	7.79	0.08	-0.29	0.0016
Poland	-0.00040	7.65	-1.76	-0.07	0.0016
Portugal	-0.01128	3.80	-15.70	-0.11	0.0136
Spain	-0.00147	-6.49	-17.71	-0.06	0.0136
Sweden	-0.00007	10.96	28.59	-0.08	0
United Kingdom	-0.00344	1.84	5.12	-0.12	0.0184
RoEU	-0.00515	2.28	-0.90	-0.04	0.0072
RoOECD	-0.15174	6.34	-2.87	-0.08	*n.a. -> 0*
CHIND	-0.13254	-2.02	0.30	-0.02	*n.a. -> 0*
TE	-0.09475	2.95	-4.14	-0.07	*n.a. -> 0*
RoW	-0.11420	-4.21	-7.30	0.00	*n.a. -> 0*

Table 4c. Supply-side impacts (2): 2° C temperature increase, ref. year 2050

	Floodings					
	Agriculture (land stock)	*Residential (K prod.)*	*Transport (K prod.)*	*Commerce (K prod.)*	*Industry (K prod.)*	*Population (L prod.)*
Austria	-0.0091	-0.6359	-0.0057	-0.0008	-0.0028	-0.0012
Belgium	-0.0157	-0.0483	-0.0035	-0.0055	-0.0193	-0.0013
Czech Republic	-0.0008	-0.1122	-0.0022	-0.0033	-0.0093	-0.0005
Denmark	0.0000	0.0004	0.0000	0.0000	0.0001	0.0000
Finland	-0.0099	-0.2128	-0.0073	-0.0050	-0.0078	-0.0011
France	-0.0015	0.0188	0.0008	0.0002	0.0009	-0.0005
Germany	0.0017	0.0048	0.0005	0.0001	0.0007	-0.0002
Greece	-0.0026	-0.0308	-0.0005	-0.0003	-0.0022	-0.0003
Hungary	-0.0082	-0.2972	-0.0073	-0.0018	-0.0054	-0.0003
Ireland	-0.0120	-0.2055	-0.0061	-0.0005	-0.0003	-0.0002
Italy	-0.0147	-1.3404	-0.0031	-0.0010	-0.0047	-0.0009
Netherlands	-0.0090	-0.0212	-0.0009	-0.0001	-0.0003	-0.0011
Poland	0.0053	0.0328	0.0006	-0.0002	-0.0007	0.0000
Portugal	-0.0118	-0.0108	-0.0012	-0.0001	-0.0004	-0.0001
Spain	-0.0150	-0.1057	-0.0019	-0.0014	-0.0041	-0.0004
Sweden	-0.0020	-0.0632	-0.0014	-0.0005	-0.0018	-0.0001
United Kingdom	-0.0379	-0.3779	-0.0113	-0.0034	-0.0248	-0.0010
RoEU	-0.0067	-0.3524	-0.0060	-0.0033	-0.0085	-0.0009
RoOECD	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
CHIND	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
TE	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
RoW	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0

Table 5a. Demand-side impacts: 4° C temperature increase, ref. year 2050

	Energy			*Tourism*	
	Gas	*Oil Products*	*Electricity*	*Mserv Demand*	*Expenditure**
Austria	-0.27	1.21	-0.26	4.24	6.46
Belgium	-0.34	0.95	0.31	0.37	0.75
Czech Republic	0.33	3.07	-5.48	2.06	0.98
Denmark	-0.99	0.15	6.17	2.87	3.25
Finland	-2.76	-0.36	-0.91	12.74	10.47
France	0.71	2.34	0.29	-0.01	-0.37
Germany	-1.45	-0.14	-0.52	3.30	47.52
Greece	7.26	-0.29	23.83	-3.39	-13.45
Hungary	5.21	7.99	14.44	-0.30	-0.89
Ireland	-1.84	-0.04	2.44	0.27	0.19
Italy	-0.39	1.46	31.76	-1.30	-66.82
Netherlands	-0.98	0.76	4.60	1.17	3.30
Poland	-0.63	1.25	-3.49	1.49	1.96
Portugal	-0.35	0.65	22.78	-3.98	-13.59
Spain	-0.84	0.65	36.57	-3.08	-76.65
Sweden	-2.96	-0.57	1.23	9.65	17.18
United Kingdom	-1.01	0.87	0.93	2.65	41.93
RoEU	0.58	2.66	4.53	1.82	4.66
RoOECD	1.83	3.34	14.49	7.22	1054.34
CHIND	4.68	5.91	13.61	-4.37	-367.77
TE	0.35	4.55	-6.13	14.61	158.01
RoW	-0.75	1.87	19.45	-3.98	-811.44

Note: * US$ billion

Table 5b. Supply-side impacts (1): 4° C temperature increase, ref. year 2050

	SLR	*Fishery*	*Agriculture*	*Ecosystems*	*Health*
	Land and K Stock	*Fish Stock*	*Land productivity*	*K Stock*	*L Productivity*
Austria	0	*n.a. -> 0*	6.51	-0.52	0.0070
Belgium	-0.01351	0.44	-9.29	-0.47	0.0040
Czech Republic	0	*n.a. -> 0*	-9.70	-0.38	0.0070
Denmark	-0.01164	16.42	17.35	-0.59	0
Finland	-0.00026	31.01	26.72	-0.44	0
France	-0.09245	0.57	-13.14	-0.46	0.0070
Germany	-0.05916	*n.a. -> 0*	-1.89	-0.49	0.0040
Greece	-0.14124	0.29	-51.19	-0.52	0.0325
Hungary	0	*n.a. -> 0*	2.84	-0.54	0.0070
Ireland	-0.45826	-2.99	-5.18	-0.90	0.0450
Italy	-0.02250	-25.81	-22.72	-0.75	0.0325
Netherlands	-0.50368	16.26	0.07	-1.17	0.0040
Poland	-0.06546	15.96	-4.33	-0.26	0.0040
Portugal	-0.06294	7.93	-38.49	-0.44	0.0325
Spain	-0.02724	-13.54	-43.43	-0.24	0.0325
Sweden	-0.00019	22.86	24.38	-0.31	0
United Kingdom	-0.35276	3.83	4.36	-0.46	0.0450
RoEU	-0.08152	4.75	-2.20	-0.15	0.0175
RoOECD	-0.38697	13.24	-7.03	-0.34	*n.a. -> 0*
CHIND	-0.63032	-4.21	0.25	-0.06	*n.a. -> 0*
TE	-0.27001	6.15	-10.14	-0.28	*n.a. -> 0*
RoW	-0.24184	-8.78	-17.89	-0.02	*n.a. -> 0*

Table 5c. Supply-side impacts (2): 4° C temperature increase, ref. year 2050

	Supply-side Impacts (2)					
	Floodings					
	Agriculture (land stock)	*Residential (K prod.)*	*Transport (K prod.)*	*Commerce (K prod.)*	*Industry (K prod.)*	*Population (L prod.)*
Austria	-0.0198	-1.3512	-0.0122	-0.0019	-0.0068	-0.0022
Belgium	-0.0436	-0.1013	-0.0065	-0.0097	-0.0343	-0.0019
Czech Republic	-0.0033	-0.2978	-0.0052	-0.0070	-0.0198	-0.0009
Denmark	-0.0043	-0.0311	-0.0006	-0.0001	-0.0004	-0.0001
Finland	-0.0182	-0.4114	-0.0144	-0.0084	-0.0132	-0.0017
France	-0.0149	-0.1363	-0.0088	-0.0017	-0.0084	-0.0012
Germany	-0.0053	-0.0066	-0.0006	-0.0001	-0.0008	-0.0004
Greece	-0.0056	-0.0941	-0.0014	-0.0007	-0.0055	-0.0004
Hungary	-0.0174	-0.5824	-0.0117	-0.0032	-0.0093	-0.0007
Ireland	-0.0354	-0.6148	-0.0180	-0.0015	-0.0010	-0.0006
Italy	-0.0306	-2.9543	-0.0070	-0.0022	-0.0105	-0.0014
Netherlands	-0.0623	-0.1097	-0.0044	-0.0010	-0.0054	-0.0020
Poland	0.0105	0.0780	0.0017	-0.0002	-0.0006	0.0001
Portugal	-0.0100	-0.0189	-0.0015	-0.0002	-0.0008	-0.0001
Spain	-0.0157	-0.1251	-0.0023	-0.0017	-0.0050	-0.0005
Sweden	-0.0026	-0.0952	-0.0029	-0.0014	-0.0048	-0.0001
United Kingdom	-0.1003	-1.0211	-0.0288	-0.0081	-0.0578	-0.0022
RoEU	-0.0086	-0.4613	-0.0082	-0.0045	-0.0116	-0.0011
RoOECD	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
CHIND	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
TE	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0
RoW	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0	n.a. -> 0

Form a quick inspection of the inputs, sea-level rise and ecosystem effects entail unambiguous negative impacts in all the countries/regions considered; the same for flooding; whereas net health impacts of climate change are everywhere positive. Tourism is positively affected by climate change in Northern European countries, where warming increases climatic attractiveness, and negatively affected in Southern European countries, becoming “too hot”. Both climate change consequences on crops and the fish stock productivity are mixed depending on the country. In general crops productivity tend to benefit from climatic change, trough positive temperature and CO2 concentration-fertilization effect, in Centre-North EU and to decrease in the South. Reduced catches affect mainly Mediterranean countries, primarily Italy and Spain, whereas Greece is almost unaffected. On the contrary Northern EU fishery is apparently advantaged by climatic change. Electricity consumption with the only exceptions of Austria, Finland, Czech Republic, Germany and Poland is expected to increase in the EU for the prevalence of a cooling effect, i.e. more air conditioning in the summer. In gas and partly oil product demand there is a prevalence of “minus signs” as a consequence of the warming effect: less energy used to warm in the winter. Note that when demand side impacts are concerned (tourism and energy), these imply by construction a re-composition rather than a shrinking/expansion of agents demand as their total budget is unaltered. Accordingly, it is very difficult to assess since the beginning if the final consequences are positive or negative for the economic system. To do so a CGE analysis is needed which is the focus of the future work.

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