

Climate change impacts in the Mediterranean: a CGE analysis

F. BOSELLO^{*,^}, F. EBOLI^{*,§}, R. PARRADO^{*,°}

* FEEM (Fondazione Eni Enrico Mattei), www.feem.it

^ University of Milan, www.unimi.it

§ CMCC (Euro-Mediterranean Center on Climate Change), www.cmcc.it

° University of Venice, www.unive.it

Corresponding author:

Francesco Bosello
Fondazione Eni Enrico Mattei
San Giorgio Maggiore
30124 Venice
ITALY
E-mail: francesco.bosello@feem.it
Phone: 041-2700449
Fax 041-2700413

Abstract

This report presents an analysis developed by ICES, a recursive-dynamic Computable General Equilibrium (CGE) model, applied to assess economically a set of climate change impacts. The analysis has been developed within the EU FP6 Circe project.

More specifically, the present analysis considers three climatic impacts estimated for the IPCC A1b SRES scenario: land and capital losses due to the increase in sea level, changes in households' energy demand (both for heating and cooling purposes) as a response to the increasing temperature and changes in tourism services demand as a response to changes in country climatic attractiveness.

In 2050, jointly considered, these impacts can induce a loss of the 1% of GDP in the Mediterranean area as a whole. Particularly adversely affected are Cyprus and Albania (-1.6% and -2.4% of GDP respectively). It also emerges that Northern-Mediterranean are clearly less vulnerable than the Southern-Mediterranean countries. Among the former the average loss in 2050 is the 0.5% of GDP, while among the latter this more than doubles. In terms of impact types, tourism and sea-level rise are the most threatening, while GDP impacts induced by demand re-composition of energy use is less of an issue and often positive

Climate change impacts trigger many indirect effects. Energy prices decline compared to the baseline (-7% oil and oil products, -4% gas in 2050), as the net effect of the GDP decrease worldwide compresses particularly energy demand. Industry and services' prices remain roughly constant at the baseline levels. Agricultural prices, affected by the decrease in available productive land, increase especially after 2025 (the maximum increase shown by rice with a +1.5% in 2050) when sea-level rise becomes more appreciable.

This has an implication on international competitiveness as typically measured by terms of trade effects. North Africa and Middle East countries, as energy exporters are particularly damaged, while EU countries which are heavy energy importers and food exporters benefit. These "second order" effects thus hamper the negative impacts in the Southern and Eastern Mediterranean countries, but smoothen that in the Euro-Mediterranean ones.

Consistently with the GDP contraction worldwide, at the industry level negative signs prevail. Within the Mediterranean countries, sectoral production is adversely affected mainly in the market services and in the energy sectors. The first are hit negatively by the reduction in tourism demand, the second by the world reduction in energy demand. However electricity production tends often to increase. This is fostered by the increased space cooling demand from households that counterbalances the decrease in aggregated demand. Food production fostered by higher prices tend to increase in the Mediterranean area.

Some fundamental qualification of our results are in order: the GDP impacts shown are calculated only on a sub set of potential adverse effects of climate change (possible consequences of increased intensity and frequency of extreme weather events and of biodiversity losses for instance are not included); irreversibilities or abrupt climate and catastrophic changes to which market driven adaptation can be only limited are neglected; costless and instantaneous market adjustments are assumed. In the light of all that, what proposed here should be taken just as the lowest possible bound for climate change costs.

1. Introduction and background

The CIRCE (Climate Change and Impact Research: the Mediterranean Environment) project has been conducted within the 6th EU Framework Programme developed with the aim to make an integrated assessment of current and future climate change impacts in the Mediterranean area. It has involved more than 60 research institutes with different skills on climate scenarios development, physical impacts quantification and socio-economic assessment. Main findings have been collected in the final RACCM (Regional Assessment of Climate Change in the Mediterranean) report that will be released in next months.

Within the Circe project, one main objective has been the socio-economic assessment of climate change impacts on the Mediterranean region. The analysis presented here reports the attempt to go beyond the direct economic costs or gains possibly induced by those impacts aiming to determine their final implications in terms of growth and wealth for the economic systems affected. The methodology proposed offers a description of the social and economic reactions triggered within economic systems by climatic impacts and their effect on the overall economic performance, including intersectoral and international market dynamics.

To do so a systemic perspective is necessary where markets and economic systems are linked and interact. One possible investigation approach and modelling tool allowing to make these concepts operational is Computable General Equilibrium (CGE) modelling.

Historically, CGE models were first developed to analyse international trade policies and to a lesser extent public sector policies. But, soon, due to their great flexibility, they started to be applied to environmental taxation and climate change impact assessment. The peculiar feature of CGE models is market interdependence. All markets are linked, as factors of production are mobile between sectors and internationally. Therefore, each change in relative prices induces a cost-minimizing input reallocation or utility maximizing consumption readjustment in the entire economic system. Eventually, CGE models can capture and describe the propagation mechanism induced by a localised shock onto the whole context. The final impact on national GDPs summarises these “higher order” effects which can be very different from the initial “first order” impacts.

In this vein a growing literature assessed the higher order cost of single impacts' categories. For a very 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; Tzigas *et al.* (1997), Darwin (1999), Ronneberger *et al.* (2009) on agriculture; Berrittella *et al.* (2007), Calzadilla *et al.* (2008) on water scarcity.

A limited number of exercises though used static or dynamic CGE models to analyze the final effect on GDP or on welfare of a larger range of impacts jointly considered. Eboli *et al.* (2010) estimated the compounded GDP effects of climate-change impacts on sea-level rise, agriculture, health, energy demand, tourism; Bosello *et al.* (2009) on sea-level rise, agriculture, health, energy demand, tourism, forestry; Aaheim *et al.* (2009) 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.

Nevertheless, among the studies quoted only Bosello *et al.* (2009) report results for the Mediterranean specified in a Northern, Southern and Eastern part. In the other studies, the

Mediterranean is not detailed as a region. At best indications are offered for the Euro-Mediterranean countries.

The exercises differ in quality and quantity of the impacts considered, in the model baselines and specifications, and in the geographical detail. Therefore the robustness of results is particularly informative. According to all studies Northern Europe is expected to gain from climate change (the highest gain is reported by Bosello *et al.* (2009) with a +1.8% of GDP in 2050), while in the Mediterranean Europe small losses or slight gains are expected (the highest losses of the -0.25% of welfare, equivalent variation, are reported by Ciscar *et al.* (2009); gains of the 0.2% of GDP by Bosello *et al.* (2009)). Losses are however moderate for temperature increases below the 2.5°C; they can be rather relevant, for quite extreme temperature increase scenarios (-1.4% of welfare according to Ciscar (2009) for +5.4°C of temperature increase). The literature, in general, points out a relatively low climate change vulnerability of the EU region compared to countries located at lower latitudes even though this is higher in its Southern part.

Both Bosello *et al.* (2009) and Aaheim *et al.* (2009) emphasize the role of market driven adaptation. For instance, for a 2°C temperature increase scenario, climate change impacts would entail a direct cost ranging from the 0.4% to the 2.3% of GDP. This is a combination of a reduction in agricultural productivity, lower tourism inflow, contraction of the energy sector and land loss to sea-level rise. But when considering economic agents and markets adjusting their behaviours in reaction to economic signals induced by climate change, the final impact on GDP is much smaller. In Bosello *et al.* (2009) the dynamics of agricultural and energy markets are sufficient to turn losses into gains. The lower energy demand induced in Europe and worldwide by higher temperatures reduces energy prices. This is particularly beneficial for a heavy energy importer like the EU. Similarly, gains in trade are associated to higher prices of agricultural commodities consequent the decline in crops' productivity. Mediterranean EU can thus export relatively more as its agricultural sector is damaged, but less than that of other countries, and at higher prices. This is a long-term effect though. Indeed these market forces are not sufficient to outweigh negative climate change effects before 2030.

Turning to the other Mediterranean Regions for which specific assessments are even scarcer, North Africa and the Middle East highlight a higher exposure, sensitivity and lower capacity to adapt with losses at around 2% of GDP.

Against this background, the present research proposes one of the first attempts to perform a country-level integrated impact assessment exercise for the Mediterranean area.

The A1b IPCC scenario has been chosen as reference scenario within the whole CIRCE project. Consistently with that scenario, a set of impact-specific studies have been performed estimating effects on tourism attractiveness (Hamilton, 2010), energy demand (Bosello and De Cian, 2009) and land loss driven by sea-level rise (Vafeidis, 2009). Finally, the results of those studies have been used as inputs to the ICES CGE model (Eboli *et al.*, 2010).

In what follows: section 2 introduces new model specifications, section 3 summarizes methodology and results from the specific impact studies used as a source information for the exercise, section 4 explains how those information have been used as input to the CGE model, section 5 presents major results and section 6 concludes.

2. New model specification

Roson (2008) reports the basic features of ICES: regional and sectoral detail, main characteristics and the procedure used to build the benchmark. The regional and sectoral details of the ICES model used in this study are recalled in Table 1.

Countries/Regions	Sectors
Italy	Rice
Spain	Wheat
France	Cereal and Grains
Greece	Vegetables and Fruits
Malta	Oil Seeds
Cyprus	Sugar Cane
Slovenia	Plants-based fibers
Croatia	Other Cereal Crops
FYug = Former Yugoslavia	Livestock
Albania	Forestry Sector
Turkey	Fishing
Tunisia	Coal
Morocco	Oil
RoNAfrica = Rest of North Africa	Gas
RoMdEast = Rest of Middle East	Oil Products
RoNME = Rest of Non Mediterranean Europe	Electricity
RoA1 = Rest of Annex 1 Countries	Industry
ChInd = China and India	Market Services
RoW = Rest of the World	Public (non market) Services

Table 1: Regional and sectoral specification of the ICES model

Palatnik *et al.* (2011) describe the improved model specification of the production side for the agricultural sectors. The main innovation is the improvement of land supply. As many other CGE models, ICES relies upon GTAP database and model (www.gtap.agecon.purdue.edu). The current structure of land supply allows an equal degree of substitution among all crops in all the world. The extension here is to incorporate a nested land supply function for both North and South Mediterranean coming from an analysis performed with the Value model for Israel and Italy. We thus refer the interested reader directly to this document for detail.

What follows here is a short introduction of the major improvement respect to the model version thereby described i.e. the development of a recursive-dynamic engine for the model. It can now replicate dynamic economic growths based on endogenous investment decisions. As standard in the CGE literature, the dynamic is recursive. It consists of a sequence of static equilibria (one for each simulation period which in the present exercise is the year) linked by the process of capital accumulation. As investment decisions which build regional capital stocks are taken one year to the other, i.e. not taking into account the whole simulation period, the planning procedure is “myopic”. Two factors drive endogenously investment and its international allocation: the differentials in expected rate of return to capital and GDP across regions and countries. In other

words, a country can attract more investment and increase the rate of growth of its capital stock when its GDP and its rate of return to capital are relatively higher than those of its competitors.

Figure 1 depicts ICES regions growth rates in the dynamic benchmark

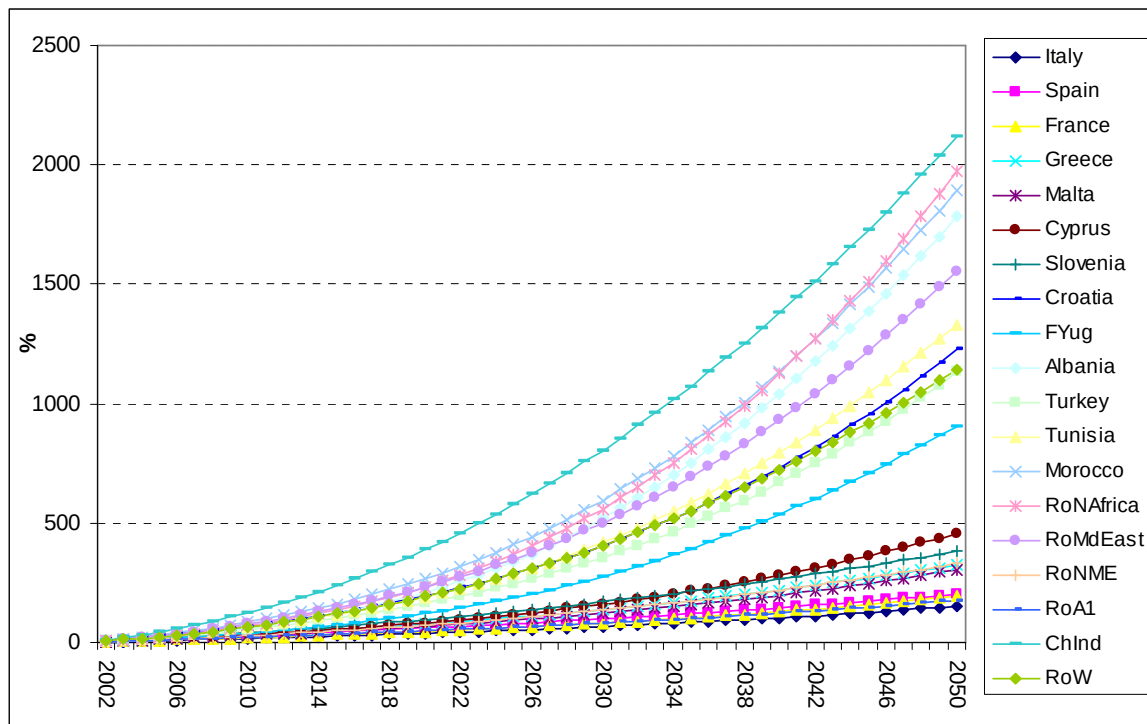


Figure 1. GDP regional growth rates in the A1B scenario

3. Assessing climate change impacts by category

Bosello *et al.*, 2009 reports the quantification of climate change impacts on energy demand and sea-level rise provided respectively by Bosello and De Cian (2009) and Vafeidis (2009), and how these have been translated into suitable inputs to the ICES CGE model.

The main features of these exercises are summarized below while the reader interested in further details is addressed directly to the cited sources.

Bosello and De Cian (2009) estimate household energy demand on a macro dynamic panel dataset spanning from 1978 to 2000, for 31 countries. Then they compute the demand elasticity to temperature of different energy vectors for cold, mild and hot countries. A cluster analysis placed Mediterranean economies within the mild region. For this area, the study highlights the presence of both a cooling effect in the summer and a heating effect in the winter. That is, summer temperature leads to higher annual electricity demand to feed a higher use of air conditioners. On the contrary,

gas and oil product demand, mainly addressing heating needs, respond negatively to temperature increases, especially when occurring in fall, spring or winter (see Table 2).

Vafeidis (2009) reports the most recent estimates of land lost because of sea-level rise from the Dynamic Integrated Vulnerability Assessment (DIVA) model (Vafeidis *et al.*, 2008). This carried out simulations for IPCC A1b, A2 and B2 scenarios until 2500, with detailed results at coastal level (reported with a spatial resolution of 5°, with 5-year time steps until 2100 and 100-year time steps from 2100 to 2500). For each scenario, both a “with adaptation” and a “without adaptation” cases have been run, and the corresponding land losses have been assessed. The economic assessment conducted with the ICES model has been performed for the A1b “without adaptation” scenario in the time span 2001-2050 (see Table 2).

Furthermore, the present study adds a new impact to the assessment, that on tourism demand estimated by Hamilton (2010). These are derived from an improved version of the Hamburg Tourism Model (HTM), an econometric simulation model of tourism flows in and between 207 countries. The core of the model consists of two econometrically estimated equations, respectively for arrivals and departures. As to departure, HTM relies upon a two-step procedure. First, it estimates the total tourists in a given country; then it divide tourists between those that travel abroad and those that stay within the country of origin. This way, the model provides the total number of holidays as well as the trade-off between holidays at home and abroad. The number of tourists that a country generates depends on the size of the population and of average income. The share of domestic tourists in total tourism depends on the climate in the home country and on per capita income. Climate is represented by the annual mean temperature. A number of other variables, such as country size, are included in the estimation, but these factors are held constant in the simulation. International tourists are allocated to all other countries on the basis of a general attractiveness index, climate, per capita income in the destination countries, and the distance between origin and destination.

4. Including impacts in 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.

Land losses to sea-level rise have been modelled as percent decreases in the stock of productive land and capital by region. Both modifications concern variables, land and capital stocks, which are exogenous to the model and therefore they are straightforwardly implemented. We do not have information on capital losses, thus we assumed they exactly match land losses¹.

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

¹ We could have avoided including capital losses; however they are important components of sea-level rise costs. Therefore, we prefer to have a rough and arbitrary estimation of this component rather than none. We are not including displacement costs.

modelled as changes in (re-scaled) households' demand addressing the "market services sector", which includes recreational services.

Changing demand functions imply to intervene on variables which are endogenous to the model. The technicality involved is more complex than in the case of exogenous variables. We adopted 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.

Table 2 summarizes the results of all this procedure presenting the computed inputs for the CGE model².

Country/ region	Households' Energy Demand			Land Loss to Sea- Level Rise (*)	Tourism	
	Natural Gas	Oil Products	Electricity		Demand Shifts	Expenditure flows(**)
Italy	-12.48	-15.61	0.73	-0.07	-1.26	-9.87
Spain	-12.45	-15.52	0.73	-0.02	-2.32	-7.78
France	-13.08	-16.45	0.78	-0.06	-0.64	-5.31
Greece	-12.00	-15.09	0.70	-0.17	-2.39	-1.97
Malta	-12.48	-15.61	0.73	0.00	-3.83	-0.07
Cyprus	-13.11	-17.38	0.74	-0.27	-3.67	-0.42
Slovenia	-12.48	-15.61	0.73	0.00	-0.55	-0.07
Croatia	-12.48	-15.61	0.73	-0.04	-3.16	-0.93
Fyug	-12.24	-15.35	0.71	-0.42	-1.04	-0.42
Albania	-12.00	-15.09	0.70	-0.27	-3.25	-0.33
Turkey	-13.11	-17.38	0.74	-0.08	-0.04	-0.15
Tunisia	-12.48	-15.61	0.73	-0.25	-4.87	-1.21
Morocco	-12.45	-15.52	0.73	-0.17	-4.19	-1.20
RoNAfrica	-12.51	-15.90	0.72	-0.07	-3.14	-13.24
RoMdEast	-13.11	-17.38	0.74	-0.42	-3.25	-56.83
RoNME	-13.72	-15.54	-2.09	-0.79	1.30	40.34
RoA1	-12.26	-16.17	0.11	-1.31	2.80	188.31
ChInd	nss	nss	20.37	-1.82	0.07	0.39
RoW	nss	-1.8262	15.69	-0.92	-1.88	-129.26

Table 2. Direct impact of climate change A1b SRES scenario: % changes wrt baseline in 2050

(*) % of total land

(**) \$ Billions

nss = not statistically significant.

² In Bosello *et al.* (2009) energy demand and sea-level rise impacts were calculated for the B2 IPCC SRES scenario. This explains the difference in the figures reported.

As long as direct impacts are concerned, it is possible to note that, on an annual basis, consistently with the summer cooling and winter heating effects, electricity demand in the Mediterranean area is expected to increase by roughly 0.7% in 2050; heating demand however is estimated to decrease by an almost uniform 12% and 15% for natural gas and oil products respectively. Sea-level rise entails land losses in all the regions considered. The amount of land loss is however a tiny percent of total regional land. The highest relative losses are expected in Eastern Mediterranean regions: Former Yugoslavia, Albania, Cyprus and Southern ones Morocco and Tunisia. Nonetheless the loss is lower than the 0.5% of total national surface. Impacts on tourism demand are clearly negative all over the Mediterranean (except for a very small gain in Turkey) which is becoming “too hot”. The higher demand contraction are experienced by Tunisia and Morocco (-4.9% and -4.2% respectively) followed by Malta, Cyprus and Croatia, which are not only warmer, but also show a higher share of tourism on services value added. Among the Euro-Mediterranean countries the biggest losers are Greece, Spain and Italy. On the contrary, climate change increases the attractiveness of non Mediterranean EU.

5. Results

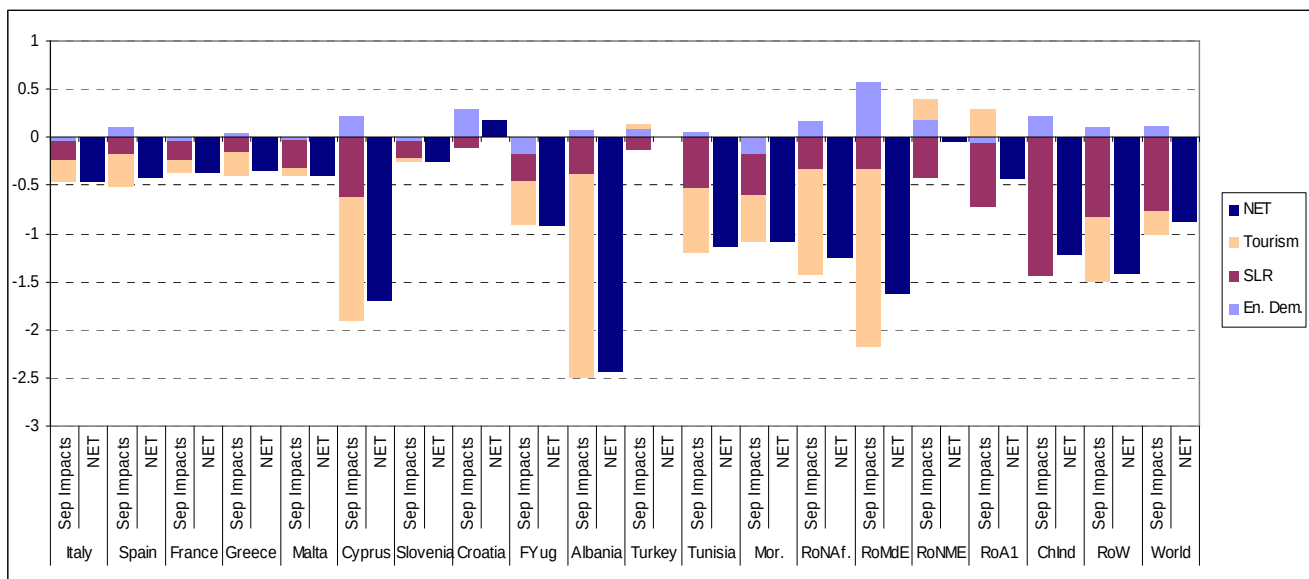


Figure 2. Climate change impact on GDP: % change wrt baseline in 2050

GDP impacts in 2050 are reported by Figure 2. In terms of aggregate impact the whole Mediterranean area loses 1.02% of GDP with the Northern-Mediterranean countries clearly less vulnerable than the Southern-Mediterranean ones. Among the former the average loss in 2050 is the 0.5% of GDP, while among the latter this more than doubles. Particularly adversely affected are Cyprus and Albania (-1.6% and -2.4% of GDP in 2050, respectively). In terms of impact types, tourism and sea-level rise are clearly the most threatening, while GDP impacts induced by demand re-composition of energy use is less of an issue and often positive. A difference emerges between

the North and the South Mediterranean. In the former, impacts associated to sea-level rise and tourism are rather balanced, while in the latter, losses of the tourism industry dominate. Summarizing, the analysis confirms the quite good adaptive capacity against climate change of Euro-Mediterranean countries and the higher vulnerability of North African and Middle East countries. This is driven not only by higher negative impacts on average, but by an economic structure where the tourism activity contributes with a higher share to the production of value added. It is also worth stressing that the impacts considered are just a small subset of those that climate change can originate. Thus, total negative impact can be expected to be quite higher than those here estimated.

The analysis is completed by the description of major indirect effects. Figure 3 highlights climate change impacts on world prices. Three clusters can be identified. Energy prices decline compared to the baseline (-7% oil and oil products, -4% gas in 2050), as the net effect of the GDP decrease worldwide compresses particularly energy demand. Industry and services' prices remain roughly constant at the baseline levels. Agricultural prices, affected by the decrease in available productive land, increase especially after 2025 (the maximum increase shown by rice with a +1.5% in 2050) when sea-level rise becomes more appreciable.

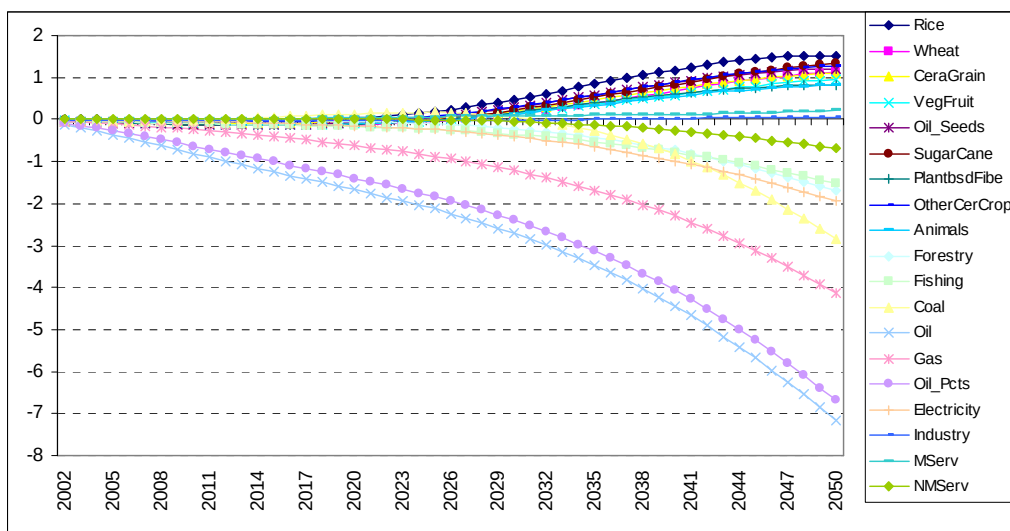


Figure 3. Climate change impacts on world prices: % change wrt baseline

This has an implication on international competitiveness as typically measured by terms of trade effects (see Figure 4).

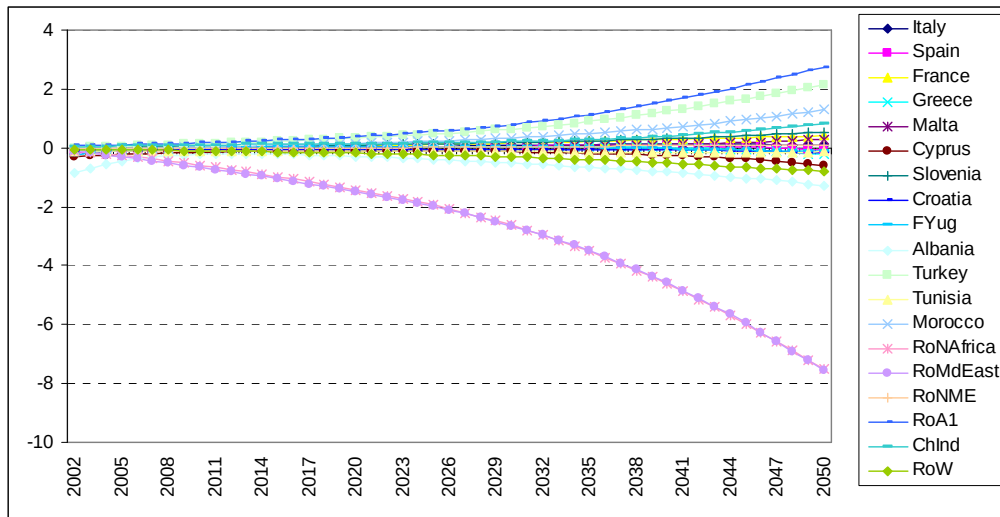


Figure 4. Climate change impacts on terms of trade: % change wrt baseline

North Africa and Middle East countries, as energy exporters are particularly damaged, while EU countries which are heavy energy importers and food exporters benefit. These “second order” effects thus hamper the negative impacts in the Southern and Eastern Mediterranean countries, but smoothen that in the Euro-Mediterranean ones, although not turning them into gains.

Table 3 shows the sectoral implications of the climate change impact considered. Consistently with the GDP contraction worldwide, negative signs prevail. Within the Mediterranean countries, sectoral production is adversely affected in the market services and in the energy sectors. The first are hit negatively by the reduction in tourism demand, the second by the world reduction in energy demand. Note, however, that electricity production tends often to increase. This is fostered by the increased space cooling demand from households that counterbalances the decrease in aggregated demand. Food productions fostered by higher prices tend to increase in the Mediterranean area.

	Italy	Spain	France	Greece	Malta	Cyprus	Slovenia	Croatia	FYug	Albania	Turkey	Tunisia	Morocco	RoNAfrica	RoMdEast
Rice	0.72	-0.09	0.00	0.20	0.55	-0.51	-0.02	0.57	0.34	0.37	0.07	-0.16	0.74	1.40	1.55
Wheat	0.48	0.16	-0.04	-0.07	0.85	0.24	-0.68	0.33	0.61	0.60	-0.23	0.83	0.34	0.96	0.04
CeraGrain	0.51	0.53	0.20	0.45	1.70	0.84	-0.02	0.55	-0.24	0.44	0.39	-0.48	0.33	1.26	-0.23
VegFruit	0.66	0.04	0.67	0.68	1.08	0.83	0.35	1.55	0.62	0.99	0.40	0.64	0.79	0.62	1.25
Oil_Seeds	1.29	0.16	0.08	0.80	3.49	0.36	0.20	0.89	0.17	-0.69	0.21	-0.34	0.23	1.40	0.96
SugarCane	0.20	0.60	0.88	1.18	1.95	6.74	0.41	1.26	0.95	1.31	0.30	0.29	-0.21	0.94	2.81
PlantbsdFibe	-0.87	-1.15	-1.27	-0.79	-0.94	-1.68	-1.01	-1.16	-2.82	-0.12	1.27	-0.51	-0.02	0.62	-0.91
OtherCerCrop	0.62	0.46	0.78	0.18	2.09	0.90	0.91	0.41	0.38	-0.38	-0.24	0.16	0.54	2.62	-0.02
Animals	0.36	0.98	0.60	0.61	0.10	0.46	-0.16	0.29	0.57	0.16	0.14	0.07	0.00	0.15	0.62
Forestry	2.40	1.82	0.16	1.18	-0.09	1.50	-0.48	0.60	2.33	3.64	0.15	2.90	-0.59	-0.28	2.58
Fishing	3.32	2.27	1.84	2.45	1.84	2.74	-1.13	0.83	3.62	3.61	1.80	1.52	0.40	-0.27	2.03
Coal	0.01	-0.02	-0.32	0.00	-0.21	0.18	-0.19	0.12	0.00	0.08	-0.18	0.01	0.01	0.10	0.21
Oil	-0.26	-0.13	-0.25	-0.43	-0.16	-1.95	-0.19	-0.49	-0.17	-0.13	-0.56	-0.11	-0.36	-0.11	-0.10
Gas	-9.17	-2.56	-1.52	-1.18	-14.99	-2.14	-10.57	-1.71	-4.08	-0.83	-17.66	-0.73	-3.66	-0.64	-0.73
Oil_Pcts	-0.04	-0.66	0.74	-0.91	-18.82	0.31	-6.27	0.41	-2.05	-0.16	-1.25	-2.07	-2.48	-2.98	-3.37
Electricity	0.93	-0.16	-2.62	0.18	2.66	2.96	-1.45	2.43	-0.39	0.03	0.62	0.04	-0.59	-0.80	-0.26
Industry	1.79	1.79	1.12	1.33	1.12	3.92	0.34	2.52	2.87	-0.05	0.30	0.33	-0.44	1.24	3.41
MServ	-0.82	-0.97	-0.28	-0.58	-2.31	-2.59	-0.49	-0.35	-0.91	-2.60	0.88	-2.46	-1.54	-2.45	-3.47
NMServ	-0.63	-0.10	-0.74	-0.85	-0.43	-0.55	0.17	-0.42	-1.24	-0.68	-0.16	0.12	-0.10	-1.18	-1.76

Table 3: Climate change impacts on sectoral production by region (cc vs baseline)

Finally, Figure 5 shows for the Mediterranean the difference in results between the general equilibrium methodology followed and a possible direct costing one. It compares the net impact on GDP already reported in Figure 2 with an estimation of direct climate change costs. The direct cost of sea-level rise is represented by the value of regional capital and land stock times the respective loss in quantity; direct costs/gains for the tourism sector are represented by the decreased/increased tourists' expenditure, direct costs/gains for the energy sector are measured by the decrease/increase in energy expenditures. All these components are summed up by region and expressed as percentage of regional GDP.

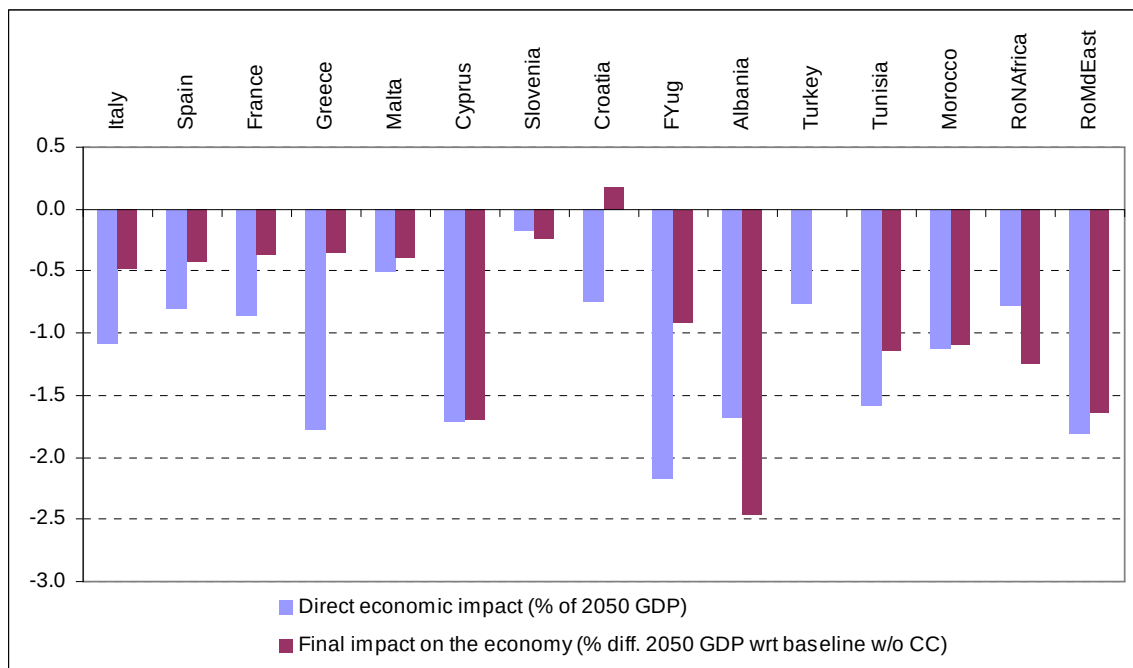


Figure 5. General equilibrium effect vs direct impacts in 2050

As said, direct costing cannot capture the systemic nature of economic relations, and accordingly can only partially assess how impacts translate into the ability of an economic system to produce flows of goods and services. Therefore the two assessments can diverge substantively. Direct costs tend to be higher than GDP effects and sometimes, like in the case of Croatia, of different sign. This however is not a rule. Enlightening are Albania and the Rest of North African regions where GDP impacts are higher than direct costs. In these regions losses in tourism industry are particularly concerning as, being one of the major drivers of aggregated demand, they induce further losses in all the other economic sectors with a strong multiplicative effect.

6. Conclusions

This report presents the final simulation results by ICES, a Computable General Equilibrium (CGE) model developed within the CIRCE project, applied to assess economically a set of climate change impacts estimated within the project itself.

This model version improves on the previous one (Bosello *et al.*, 2009), developing a recursive-dynamic setting where economic growth is driven by endogenous capital accumulation processes.

The present analysis considers three climatic impacts estimated for the IPCC A1b SRES scenario: land and capital losses due to the increase in sea level, changes in households' energy demand (both for heating and cooling purposes) as a response to the increasing temperature, and changes in tourism services demand as a response to changes in country climatic attractiveness.

In 2050, jointly considered, these impacts can induce a loss of the 1% of GDP in the Mediterranean area as a whole. Particularly adversely affected are Cyprus and Albania (-1.6% and -2.4% of GDP, respectively). It also emerges that Northern-Mediterranean are clearly less vulnerable than the Southern-Mediterranean countries. Among the former the average loss in 2050 is the 0.5% of GDP, while among the latter this more than doubles.

In terms of impact types, tourism and sea-level rise are the most threatening, while GDP impacts induced by demand re-composition of energy use is less of an issue and often positive.

Climate change impacts trigger many indirect effects. Energy prices decline compared to the baseline (-7% oil and oil products, -4% gas in 2050), as the net effect of the GDP decrease worldwide compresses particularly energy demand. Industry and services' prices remain roughly constant at the baseline levels. Agricultural prices, affected by the decrease in available productive land, increase especially after 2025 (the maximum increase shown by rice with a +1.5% in 2050) when sea-level rise becomes more appreciable.

This has an implication on international competitiveness as typically measured by terms of trade effects. North Africa and Middle East countries, as energy exporters are particularly damaged, while EU countries which are heavy energy importers and food exporters benefit. These "second order" effects thus hamper the negative impacts in the Southern and Eastern Mediterranean countries, but smoothen that in the Euro-Mediterranean ones.

Consistently with the GDP contraction worldwide, at the industry level negative signs prevail. Within the Mediterranean countries, sectoral production is adversely affected mainly in the market services and in the energy sectors. The first are hit negatively by the reduction in tourism demand, the second by the world reduction in energy demand. However electricity production tends often to increase. This is fostered by the increased space cooling demand from households that counterbalances the decrease in aggregated demand. Food production fostered by higher prices tend to increase in the Mediterranean area.

Some major conclusions can be derived.

Climate change confirms its adverse distributional implications also at the Mediterranean level as losses in economic activity are more pronounced in relatively poorer regions.

These losses are not negligible even when analyzed with a general equilibrium approach which takes into account the ability of markets to adapt to adverse shocks. Accordingly, market-driven adaptation cannot be the solution of the climate change problem. Proactive planned policies must be put in place.

Outcomes from a general equilibrium assessment exercise are substantively different from what can be obtained by applying a direct costing methodology. This flags the interest in conducting such an exercise. However, given that the two approaches stress different aspects of the issue they should be conceived as complement rather than substitutes.

To conclude, some fundamental qualification of our results are in order: the GDP impacts shown are calculated only on a sub set of potential adverse effects of climate change (possible consequences of increased intensity and frequency of extreme weather events and of biodiversity losses for instance are not included); irreversibilities or abrupt climate and catastrophic changes to which market driven adaptation can be only limited are neglected; costless and instantaneous market adjustments are assumed. In the light of all that, what proposed here should be taken just as the lowest possible bound for climate change costs.

Acknowledgements

This paper has been produced within the framework of the project CIRCE - Climate Change and Impact Research: the Mediterranean Environment, contract N. 036961, funded by the European Commission within the Sixth Framework Programme.

References

- Aaheim A., Amundsen H., Dokken T., Ericson T. and Wie T., (2009), "A macroeconomic assessment of impacts and adaptation to climate change in Europe", ADAM project D-A.1.3b.
- Berrittella, M., A.Y. Hoekstra, K. Rehdanz, R. Roson and R.S.J. Tol (2007), "The Economic Impact of Restricted Water Supply: A Computable General Equilibrium Analysis" *Water Research* 42, 1799-1813.
- Bosello, F. and De Cian, E. (2009), "Energy demand and temperature changes. Econometric estimation", Deliverable 10.5.3, CIRCE Project (pn 036961)
- Bosello, F., Eboli, F. and R. Parrado (2009), "Climate change impacts in the Mediterranean: Preliminary results by means of a CGE analysis", Deliverable 10.7.2 CIRCE Project (pn 036961)
- Bosello, F., Roson, R. and R.S.J. Tol (2006), " Economy wide estimates of the implications of climate change: human health" *Ecological Economics*, 58, 579-591
- Calzadilla, A., Rehdanz, K., & Tol, R. (2010), "The Economic Impact of More Sustainable Water Use in Agriculture: A CGE Analysis", *Journal of Hydrology* 384, 292-305
- Ciscar, J.C. (2009), "Climate change impacts in Europe: Final report of the PESETA project", J.C. Ciscar (Ed.), JRC Technical Report, EUR 24093 EN, Spain
- Darwin, R. F. (1999), 'A FARMER's View of the Ricardian Approach to Measuring Agricultural Effects of Climatic Change, ' *Climatic Change*, 41 (3-4), 371-411.
- Darwin, R. F. and Tol, R. S. J. (2001), "Estimates of the Economic Effects of Sea Level Rise", *Environmental and Resource Economics*, 19, 113-129.
- Deke, O., Hooss, K. G., Kasten, C., Klepper, G., & Springer, K. (2002) Economic Impact of Climate Change: Simulations with a Regionalized Climate-Economy Model. Kiel Institute of World Economics, Kiel, 1065.
- Eboli F., Parrado R. and Roson R., (2010), "Climate Change Feedback on Economic Growth: Explorations with a Dynamic General Equilibrium Model", *Environment and Development Economics*, Volume 15 (5), pp 515 -533
- Hamilton J., (2009), "Report on the collected datasets", Deliverable 10.2.4, Circe project. (pn 036961).
- Hamilton J., (2010), "Updated version of the global tourism model HTM", Deliverable 10.2.7 (in progress), Circe project. (pn 036961).
- Palatnik R.R., Kan I., Rapaport-Rom M., Ghermandi A., Eboli F. and Shechter M., (2011), "Land transformation analysis and application", *GTAP* conference paper available at https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=3508
- Ronneberger, K., Berrittella, M., Bosello, F. and R.S.J. Tol (2009), KLUM@GTAP: introducing biophysical aspects of land use decisions into a general equilibrium model. A coupling experiment", *Environmental Modelling and Assessment*, Vol. 14, n. 2.

Roson, R. (2008), "Firs version CGEmodel prototype", Deliverable 10.7.1 CIRCE Project (pn 036961)

Tsigas, M.E., Frisvold, G.B. and B. Kuhn (1997), 'Global Climate Change in Agriculture' in Global Trade Analysis: Modeling and Applications. Thomas W. Hertel, editor, Cambridge University Press.

Vafeidis, A. T., Nicholls, R. J., Boot, G., Cox, J., Grashoff, P. S., Hinkel, J., Maatens, R., McFadden, L., Spence, T. & Tol, R. S. J. (2008), "A new global coastal database for impact and vulnerability analysis to sea-level rise", *Journal of Coastal Research*, 24(4):917-924

Vafeidis, N. (2009), "Updated version of the DIVA-Med database", Deliverable 10.6.2, Circe project. (pn 036961)