Centro Euro-Mediterraneo sui Cambiamenti Climatici

Research Papers
Issue RP0199
December 2013

CIP - Climate Impacts and Policy Division

Climate Change Impacts: A New Integrated Assessment

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SUMMARY This report develops a climate change economic impact assessment, applying the Intertemporal Computable Equilibrium System (ICES) model developed at CMCC. The inputs for the exercise derive from the updated estimation of climate change impacts conducted under GEMINA WP6.2.9 P55. They refer to changes in tourism and energy demand patterns; to changes in land and capital losses to sea-level rise, to changes in fish stock availability, to ecosystem losses, to changes in crops productivity, to changes in labour productivity related to changes in health status, to potential losses induced by river floods. They are also computed for two different temperature increase scenarios: + 2°C and +4°C above pre-industrial level. Results show that: climate change impacts are non linear in temperature; that the Euro Mediterranean area is more vulnerable than Northern Europe, that losses can be relevant even in a context of smooth climate change without catastrophic events.

Keywords: Climate change impact assessment, CGE models

This report represents the Deliverable P.56 developed within the framework of Work Package 6.2.9 of the GEMINA project, funded by the Italian Ministry of Education, University and Research and the Italian Ministry of Environment, Land and Sea.

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SUMMARY

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1. INTRODUCTION

This report develops a climate change economic impact assessment applying the Intertemporal Computable Equilibrium System (ICES) model developed at CMCC. ICES is a recursive-dynamic computable general equilibrium (CGE) model for the world economic system. It improves upon the static structure of the GTAP-E model (Burniaux and Truong, 2002). The calibration year is 2004, data come from the GTAP7 database (Narayanan and Walmsley, 2008) and the simulation time is 2004-2050. The inputs for the exercise derive from the updated estimation of climate change impacts conducted under GEMINA WP6.2.9 P55: "Climate Change Impacts: New Estimation and Modeling" (Bosello et al. 2012). They refer to changes in tourism and energy demand patterns; to changes in land and capital losses to sea-level rise, to changes in fish stock availability, to ecosystem losses, to changes in crops productivity, to changes in labour productivity related to changes in health status, to potential losses induced by river floods. They also are computed for two different temperature increase scenarios: + 2°C and +4°C above pre-industrial level. Table 1, Table 2, Table 3, Table 4, Table 5, Table 6, summarize the impacts as input information for the ICES model. For detailed description on how these impacts have been computed refer directly to Bosello et al. (2012).

Table 1: 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 2: 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 3: Supply-side impacts (2): 2° C temperature increase, ref. year 2050

	Floodings					
	Agriculture	*Residential*	*Transport*	*Commerce*	*Industry*	*Population*
	(land stock)	*(K prod.)*	*(K prod.)*	*(K prod.)*	*(K prod.)*	*(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 4: 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 5: 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 6: Supply-side impacts (2): 4° C temperature increase, ref. year 2050

	Supply-side Impacts (2)					
	Floodings					
	Agriculture	*Residential*	*Transport*	*Commerce*	*Industry*	*Population*
	(land stock)	*(K prod.)*	*(K prod.)*	*(K prod.)*	*(K prod.)*	*(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

2. THE SOCIAL-ECONOMIC BASELINE

Table 7 reports region and sector aggregations for this study. Regions have been chosen in order to detail as much as possible the EU countries and the Euro Mediterranean area, whereas industries' detail is the closest possible to the sectoral impacts estimated by source studies surveyed under GEMINA P55.

Table 7: Regional and sectoral coverage of the ICES model (this study)

Countries/Regions	Sectors
Austria	Agriculture Timber Fishing Coal Oil Gas Oil Products Electricity Other Industry Transportation Residential Market Services Public Services
Belgium	
Czech Republic	
Denmark	
Finland	
France	
Germany	
Greece	
Hungary	
Ireland	
Italy	
Neth.ds	
Poland	
Portugal	
Spain	
Sweden	
UK	
RoEU	
ROECD	
CHIND	
TE	
ROW	

EU future GDP national and regional growth rates reported in Figure 1 derive from the 2012 Ageing Report issued by EU the Commission.[1]

[1] http://ec.europa.eu/social/main.jsp?langId=en&catId=89&newsId=1326&furtherNews=yes. The Ageing Report (European Commission 2012a), has been prepared as part of the mandate the Economic and Financial Affairs Council (ECOFIN) gave to the Economic Policy Committee (EPC) in 2009 to update and further deepen its common exercise of age-related expenditure projections by 2012, on the basis of a new population projection by Eurostat. It contains projections, of the budgetary impact of the ageing population in the 27 EU Member States over the period 2010–2060 and has been presented to the ECOFIN Council in May 2012. Thus, it can be considered the more up to date, well established and shared reference for the EU policy debate.

Population trends (Figure 2) also replicate the 2012 Ageing Report for the EU27. For non-EU27 regions, population evolves according to UN (2011) and GDP according to the A2 IPCC SRES scenario.

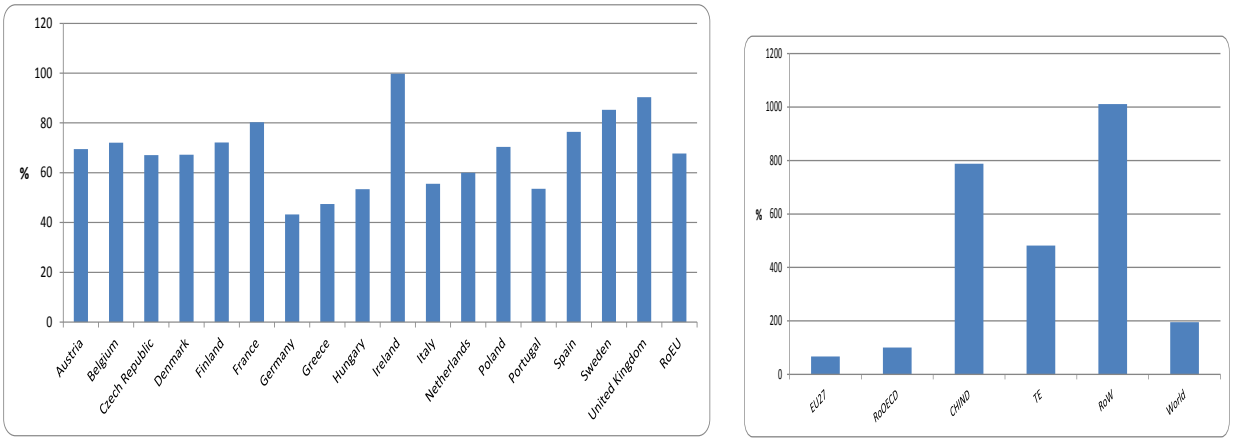

Figure 1: Baseline GDP growth rates by country (% change 2004-2050)

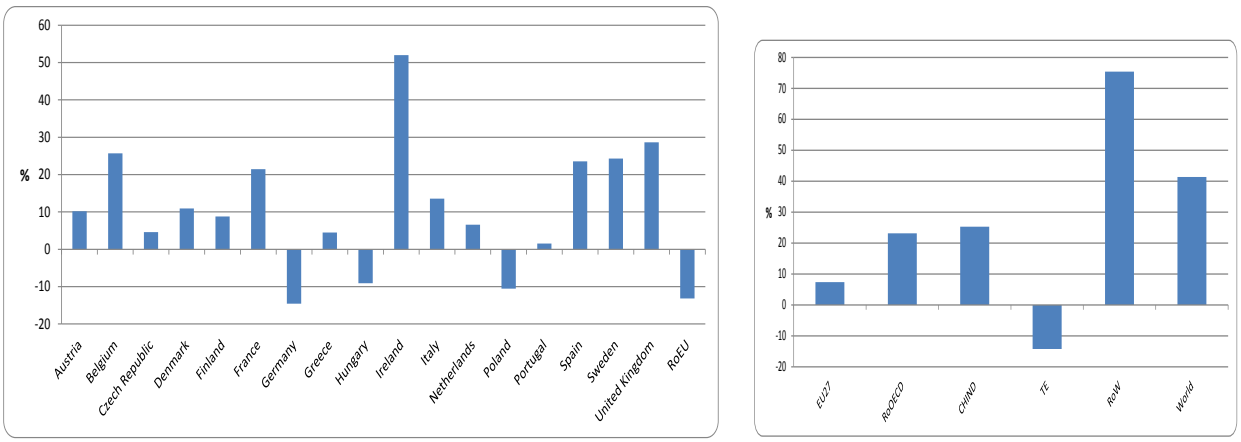

Figure 2: Baseline population growth rates by country (% change 2004-2050)

3. RESULTS

Figure 3 reports the dynamics of climate change impact on the EU real GDP. Figure 4 and Figure 5 report GDP impacts in 2050 for the 2°C and 4°C temperature increase scenarios and the decomposition of impacts by category.

The EU 27 as a whole experiences a GDP loss of the -0.16% and the -0.74% in the 2°C and 4°C cases respectively. (The loss for the world as a whole is larger: -0.7% and -1.8% of GDP in 2050 for 2°C and 4°C respectively). Impacts therefore are non-linear in temperature and across time. About the first result, it is interesting to note that it does not derive from an exogenous assumption imposed by construction to the functional form of economic damages from climate change[2]. Rather, it stems from the direct computation of each single and different climate change consequence on the economic activity assessed by the ICES model. The exercise also highlights that losses are rather moderate in the aggregate[3]. However they are highly differentiated by country, ranging from the +0.56% of GDP in Denmark to the -1.76% in Greece in the 2°C temperature increase scenario; from the +0.59% of GDP in Finland to the -6.24% in Greece in the 4°C temperature increase scenario. In general GDP effects are slightly positive or basically null in the Northern European countries (Denmark, Finland, Germany, Sweden, the UK) and negative in the Southern EU, highlighting the higher vulnerability of the Mediterranean area. Among impacts type, agriculture clearly dominates, followed by tourism and ecosystem. These three impacts together build more than 70% of the final GDP result in the majority of the EU countries. At the EU level, however, positive and negative agricultural impacts almost compensate each other. Also country specific vulnerability is worth noticing. For instance, in Greece and Spain, agriculture and tourism impacts are by large the more concerning; agriculture is less of an issue in Italy, Belgium and Poland, where on the contrary tourism and ecosystem losses appear to be more important.

Table 7 and Table 8 report climate change impacts on sectoral production. In general these tend to follow the direction of the climatic shocks, but not always. On the one hand they are the final net resultant of all the climatic shocks jointly implemented. Therefore, impacts interactions play a role in determining the final outcome. On the other hand, also the macroeconomic-aggregate feedback on sectoral activity

[2] This is typically the case in those models making use of reduced-form climate change damage functions, see for instance Nordhaus and Boyer (1999), Manne and Richels (2005), Bosetti et al. (2006).

[3] Note that only river flooding are included in the assessment and just for the EU countries and that catastrophic events are not considered.

transmitted by trade patterns, matters. A straightforward example is what happens in the energy sectors in the 4°C case. Take for instance Greece: household electricity demand is expected to increase because of a strong cooling effect, however the final production of the sector is negative. Indeed Greece experiences a severe aggregate GDP loss because of climate change which prevails on any single shock. Accordingly also its total energy demand, including that of electricity net of the cooling effect, declines. Aggregate GDP effects are also the major drivers of production performances in the "industry" macro-sector which is directly affected just by a very tiny productivity decline induced by increased expected losses from floods.

Picking some highlights: the negative performance of agricultural sectors especially in Spain, Greece, Portugal (-8.7%, -8.5%, -5.2% respectively in the 2°C temperature increase scenario n 2050) and partly in Italy and France (-2.7%, -2.3% respectively in the 2°C temperature increase scenario in 2050) are evident; the negative impacts on the service sector in the same countries (-2.08% in Greece, -1.01% in Spain, -0.97 in Portugal, -1.34% in Italy in the 2°C 2050) derive from the negative effects hitting recreational tourism services; the decline in fishery production which is particularly high in Italy and Spain (-8.3%, -3.9% respectively in the 2°C scenario in 2050); the generalized prevalence of production contraction in the energy sectors driven as said by the slump of world energy demand. Note also that industrial production is negatively affected in Denmark and Finland (-0.8%, -3.1% respectively in 2050 in the 2°C temperature increase scenario) notwithstanding the positive GDP impact of climate change in those countries. This is another case where rebound effects play a role. The contraction in world demand can in fact impact negatively industrial production also in those countries where climate change is in fact positive.

Table 10 and Table 11 report the effects of climate change impacts as they are transmitted to labour demand. It is important to stress that the ICES CGE model depicts a Walrasian, perfectly clearing/full employment labour market. The first and most obvious consequence is that unemployment is not modelled. The second is that any shock on the labour market implies just a re-distribution of the labour forces from those sectors whose production, and factor prices, are declining more in relative terms, toward those sectors where the opposite happens. Accordingly, one or more sectors will be always gaining in terms of labour demand. This said, the redistribution of the labour force could indirectly provide some insights of possible tensions on the labour market that climate change may originate. Higher labour demand contractions (Table 10[4]) are concentrated in the agricultural sector especially in Greece (-5.7%),

[4] The comments on Table 11 are similar qualitatively

Spain (-5.9%) and Portugal (-2.7%); in the fishing sector in Italy (-7.9%) and Spain (-4.5%); in the service sector in Hungary (-1.3%), Italy (-0.7%) and Portugal (-0.5%). Industrial labour demand declines particularly in Finland (-4%), Sweden (-1.6%) and Hungary (-1.4%); energy sectors tend also to expel labour force. To conclude, Figure 6, Figure 7 and Table 12 report climate change impacts on world prices; Figure 8 and Figure 9 on terms of trade. Prices highlight a generalized decline consistently with the demand decrease at the world level induced by GDP contraction. The reduction is particularly evident for the forestry and fishing products and for energy commodities. Agricultural prices show an opposite trend however, as the land scarcity induced by flooding and sea-level rise and the decreased land productivity especially at the mid-low latitudes induces a negative supply-side effect more than offsetting the reduced demand.

This has direct implication for terms of trade. In general, EU countries which are, broadly speaking, energy importers and food exporters, benefit from the price shifts and gain. Exceptions are those southern countries like Greece, Spain, Portugal and also Italy where the GDP contraction is particularly high and domestic prices decreases more compared to imported prices.

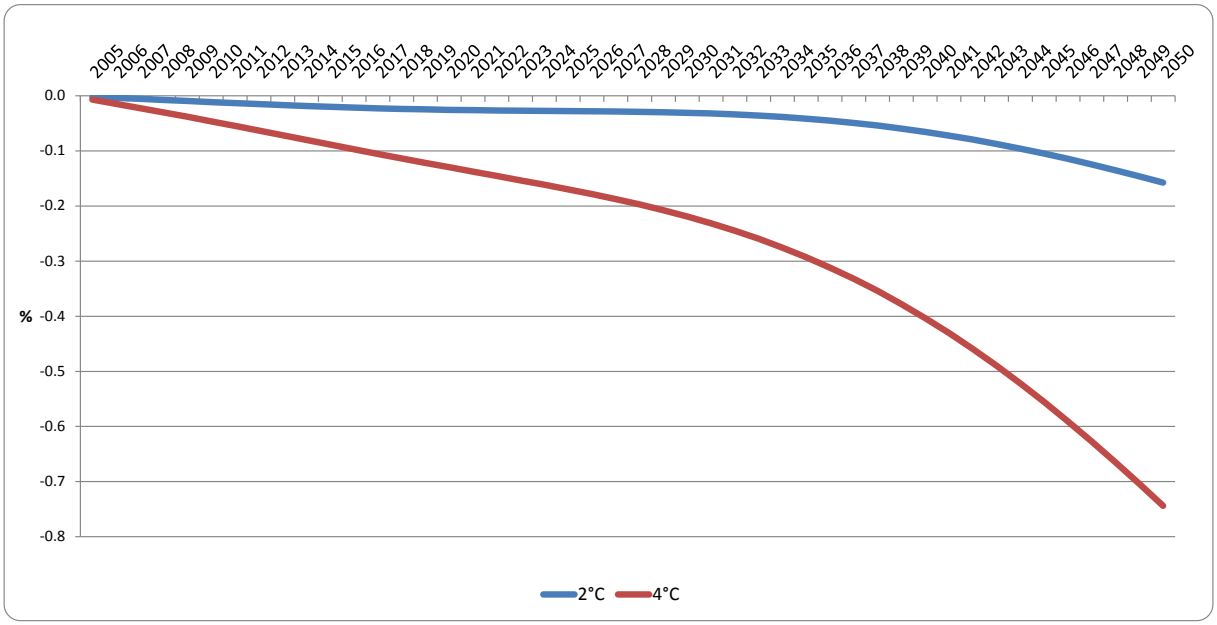

Figure 3: Climate change impacts on EU real GDP (% change wrt baseline) - 2 °C and 4 °C temperature increase

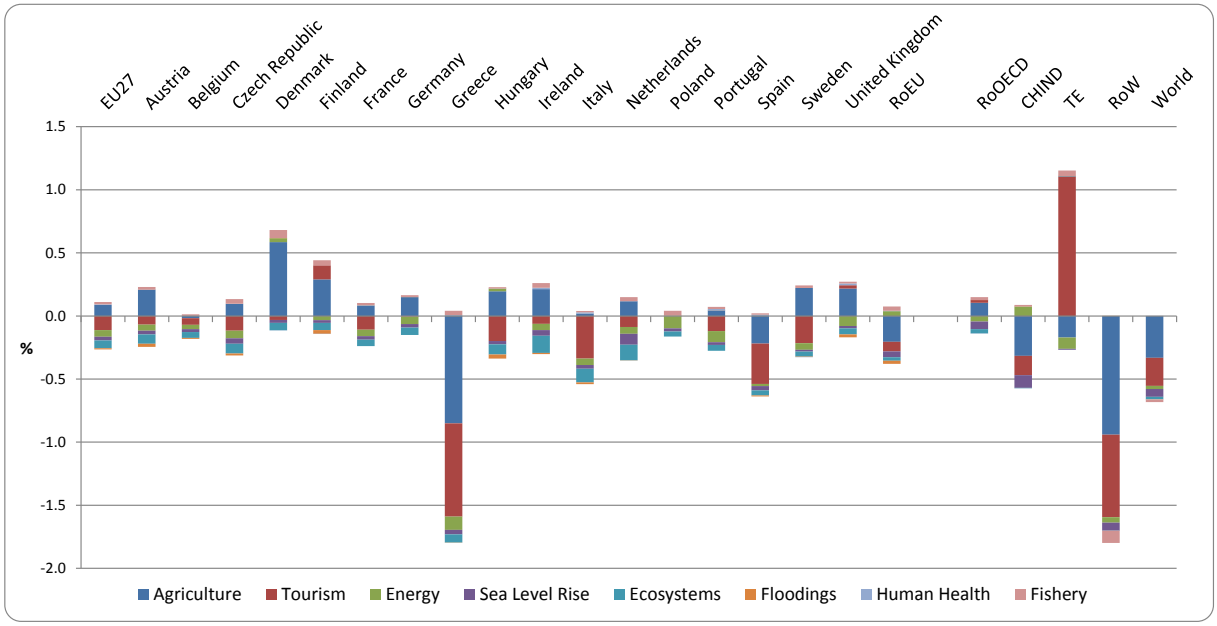

Figure 4: Climate Change impacts on real GDP (% change wrt Baseline) and impact decomposition. 2°C temperature increase ref. year 2050

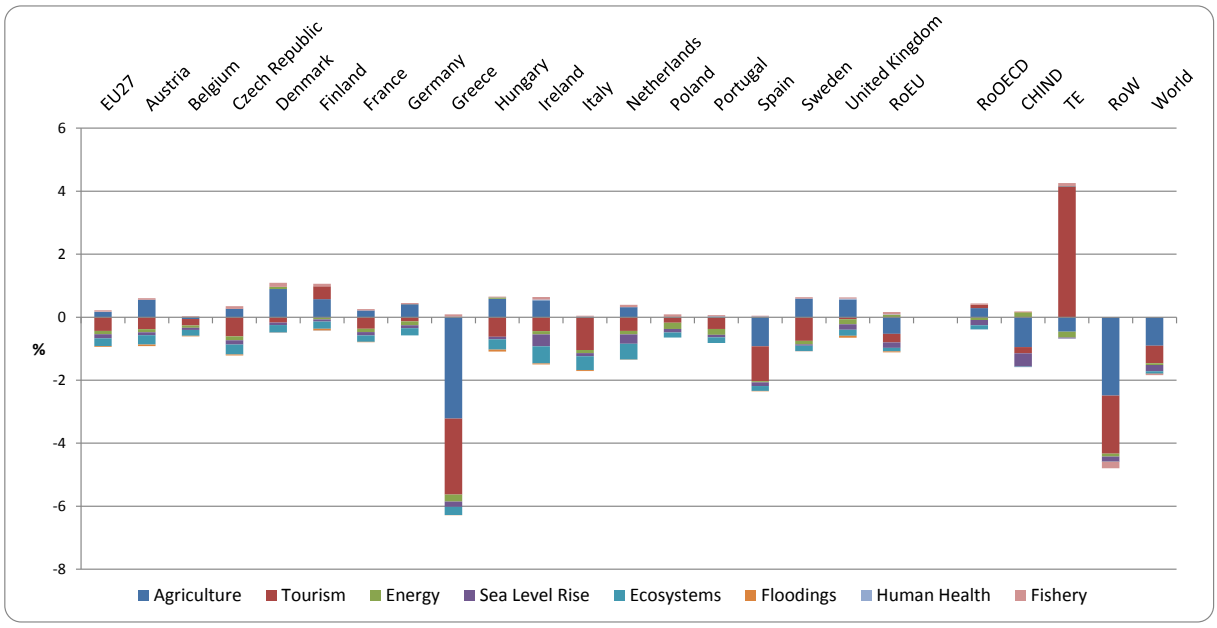

Figure 5: Climate Change impacts on real GDP (% change wrt Baseline) and impact decomposition. 4°C temperature increase ref. year 2050

Table 8: Sectoral Production in 2050 (% change wrt Baseline) - 2 °C temperature increase scenario

	Agriculture	Forestry	Fishing	Coal	Oil	Gas	Oil_Pcts	Electricity	Industries	Transport	Residential	Mkt Services	Public Services
Austria	5.47	-1.10	-0.62	-0.01	-0.02	-1.23	0.37	-0.34	-0.10	-1.25	-0.69	-0.07	0.09
Belgium	-1.58	-1.06	-1.44	0.01	-0.02	-0.09	0.09	-0.08	0.46	-0.28	-0.24	-0.45	-0.13
Czech Republic	-0.03	-1.38	-1.39	-0.02	-0.02	-0.15	0.32	-1.12	0.01	-0.60	-0.06	-0.24	0.12
Denmark	13.46	-2.71	3.71	-0.01	-0.06	-0.45	0.82	0.67	-0.84	-1.87	0.46	-0.01	0.50
Finland	19.09	-2.19	8.85	-0.04	-0.06	-3.63	0.91	-1.00	-3.08	-1.85	-0.72	0.86	1.04
France	-2.33	-2.04	-1.21	0.05	-0.01	-0.28	0.30	0.39	0.70	-0.16	-0.17	-0.28	-0.15
Germany	0.38	-2.68	-0.81	-0.03	-0.02	-0.69	0.27	-0.65	-0.38	-0.73	-0.44	0.20	0.12
Greece	-8.47	-1.95	-0.80	0.21	0.09	0.13	-0.25	0.72	-0.49	4.74	-3.66	-2.08	-1.40
Hungary	2.11	-3.57	-2.77	0.03	-0.06	1.09	0.49	1.79	-0.86	-0.66	0.12	-0.72	0.07
Ireland	-0.11	-2.65	-1.56	0.00	-0.02	-0.64	0.30	0.12	0.35	-0.73	-0.01	-0.60	-0.07
Italy	-2.66	-0.98	-8.27	0.11	0.01	0.35	0.20	1.87	1.78	0.30	-0.79	-1.34	-0.97
Netherlands	0.81	-2.17	3.65	0.00	-0.03	-0.14	-0.50	-0.06	-0.20	-0.45	-0.29	-0.41	-0.03
Poland	-0.40	-1.45	1.14	-0.01	-0.01	-0.58	0.35	-0.82	-0.35	-0.52	-0.04	0.00	0.29
Portugal	-5.26	-2.51	-3.34	0.10	0.01	0.59	0.33	2.10	2.80	0.45	-0.99	-0.97	-1.34
Spain	-8.74	-0.78	-3.91	0.09	0.04	-0.60	-0.04	2.79	2.98	1.36	-3.05	-1.01	-1.16
Sweden	17.12	-1.86	4.61	-0.01	-0.01	-0.22	-0.01	-1.23	-1.41	-1.38	-2.06	0.69	0.36
United Kingdom	3.60	-1.71	0.35	-0.01	-0.04	-0.60	0.11	-0.37	-0.55	-0.74	-0.53	0.28	0.15
RoEU	1.85	-4.61	-2.61	-0.09	-0.12	-0.65	-0.21	-0.72	-1.04	-1.22	0.25	-0.59	0.19
RoOECD	-1.21	-2.73	2.42	-0.02	-0.07	-0.42	0.92	0.85	-2.30	-1.06	-1.23	1.08	0.09
CHIND	0.03	-0.57	-0.60	0.04	0.00	0.24	0.52	0.30	0.13	-0.59	-0.93	-1.45	-0.57
TE	-1.14	-0.31	0.54	-0.02	-0.03	-0.52	0.28	-1.55	-0.60	0.01	-1.13	3.11	0.50
RoW	-1.85	-0.26	-0.97	0.03	0.02	0.13	-0.88	1.27	-1.31	0.10	-2.03	-2.24	-1.11

Table 9: Sectoral Production in 2050 (% change wrt Baseline Scenario) - 4 °C temperature increase

	Agriculture	Forestry	Fishing	Coal	Oil	Gas	Oil_Pcts	Electricity	Industries	Transport	Residential	Mkt Services	Public Services
Austria	6.42	-2.98	-2.11	-0.05	-0.09	-3.97	1.73	-1.35	-0.46	-3.01	-1.63	-0.49	0.63
Belgium	-3.89	-3.13	-4.93	-0.01	-0.08	0.01	0.67	-1.20	0.47	-0.56	-0.98	-1.21	0.04
Czech Republic	-0.08	-3.78	-4.57	-0.10	-0.08	0.06	1.20	-3.86	-0.57	-1.61	-0.44	-1.05	0.27
Denmark	12.07	-7.74	5.97	-0.03	-0.14	-1.14	1.82	1.13	-1.00	-2.78	-0.42	-0.30	0.81
Finland	16.83	-5.16	16.85	-0.10	-0.15	-8.31	2.22	-2.46	-6.75	-3.47	-1.28	2.64	3.69
France	-5.94	-6.06	-4.09	-0.04	-0.08	-1.76	1.24	-0.48	0.61	-0.77	-0.60	-0.77	-0.06
Germany	1.05	-7.57	-2.65	-0.11	-0.08	-2.14	1.59	-2.15	-1.53	-1.81	-0.75	0.24	0.62
Greece	-24.13	-4.70	-2.81	0.27	-0.11	-5.14	-0.94	-1.79	-3.61	16.61	-15.32	-6.54	-6.97
Hungary	3.99	-8.85	-8.39	-0.02	-0.24	1.66	0.81	2.86	-2.81	-1.64	0.21	-1.67	0.18
Ireland	-0.45	-7.07	-4.26	-0.04	-0.08	-2.50	0.88	-0.67	-0.02	-2.39	-0.71	-2.40	-0.43
Italy	-7.28	-2.28	-17.91	0.18	-0.03	-0.81	0.02	3.44	4.35	0.23	-4.86	-3.71	-3.17
Netherlands	1.89	-6.53	6.49	-0.03	-0.14	-0.72	-1.59	-1.24	-1.28	-0.76	-1.19	-1.64	-0.29
Poland	-0.93	-3.74	-0.22	-0.08	-0.07	-1.68	1.46	-2.11	-1.24	-1.22	-0.01	-0.43	0.72
Portugal	-15.75	-6.16	-10.48	0.22	0.01	0.89	0.50	3.91	7.98	1.59	-6.67	-2.30	-4.96
Spain	-22.96	-1.71	-9.23	0.19	0.08	-4.27	-0.98	4.55	7.59	3.62	-12.90	-2.66	-5.02
Sweden	16.00	-4.77	7.67	-0.02	-0.02	0.16	0.25	-3.67	-3.78	-3.17	-4.30	1.39	1.75
United Kingdom	3.62	-4.49	-0.07	-0.06	-0.16	-1.93	0.67	-1.41	-1.41	-1.84	-1.03	0.18	0.36
RoEU	4.71	-11.52	-10.45	-0.37	-0.42	-2.08	-0.68	-3.01	-3.56	-3.45	0.68	-1.44	1.09
RoOECD	-3.05	-8.09	3.37	-0.13	-0.27	-1.66	3.79	1.41	-7.31	-2.90	-2.03	2.69	1.16
CHIND	-0.31	-1.50	-1.53	0.06	-0.02	0.28	0.66	0.03	0.59	-1.56	-4.04	-3.51	-2.52
TE	-2.95	-0.95	1.15	-0.15	-0.15	-1.52	1.65	-3.61	-2.89	0.24	-2.54	10.93	2.51
RoW	-4.47	-0.75	-2.18	0.07	0.03	0.03	-3.17	1.11	-2.63	0.68	-7.82	-5.30	-4.39

Table 10: Labour demand in 2050 (% change wrt Baseline Scenario) - 2 °C temperature increase

	Agriculture	Forestry	Fishing	Coal	Oil	Gas	Oil_Pcts	Electricity	Industries	Transport	Residential	Mkt Services	Public Services
Austria	5.68	-1.83	-3.26	-0.19	-0.35	-1.53	-1.50	-0.69	-0.18	-2.03	-0.27	-0.08	0.18
Belgium	-0.24	-2.24	-3.28	0.10	-0.14	-0.27	-0.48	0.18	0.55	-0.38	0.18	-0.24	-0.11
Czech Republic	1.14	-1.66	-3.57	-0.13	-0.22	-0.38	-0.89	-1.37	-0.11	-1.14	0.09	-0.19	0.19
Denmark	12.40	-3.63	0.19	-0.33	-0.61	-1.70	-2.51	-0.39	-1.13	-3.63	0.26	-0.30	0.39
Finland	16.88	-3.40	3.89	-0.69	-0.89	-4.50	-4.08	-2.94	-4.03	-4.51	-1.68	0.07	0.84
France	-0.96	-2.87	-3.04	0.20	-0.14	-0.29	-0.34	0.50	0.76	-0.42	-0.04	-0.09	-0.07
Germany	1.23	-3.42	-3.27	-0.17	-0.36	-0.95	-1.30	-0.75	-0.39	-1.49	-0.29	0.40	0.19
Greece	-5.70	-1.93	-2.02	0.83	0.87	2.46	4.75	4.14	1.51	8.70	-1.31	1.26	-0.52
Hungary	2.66	-3.85	-4.50	0.12	-0.41	0.89	-1.67	0.98	-1.37	-2.15	-0.04	-1.26	-0.07
Ireland	0.71	-2.76	-3.24	-0.02	-0.27	-0.59	-0.90	-0.04	0.52	-1.54	0.33	-0.41	0.01
Italy	-0.93	-1.04	-7.93	0.50	0.12	0.65	0.87	2.46	2.18	0.96	0.72	-0.73	-0.90
Netherlands	1.70	-3.45	0.97	-0.04	-0.27	-0.27	-1.67	-0.21	-0.31	-1.15	-0.04	-0.14	0.10
Poland	0.67	-1.82	-2.89	-0.08	-0.25	-0.88	-0.85	-0.98	-0.35	-1.11	0.09	0.19	0.35
Portugal	-2.68	-3.16	-3.90	0.59	0.22	1.56	1.56	2.87	3.20	1.54	-0.24	-0.50	-1.27
Spain	-5.85	-0.91	-4.47	0.97	0.51	0.79	3.08	4.94	3.89	3.89	-2.08	-0.12	-0.80
Sweden	14.49	-2.49	0.01	-0.30	-0.60	-1.56	-2.80	-1.41	-1.62	-2.48	-2.06	0.63	0.34
United Kingdom	3.83	-2.64	-2.34	-0.19	-0.38	-1.04	-1.73	-0.59	-0.66	-1.72	-0.23	0.38	0.25
RoEU	2.36	-4.76	-7.03	-0.39	-0.55	-1.20	-2.64	-2.05	-1.69	-3.07	-0.22	-1.35	0.01
RoOECD	-0.86	-3.94	-0.98	-0.26	-0.61	-1.10	-2.42	-0.07	-2.54	-2.70	-1.14	1.06	0.06
CHIND	0.74	-1.20	-1.54	0.33	0.09	0.93	0.96	1.39	0.60	-0.16	-0.41	-1.02	-0.40
TE	-0.42	-0.95	-1.19	-0.18	-0.31	-1.70	-1.35	-2.78	-1.00	-0.78	-0.38	3.96	0.48
RoW	-0.07	-1.23	-1.96	0.79	0.55	1.31	2.42	3.67	0.11	2.31	-0.30	-0.92	-0.59

Table 11: Labour demand in 2050 (% change wrt Baseline Scenario) - 4 °C temperature increase

	Agriculture	Forestry	Fishing	Coal	Oil	Gas	Oil_Pcts	Electricity	Industries	Transport	Residential	Mkt Services	Public Services
Austria	8.16	-4.76	-9.65	-0.67	-1.17	-4.71	-4.49	-2.08	-0.35	-5.21	-0.25	0.10	0.93
Belgium	-0.37	-6.25	-10.21	-0.11	-0.73	-0.88	-2.79	-0.50	0.71	-1.48	0.73	-0.29	0.08
Czech Republic	3.09	-4.47	-10.50	-0.65	-0.89	-0.86	-3.51	-4.40	-0.64	-3.28	0.50	-0.27	0.77
Denmark	12.62	-9.92	-2.58	-0.71	-1.35	-3.73	-5.37	-0.44	-1.20	-6.18	-0.29	-0.21	0.81
Finland	15.26	-7.64	6.06	-1.62	-2.22	-9.94	-9.51	-6.16	-8.43	-9.06	-2.66	1.29	3.35
France	-2.47	-8.16	-9.23	-0.03	-0.84	-1.76	-2.72	-0.13	0.88	-2.47	0.19	0.10	0.39
Germany	3.38	-9.34	-9.40	-0.73	-1.35	-2.86	-4.36	-2.53	-1.51	-4.55	-0.03	1.22	0.95
Greece	-16.79	-4.57	-6.32	1.21	2.29	3.32	14.96	8.10	3.07	31.83	-7.80	5.21	-4.08
Hungary	5.80	-9.44	-12.60	-0.16	-1.43	1.34	-5.99	1.19	-3.67	-5.56	0.36	-2.16	0.15
Ireland	1.93	-7.31	-8.93	-0.44	-1.01	-2.12	-3.47	-1.12	1.33	-5.05	1.13	-0.95	0.05
Italy	-2.58	-2.40	-17.91	0.97	0.05	0.12	0.76	5.13	6.06	2.08	-0.49	-0.85	-2.96
Netherlands	4.46	-9.74	-1.43	-0.52	-1.07	-1.22	-6.11	-1.60	-1.49	-3.32	0.12	-0.17	0.44
Poland	1.98	-4.62	-9.03	-0.49	-0.97	-2.19	-3.19	-2.83	-1.08	-3.35	0.77	0.60	1.05
Portugal	-8.63	-7.40	-11.66	1.33	0.49	2.92	3.64	6.26	9.59	4.78	-3.31	-0.16	-4.64
Spain	-15.61	-1.84	-11.78	2.22	1.22	-0.63	7.30	10.91	10.68	11.15	-9.81	0.65	-3.83
Sweden	15.07	-6.19	-4.26	-1.02	-1.81	-3.85	-7.98	-3.76	-4.14	-6.17	-4.08	1.55	1.77
United Kingdom	5.37	-6.65	-7.46	-0.74	-1.25	-3.07	-5.28	-1.78	-1.55	-4.86	0.24	1.08	0.80
RoEU	6.14	-11.85	-20.68	-1.56	-1.91	-3.70	-8.82	-6.73	-5.12	-8.91	-0.48	-2.97	0.63
RoOECD	-2.33	-11.06	-5.51	-1.32	-2.20	-4.07	-8.10	-2.02	-8.01	-8.49	-1.18	2.84	1.18
CHIND	1.93	-3.07	-4.72	0.59	-0.06	1.11	0.48	2.28	1.91	-0.78	-1.68	-1.75	-1.92
TE	-1.49	-2.93	-2.10	-1.07	-1.49	-4.95	-6.11	-7.89	-4.60	-3.62	-0.45	13.24	2.27
RoW	0.38	-3.28	-6.04	1.86	1.28	2.31	4.56	6.94	1.21	6.25	-2.61	-1.38	-2.92

Table 12: World prices in 2050 (% change wrt Baseline Scenario) – 2 °C and 4 °C temperature increase

	2 °C	4 °C
Agriculture	2.00	5.42
Forestry	-5.60	-14.51
Fishing	-8.76	-25.43
Coal	-0.75	-4.03
Oil	-1.97	-7.12
Gas	-1.82	-5.50
Oil_Pcts	-1.93	-6.90
Electricity	-1.11	-3.44
Industries	-0.26	-0.89
Transport	-1.06	-3.34
Residential	0.46	2.89
Mkt Services	0.12	0.49
Public Services	-0.01	0.55

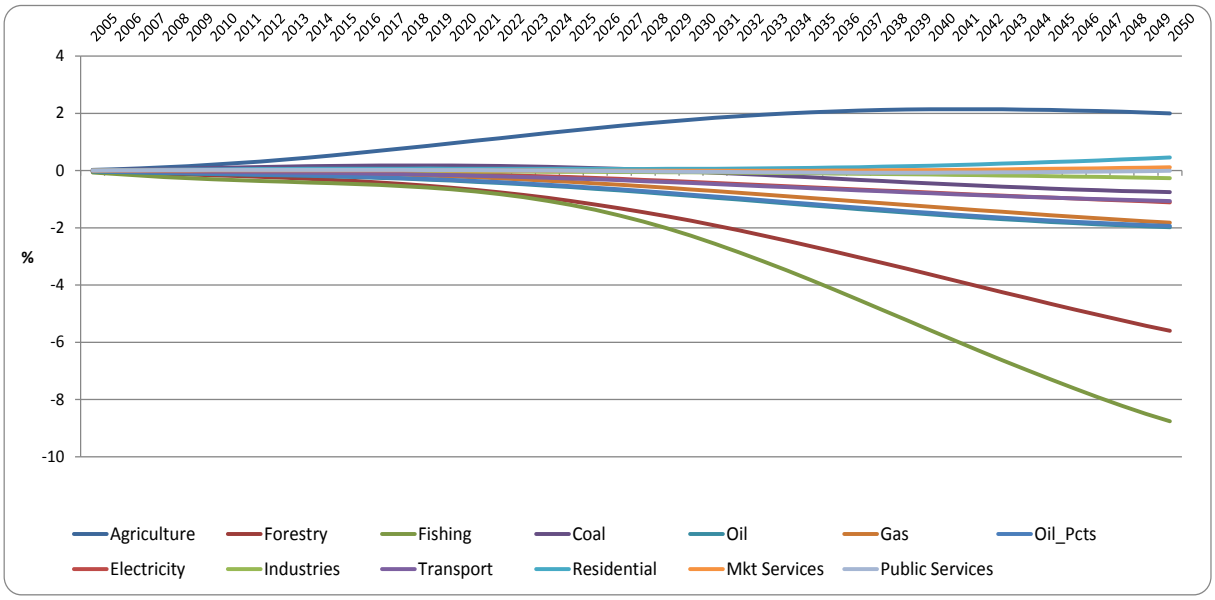

Figure 6: World prices: % change wrt baseline - 2 °C temperature increase

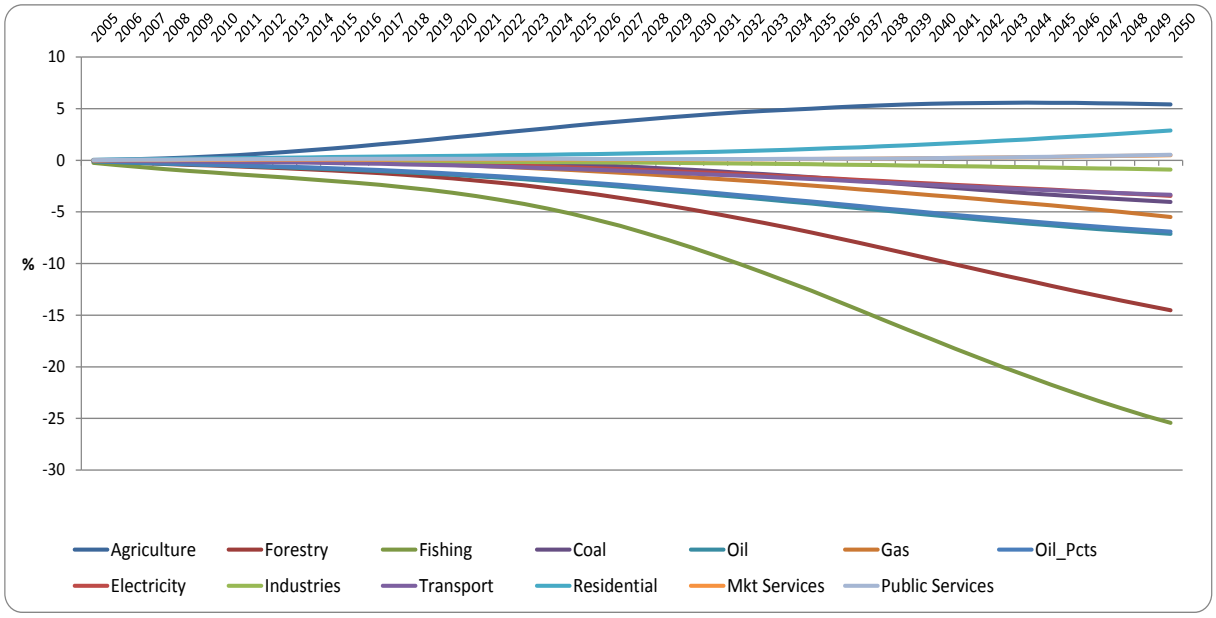

Figure 7: World prices: % change wrt baseline - 4 °C temperature increase

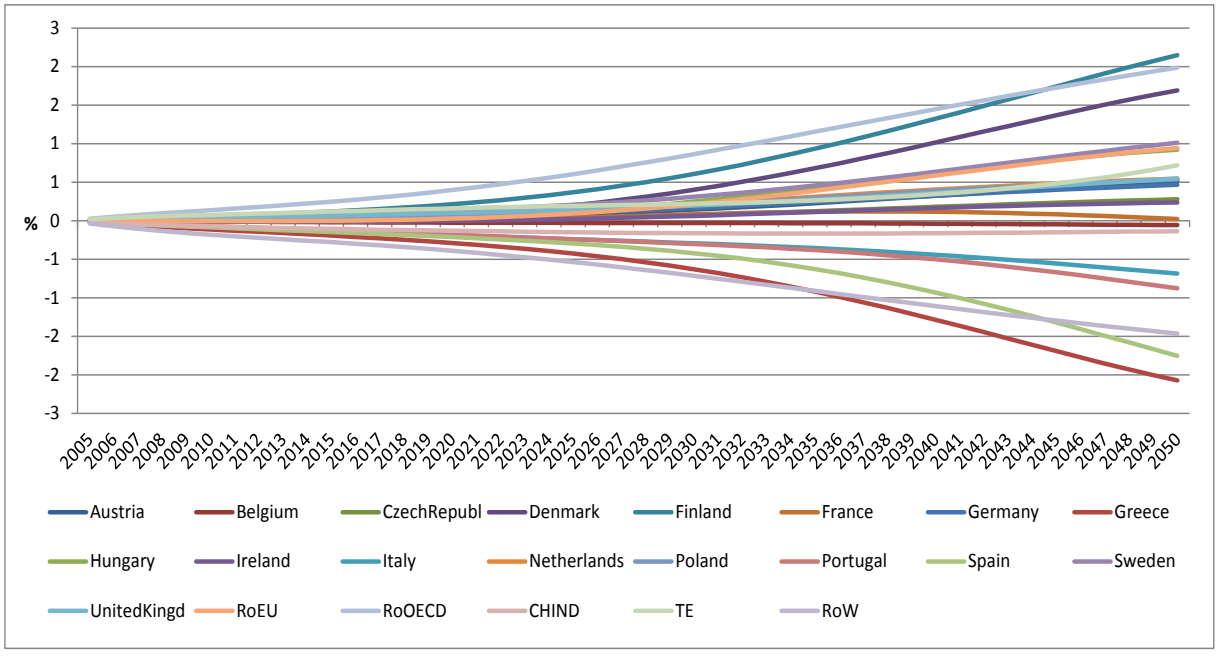

Figure 8: Terms of trade: % change wrt baseline - 2 °C temperature increase

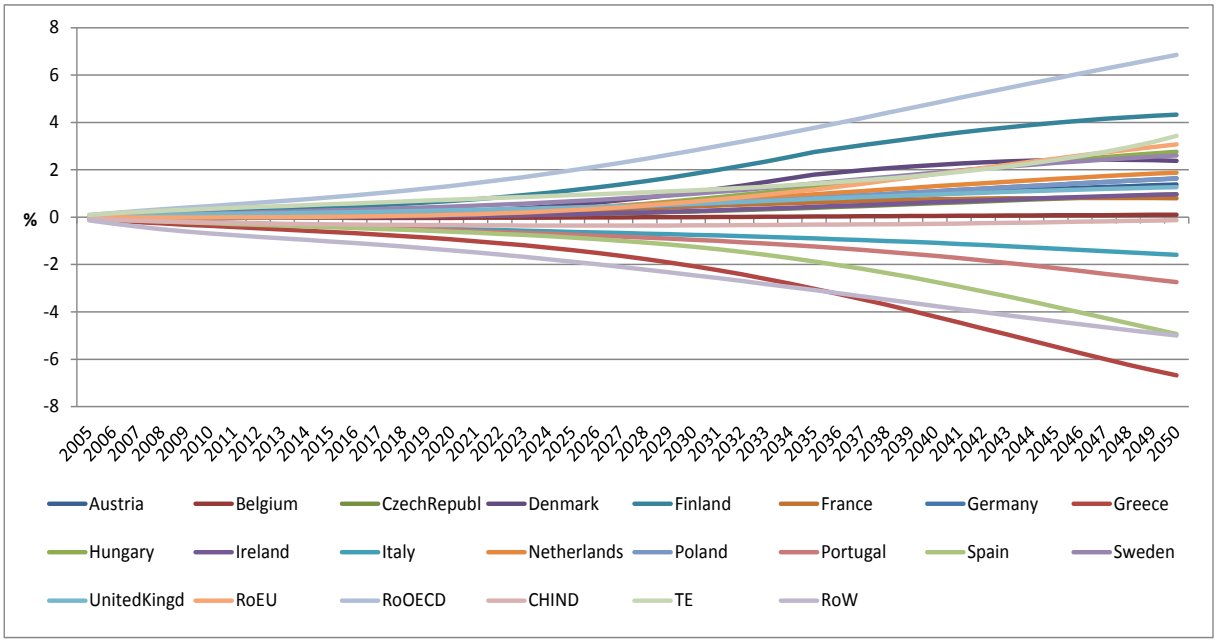

Figure 9: Terms of trade: % change wrt baseline - 4 °C temperature increase

4. DISCUSSION AND CONCLUSIONS

The present research develops a climate change integrated impact assessment exercise, whose economic evaluation is based on a CGE approach and modeling effort.

Impact types considered are those originated by: sea-level rise, changes of energy demand, of crops productivity, of fish stock productivity, of tourism flows, ecosystem losses, flooding and health. Information on all the impacts mentioned, except those on health and flooding, are available with a global coverage. Data on health and flooding are available for the EU only.

Impacts are economically assessed for a 2 °C and 4 °C warming scenarios, both are assumed to occur in 2050.

ICES estimates indicate that a temperature increase of 2°C compared to pre-industrial levels in 2050 could lead to global GDP losses of about 0.7% compared to a hypothetical scenario where no climate change is assumed to occur. Doubling the temperature increase world losses are the -1.8% of GDP.

The EU 27 as a whole experiences a GDP loss of the -0.16% and the -0.74% in the 2°C and 4°C cases respectively. The apparent low vulnerability of the EU hide important country specificities: the Euro Mediterranean region is more severely hit

with Greece top-loser (-1.76% and -6.24% of GDP in 2050 in the 2°C and 4°C temperature increase scenarios respectively), the Northern one gaining or remaining basically unaffected. Among impacts type, agriculture clearly dominates, followed by tourism and ecosystem. These three impacts together build more than 70% of the final GDP result in the majority of the EU countries. Interesting is also country specific vulnerability. For instance, in Greece and Spain, agriculture and tourism impacts are the more concerning by far; agriculture is less of an issue in Italy, Belgium and Poland, where on the contrary tourism and ecosystem losses there appear to be more important.

Sectoral production tends to follow generally the direction of the climatic shocks, but not always as impacts interactions and aggregate effects also play a role in determining the final outcome. The more evident result is the negative performance of agricultural sectors especially in Spain, Greece, Portugal (-8.7%, -8.5%, -5.2% respectively in the 2°C temperature increase scenario in 2050) and partly in Italy and France (-2.7%, -2.3% respectively in the 2°C temperature increase scenario in 2050); the negative impacts on the service sector encompassing negatively hit recreational tourism services in the same countries (-2.08% in Greece, -1.01% in Spain, -0.97% in Portugal, -1.34% in Italy in the 2°C 2050); the decline in fishery production in Italy and Spain (-8.3%, -3.9% respectively in the 2°C scenario in 2050); the generalized prevalence of production contraction in the energy sectors driven by the slump of world energy demand. Interestingly industrial production declines also in Denmark and Finland (-0.8%, -3.1% respectively in 2050 in the 2°C temperature increase scenario) notwithstanding the positive GDP impact of climate change in those countries. The contraction in world demand in fact impact negatively industrial production also in those countries where climate change is positive.

The ICES CGE model depicts a Walrasian, perfectly clearing/full employment labour market therefore unemployment is not modelled. Any shock on the labour market implies just a re-distribution of the labour forces from those sectors whose production, and factor prices, are declining in relative terms, toward those sectors where the opposite happens. This said, the redistribution of the labour force could indirectly provide some insights of possible tensions on the labour market that climate change may originate. In 2050, when the temperature increases 2°C, higher labour demand contractions are concentrated in the agricultural sector especially in Greece (-5.7%), Spain (-5.9%) and Portugal (-2.7%); in the fishing sector in Italy (-7.9%) and Spain (-4.5%); in the service sector in Hungary (-1.3%), Italy (-0.7%) and Portugal (-0.5%). Industrial labour demand declines particularly in Finland (-4%), Sweden (-1.6%) and Hungary (-1.4%); energy sectors tend also to expel labour force.

The dynamics induced on world prices - generalized decline except of those of agricultural commodities - tends to benefit EU countries terms of trade with the exception of Greece, Spain, Portugal and also Italy where the GDP contraction is particularly high and domestic prices decreases more compared to imported prices.

To conclude the major caveats in interpreting these results are discussed.

Firstly, the impact list here considered, albeit wide, is still incomplete. Extreme events like droughts and more in general hydro-geological risk not only associated to river floods deserve a much better coverage and consideration.

Secondly, the treatment of non market ecosystem losses is highly speculative, and uncertain. This is another field of research where economic assessment, especially conducted with a macro perspective is almost lacking.

Thirdly, high simplifications have been also adopted to extrapolate impacts of the 2°C case to the 4°C scenario which prevented the consideration of discontinuities which are typical of environmental phenomena. By the same token, simplifying assumptions have been adopted to match the geographical specification of the impact study source of the inputs for the CGE model and that of the CGE model itself.

Fourthly, a set of specific warnings relate to the specific economic investigation tool used: CGE models are based on a “Walrasian” view of the economic system, where all markets are in equilibrium and respond to the decision of optimising agents. Accordingly they cannot examine imperfect markets’ behaviour. In the specific case, this is particularly relevant for the analysis of labour market effects of climate change. Basically: the current CGE model is not appropriate for that analysis if not to highlight just some potential “tensions” that in that market may originate. In CGE models the adjustment to equilibrium is instantaneous, thus they cannot represent frictions nor transitions. CGE models are usually calibrated to some specific years, thus they can offer reliable information only if the economic context remains reasonably similar to the initial one, therefore they should be used only for short-term analyses. CGE models are usually static and, when dynamic, they usually allow for myopic expectations and systematic errors. To conclude, CGE models are GDP oriented. Accordingly their assessment is more sensitive to shocks affecting flows and not stocks. This means that for instance stock losses like those affecting land or more generally property values, are only indirectly and partially captured as long as they impair the ability of one country to produce goods and services. In this sense stock losses are underestimated by CGE models.

All this said, this exercise is however useful in highlighting at least some qualitative tendencies and the order of magnitude of the phenomena involved.

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