FONDAZIONE ENI ENRICO MATTEI

Climate change impacts and market driven adaptation: The costs of inaction including market rigidities

EUROPEAN COMMISSION
European Research Area

SEVENTH FRAMEWORK PROGRAMME

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FEEM - IEFE Joint Seminar
Venice, 17th July 2014

1. Introduction

Research part of the GLOBAL IQ Project - *Impacts Quantification of global changes an* EU Seventh Framework Programme (FP7/2007-2013), in which climate change is one of the global challenges considered.

Whereas responses to climate change can be in the form of mitigation or adaptation measures, for the purposes of this paper we focus only on adaptation and consider mitigation efforts as exogenous.

Adaptation: Adjustments in response to actual or expected climatic stimuli, and their effects or impacts to:

- moderate or offset potential damages
- take advantages of opportunities associated with changes in climate

These actions can be broadly classified as ***autonomous*** or ***planned*** adaptation.

Market-driven (autonomous) adaptation: Adjustments in supply and demand following changes in relative prices triggered by climate change impacts.

Cost of inaction: There are ***no policy-driven nor planned-adaptation*** responses to climate change, but only market adjustments.

2. Motivation

- The assessments of climate change impacts are important to understand its possible consequences and therefore design appropriate policy responses.
- Computable General Equilibrium (CGE) models are among the tools used for these assessments → allow for endogenous price formation and market autonomous response to economic shocks (Ciscar et al., 2011, 2013, Aaheim et al. 2010, Eboli et al. 2010)
- The nature of a CGE model, in which all sectors and regions are interconnected, allows to capture the propagation of indirect effects related to different climate change impacts.

- As every model, CGEs rely on a series of assumptions:
  - Frictionless and instantaneous adjustments to a new equilibrium after a shock affecting relative prices.
  - Strong degree of substitutability in both production and consumption structures
  - This kind of assumptions could underestimate the final outcomes.

➢ Extend the our assessment estimates by relaxing these assumptions.

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2. Objectives

✓ Climate change as a global challenge

→ what is its economic relevance?

✓ What is the role of market-driven adaptation?

- Firstly “full market-driven adaptation” is assumed,
- Then limits or frictions in market adjustments are introduced.

✓ Does CC impact estimates from CGE models “differ” from other Integrated Assessments (IA)?

- Construction of reduced-form climate change damage functions starting from CGE results
- Comparison with the existing modelling literature developing “hard linked IA models”.

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3. The model: ICES

Recursive dynamic computable general equilibrium (CGE) model

- ✓ Based on the GTAP 8 database (Narayanan et al. 2012). Calibration year 2007
- ✓ Simulation period: 2007-2050 in one-year time steps
- ✓ 25 countries/regions (this study)
- ✓ 19 sectors (this study)
- ✓ Standard in CGE essence:
  - ✓ Inter sectoral and international trade flows explicitly modelled
  - ✓ Optimizing agents' endogenous response to (endogenous) price signals represents «market-driven adaptation»

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3. Regional and sectoral detail of the ICES model

Regional detail				
Europe	***Africa/Middle East***	***Americas***	***Asia***	***Oceania***
North Europe	North Africa	USA	Japan	Australia
North_EU15	Sub-Saharan Africa	Canada	South Korea	New Zealand
Med_EU15	South Africa	Rest of LACA	South Asia	
Med_EU12	Middle East	Brazil	India	
East_EU12		Mexico	China	
Rest of Europe			East Asia	
Russia				
Rest of FSU				

Sectoral detail	
Sectors	***Energy sectors***
Agriculture	Coal
Forestry	Oil
Fishing	Gas
Energy sectors (see right column) →	NuclearFuel
Energy Intensive industries	Oil_Pcts
Other industries	Ely_Nuclear
Transport	Ely_Biomass
Market Services	Ely_Hydro
Public Services	Ely_Solar
	Ely_Wind
	Ely_Other

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4. Climate change impacts assessed and modelling strategy

Agriculture	(Δ crop yields) Δ land productivity
Ecosystems	Δ services from physical capital stock
Energy Demand	Δ residential demand of oil, gas, electricity
Fishery	Δ natural resource stock used by the fishing industry
Forestry	Δ in productivity of natural resource stock used by the wood processing sector
Health	Δ labour productivity as well as private and public expenditures
Sea-Level Rise	Δ in land and physical capital stock
Tourism	Δ in households' demand for recreational services (part of market services) and in expenditure

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Climate change impacts: Sources

CC Impacts	Sources	Available Scenarios
Agriculture	PIK - LPJmL ISI-MIP runs	RCPs 2.6, 6.0, and 8.5
Health	Tol (2002)	Reduced form
Ecosystem	Warren et al (2006)	Reduced form
Tourism	Hamburg Tourism Model - Bigano et. al (2007) CLIMATECOST project	A1, B2
Energy demand	POLES model - Criqui (2001), Criqui et. al (2009) CLIMATECOST project	A1B
Forestry	PIK – LPJmL, Bondeau et. al (2007), Tiejten et al (2009) CLIMATECOST project	A1B
Fisheries	Cheung et. al (2010) SESAME project	A1B
Sea level Rise	Diva model - Vafeidis et. al (2008) CLIMATECOST project	A1B

Summary of scenarios

- Economic reference → Shared Socio-Economic Pathways SSP (O'Neill et al. 2012)
  - SSP2 ("middle of the road")
  - Projections for population and GDP growth trends (OECD)

- Climate change scenarios → Representative Concentration Pathways
  - Impacts reconstructed for RCPs 2.6, 6.0 and 8.5
  - Mapping impacts associated to temperature trends of A1, A1B, B2 (SRES) to each RCP.

➢ "Full" market-driven adaptation assessment

➢ "Limited" market-driven adaptation:
- Trade (*LA-TR*):
- Labor mobility (*LA-LM*):
- Primary factor substitution (*LA-PFS*):

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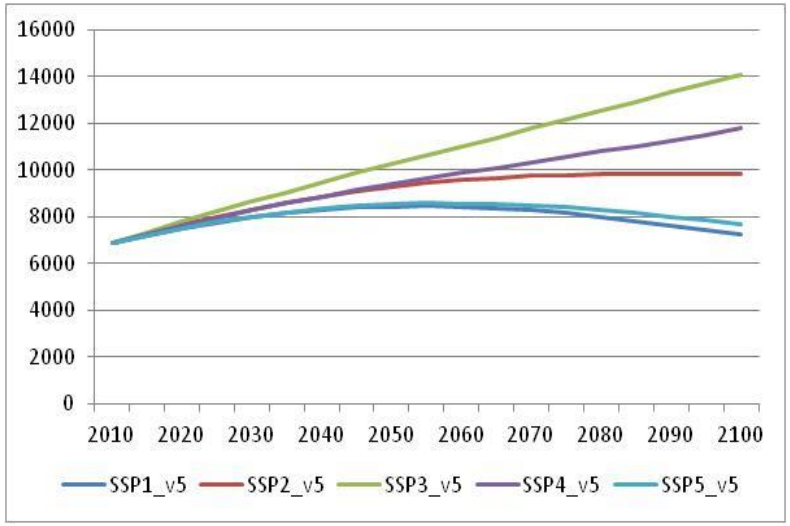
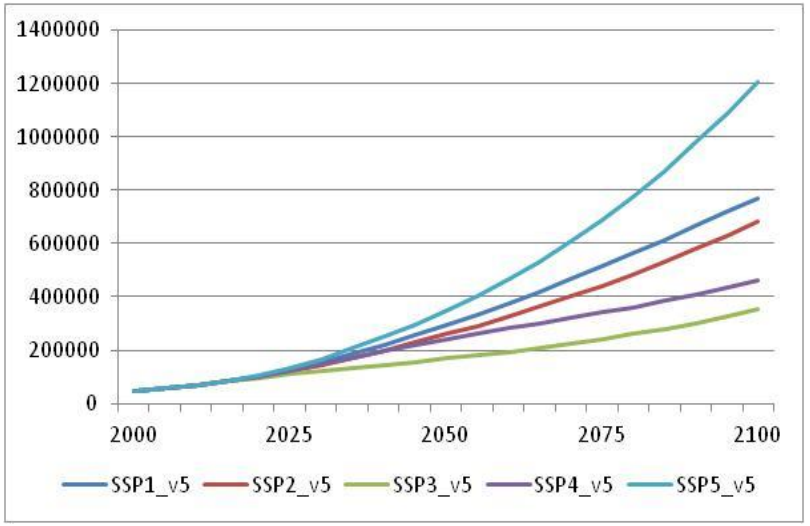
Macro economic drivers of SSP2

World population SSPs (Million)

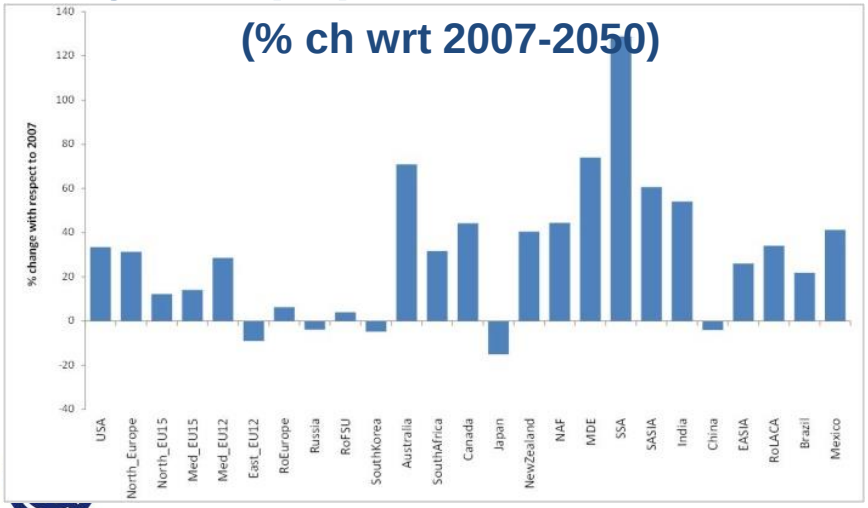


World GDP SSPs ($ Billion)



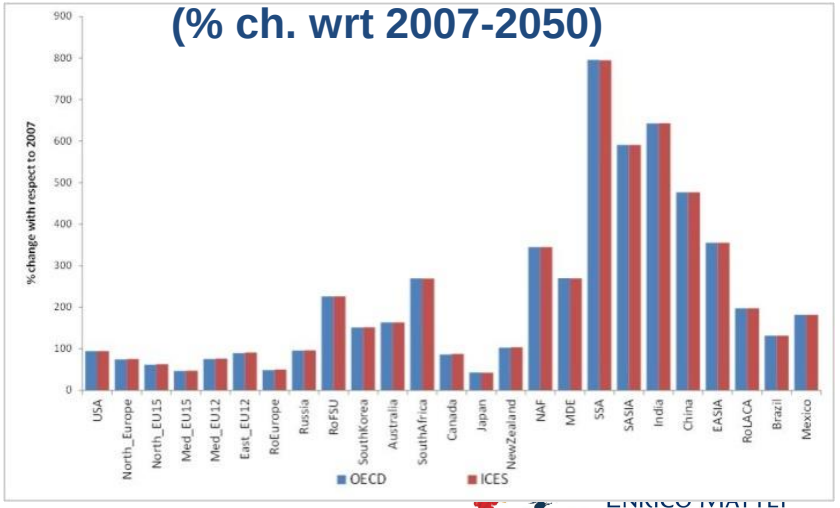
Regional population trends SSP2

(% ch wrt 2007-2050)



Regional GDP trends SSP2

(% ch. wrt 2007-2050)



Source: https://secure.iiasa.ac.at/web-apps/ene/SspDb/dsd?Action=htmlpage&page=welcome

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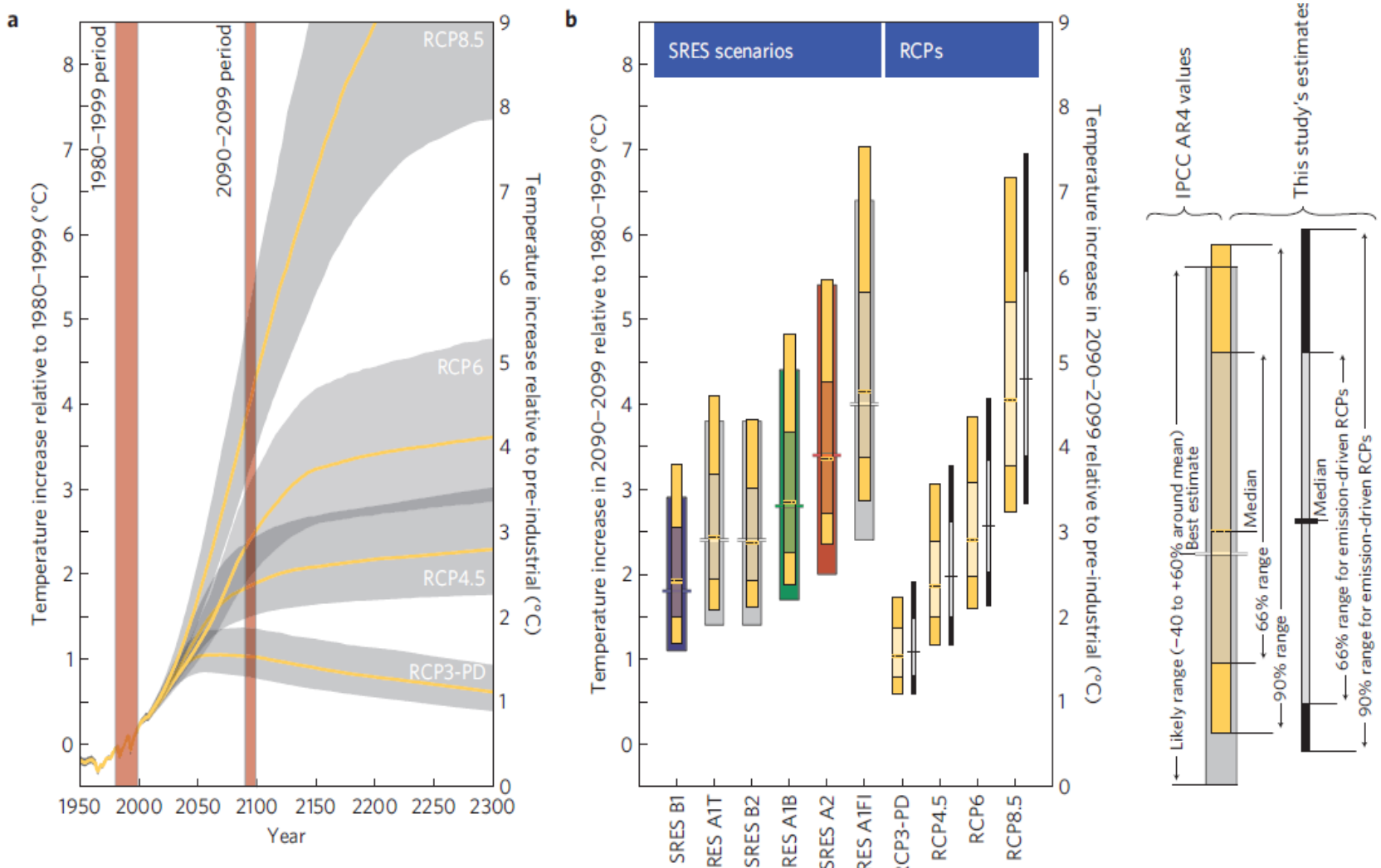
Temperature increase in the different RCPs



Source: Rogelj et al (2012)

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Full market-driven adaptation

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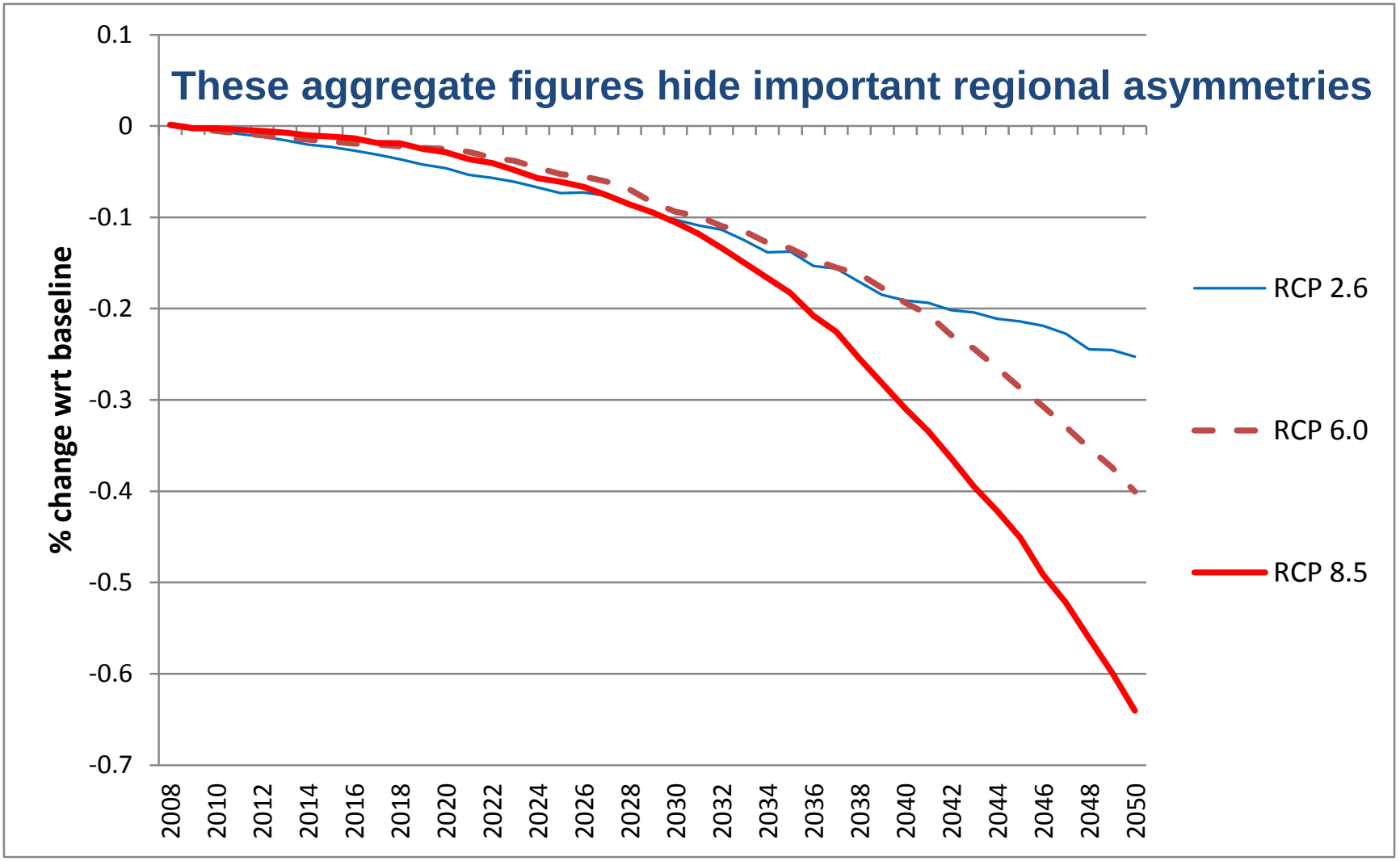
Climate Change Impact on Gross World Product



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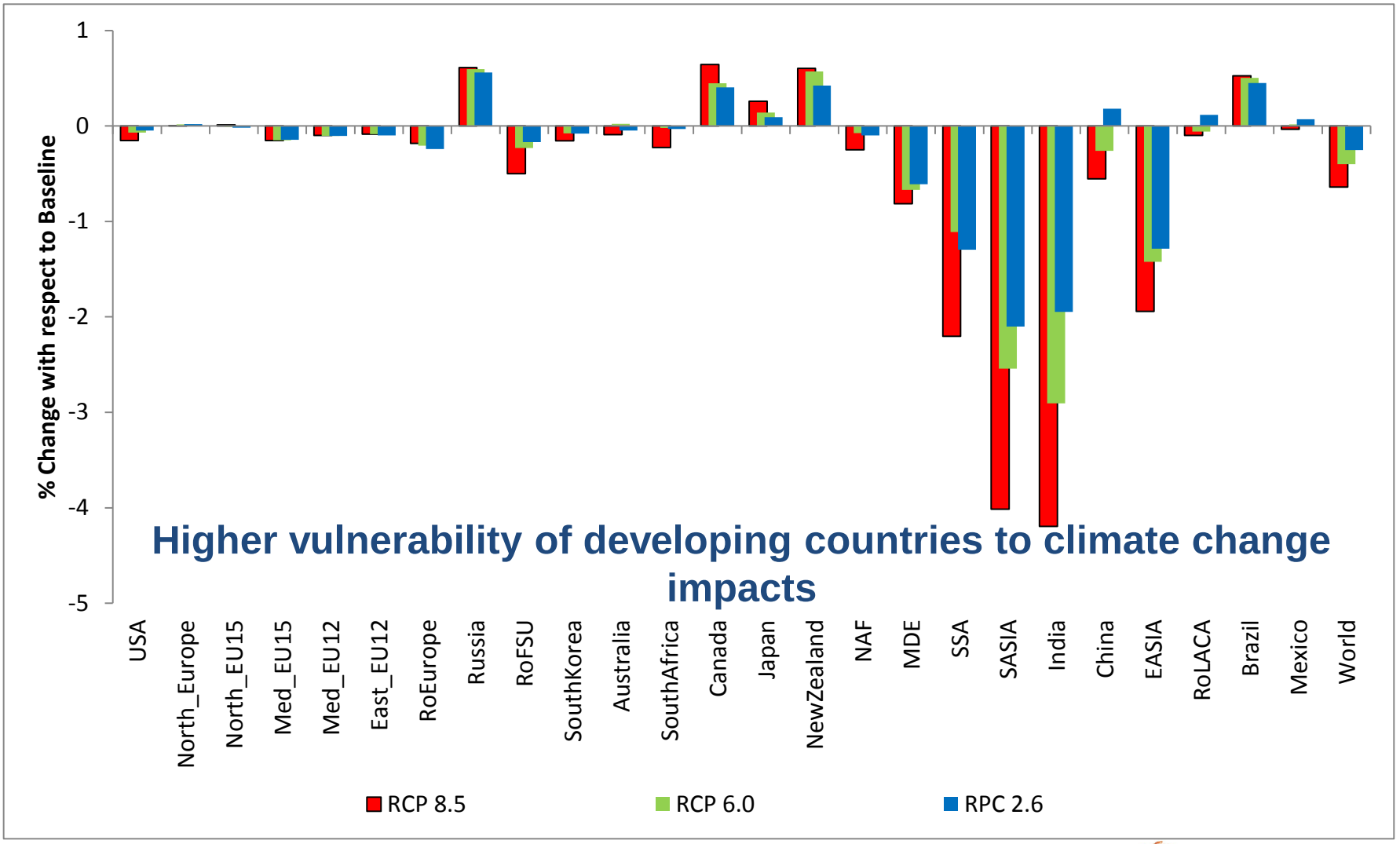
CC impacts on GDP in 2050 – regional breakdown



Higher vulnerability of developing countries to climate change impacts

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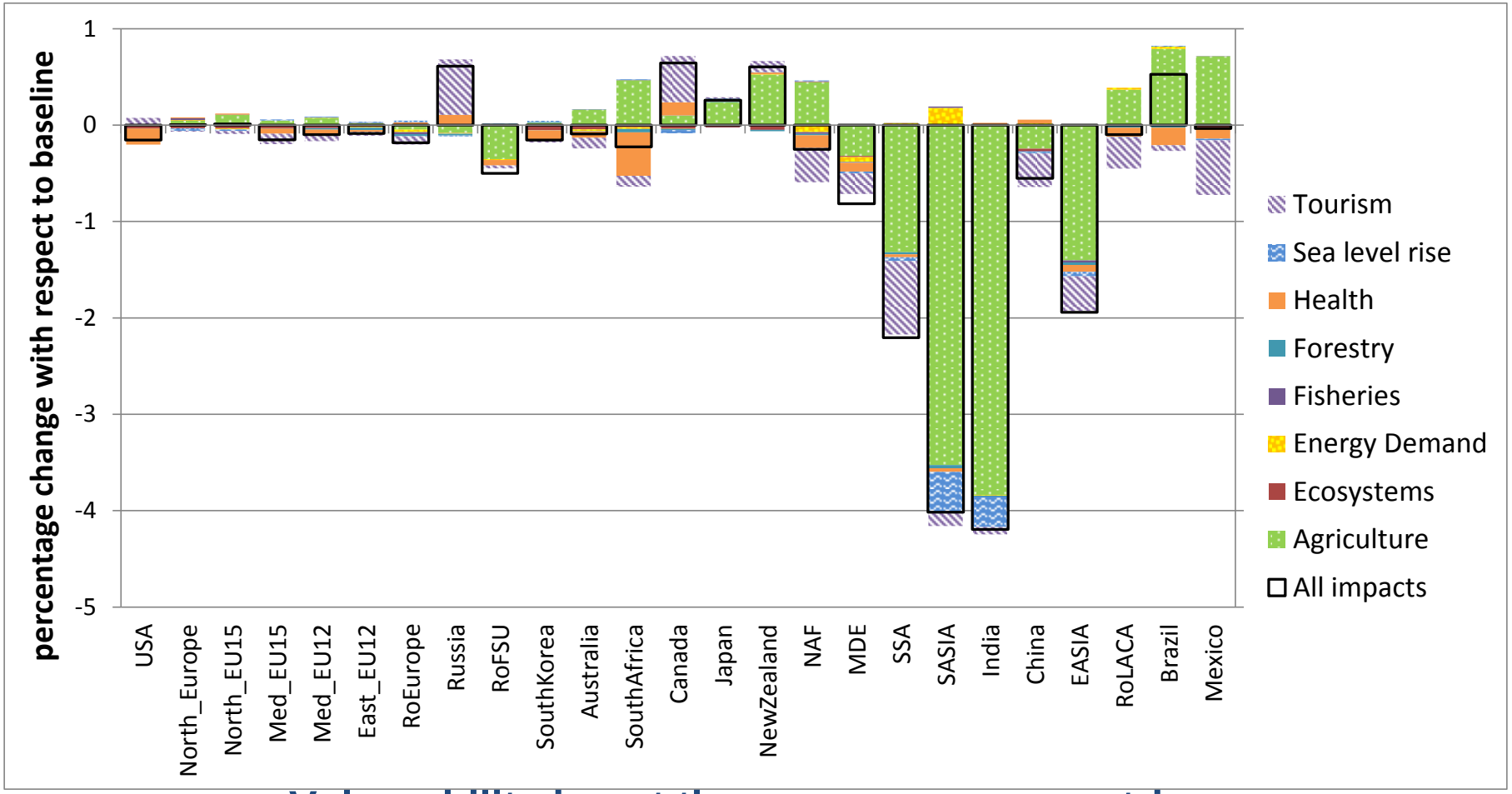
CC impacts on GDP in 2050 – decomposition RCP 8.5



Vulnerability is not the same across countries.

Most significant effects come from agriculture, tourism, sea level rise, and health

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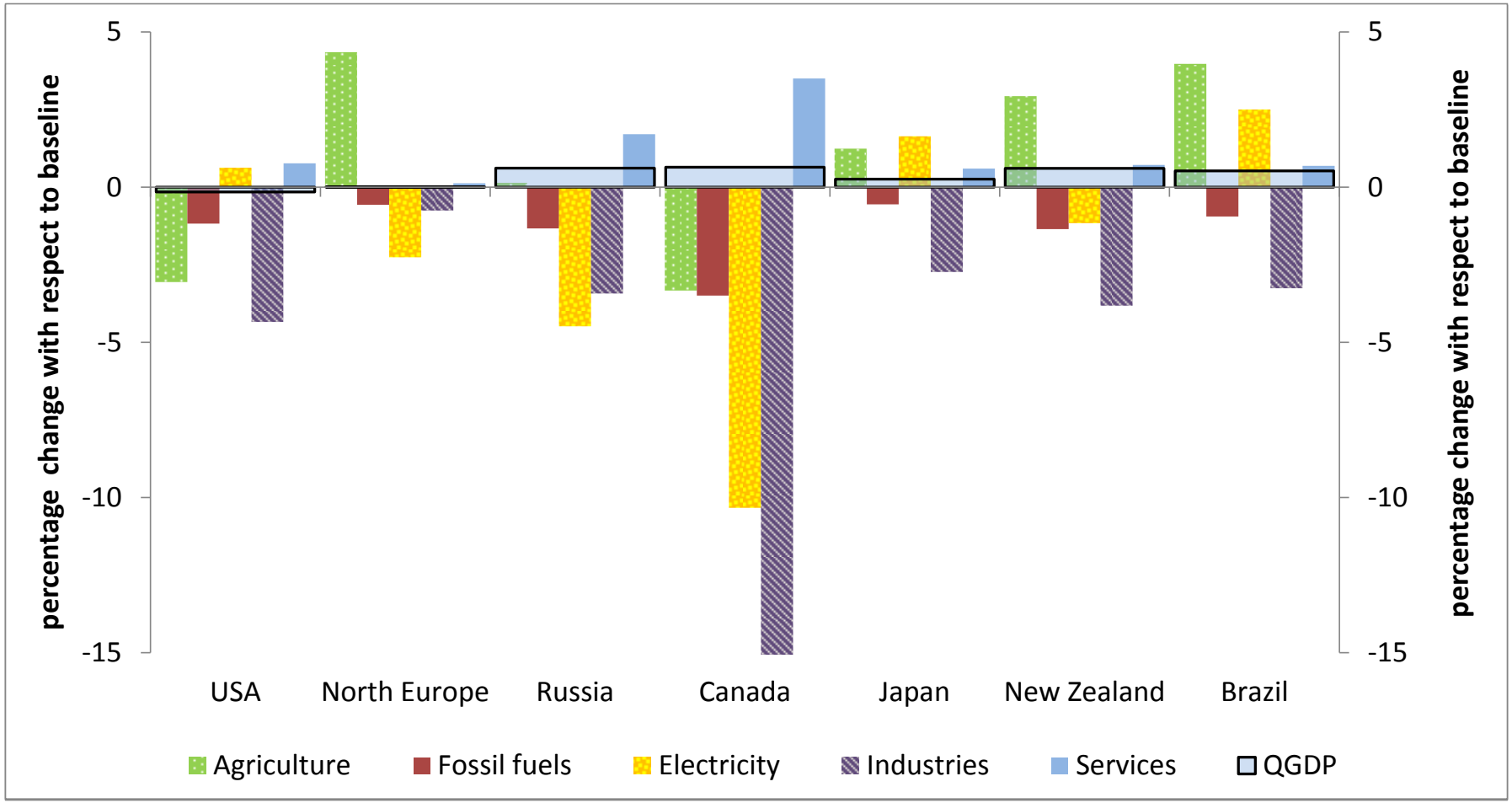
CC Impacts on GDP and value added by sector (RCP 8.5)



There are vulnerable sectors that will suffer a loss within developed regions, even though those regions experience a positive (aggregate) effect of climate change, in terms of GDP

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5. Reduced-form climate damage functions

- Use data from RCPs to obtain also different (namely 3) temperature increases and impacts on GDP for the same year.
- To “clean” or control for the social economic factors we selected as reference one single year (2050).
- For the same level of GDP in 2050 we have three pairs (GDP cost, temperature increase) for each region to account for ***market damages***.

- We include a ***catastrophic damage*** component following Nordhaus and Boyer (2000) and Nordhaus (2007).

- The ***total damage*** is the sum of ***market + catastrophic damages*** which we finally use to extrapolate the reduced-form climate change damage function.

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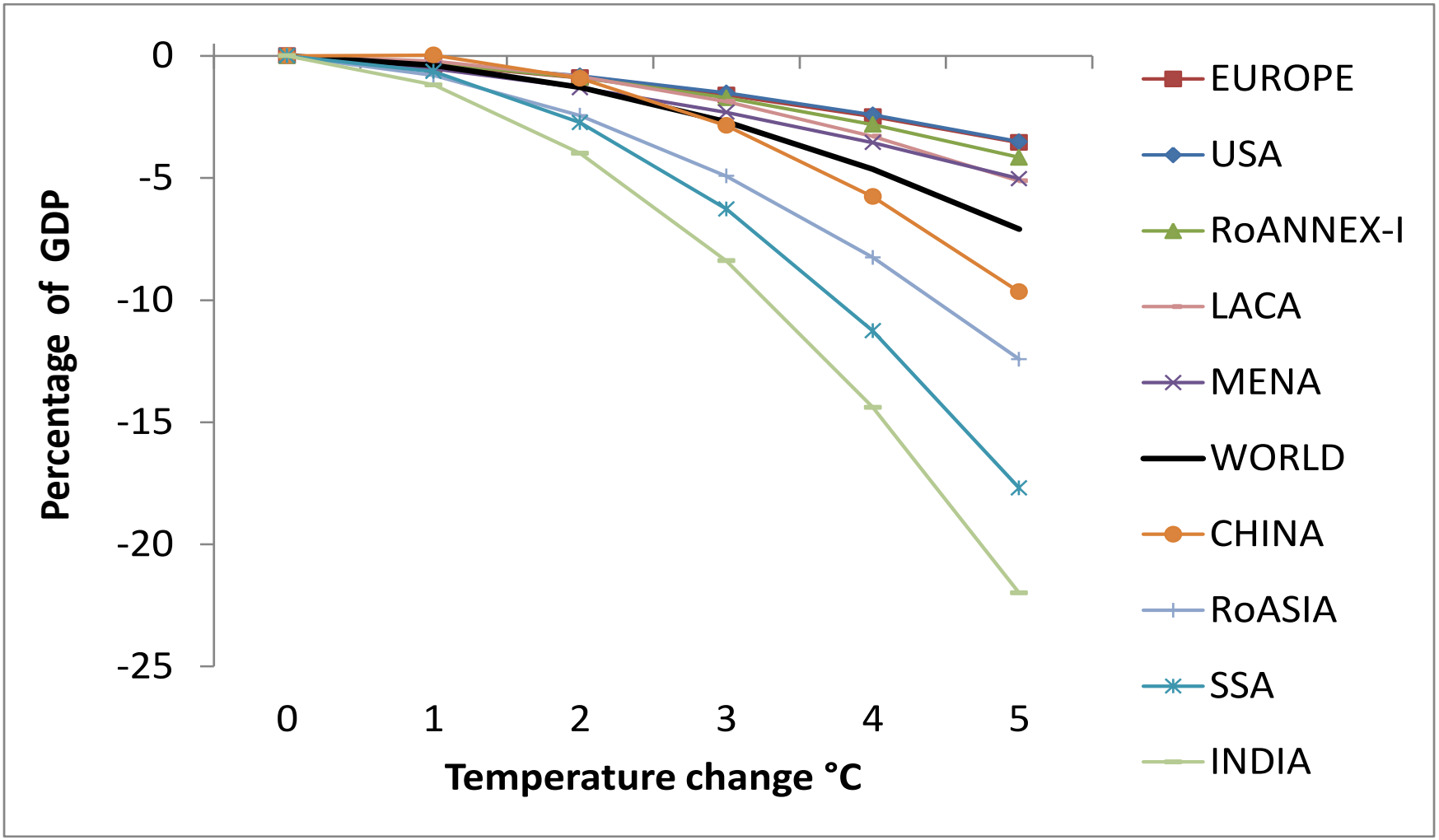
Regional reduced form damage functions for total impacts



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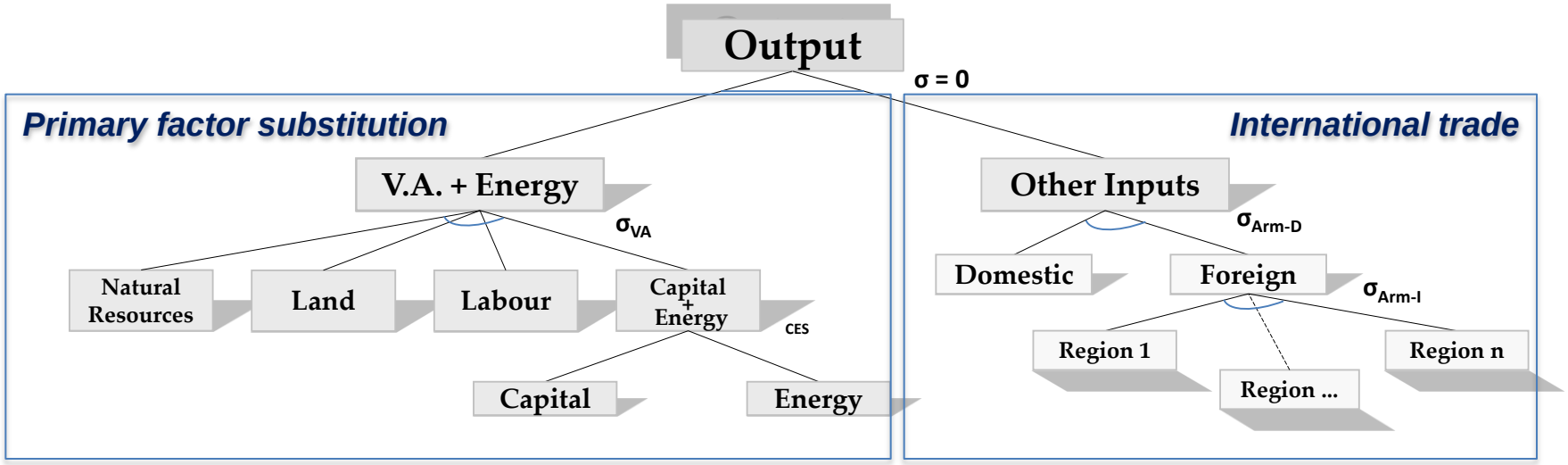
Limited market-driven adaptation

Limiting adaptation in ICES

- "Market-driven adaptation" possibilities on the supply side in ICES are governed by substitution elasticities.
- These parameters allow to model the combination possibilities of inputs as well as their sourcing (domestic or imported).



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Limited Adaptation Scenarios (1)

1. **International Trade "more difficult" *(LA-TR)*:** Reducing the model's flexibility to accommodate international trade flows.

   - Armington elasticities reduced to 75% of original values
   - Based on ratio of mean elasticity to the lower end of the 68% confidence interval: μ/(μ- 1σ). (Hertel et al., 2007)

2. **Productive processes "more difficult" - Supply side (LA-PFS):** Decreasing the flexibility to combine production factors (labor, natural resources, land and capital-energy).

   - Primary factor substitution elasticity reduced to 75% of original values
   - Based on ratio of short term to medium term elasticities. (Jomini et al., 1991)

«Limited Adaptation Scenarios (2)»

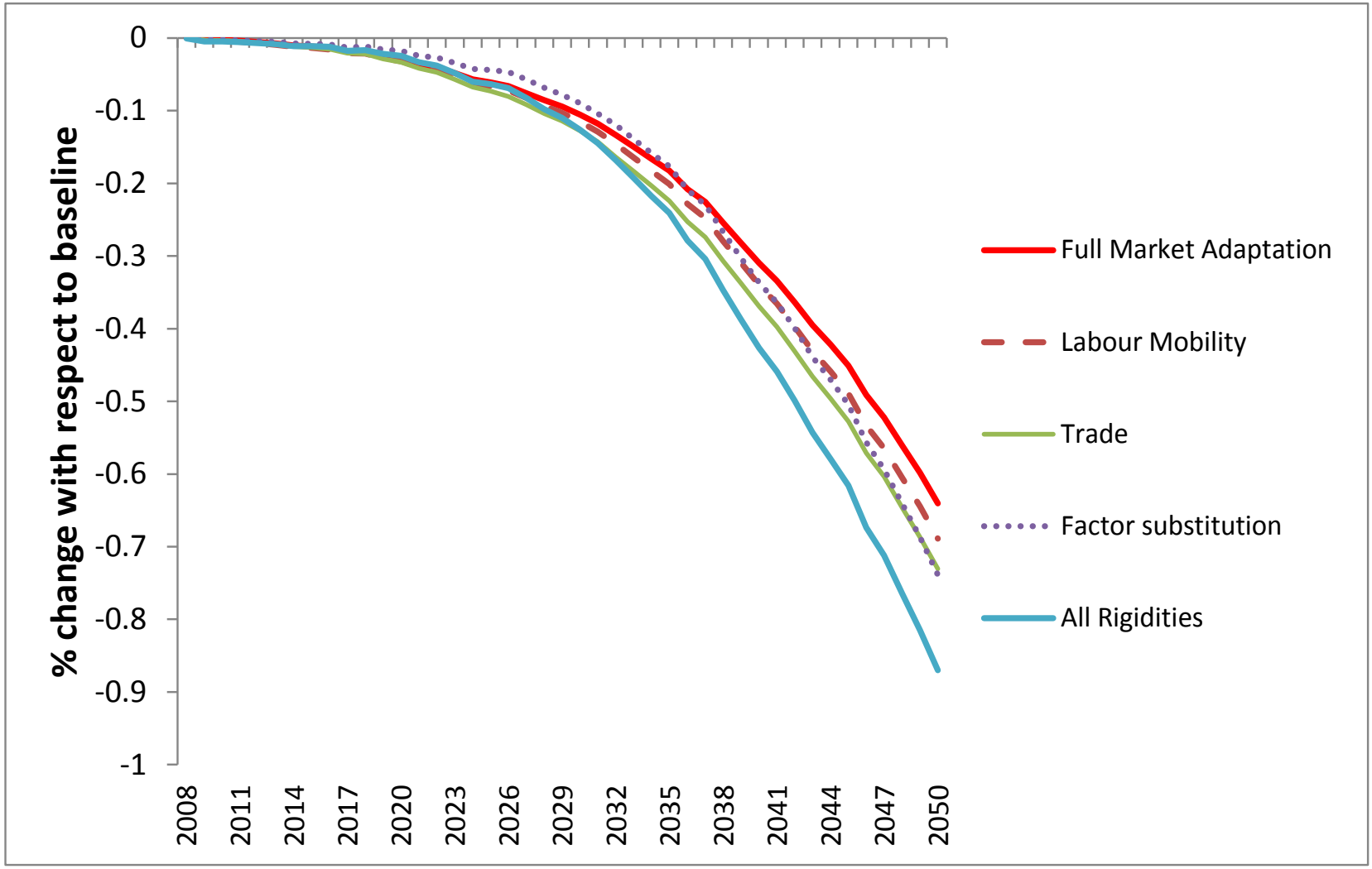
3. **Reduced labour mobility (LA-LM):** Limiting workers mobility within each region.
   - Original formulation: Labour is perfectly mobile between sectors with an uniform wage
   - Reduce labour mobility within the economy by allowing for wage differences

4. **All rigidities (LA-TR + LA-PFS + LA-LM): LA-AR**

For a consistent assessment of each rigidity we must:

- Re-calibrate the economic reference scenario (SSP2)
- Run the corresponding climate change impacts simulations for each RCP.
- Compare the CC simulations with the re-calibrated reference scenario

Climate change impacts on GWP for RCP 8.5



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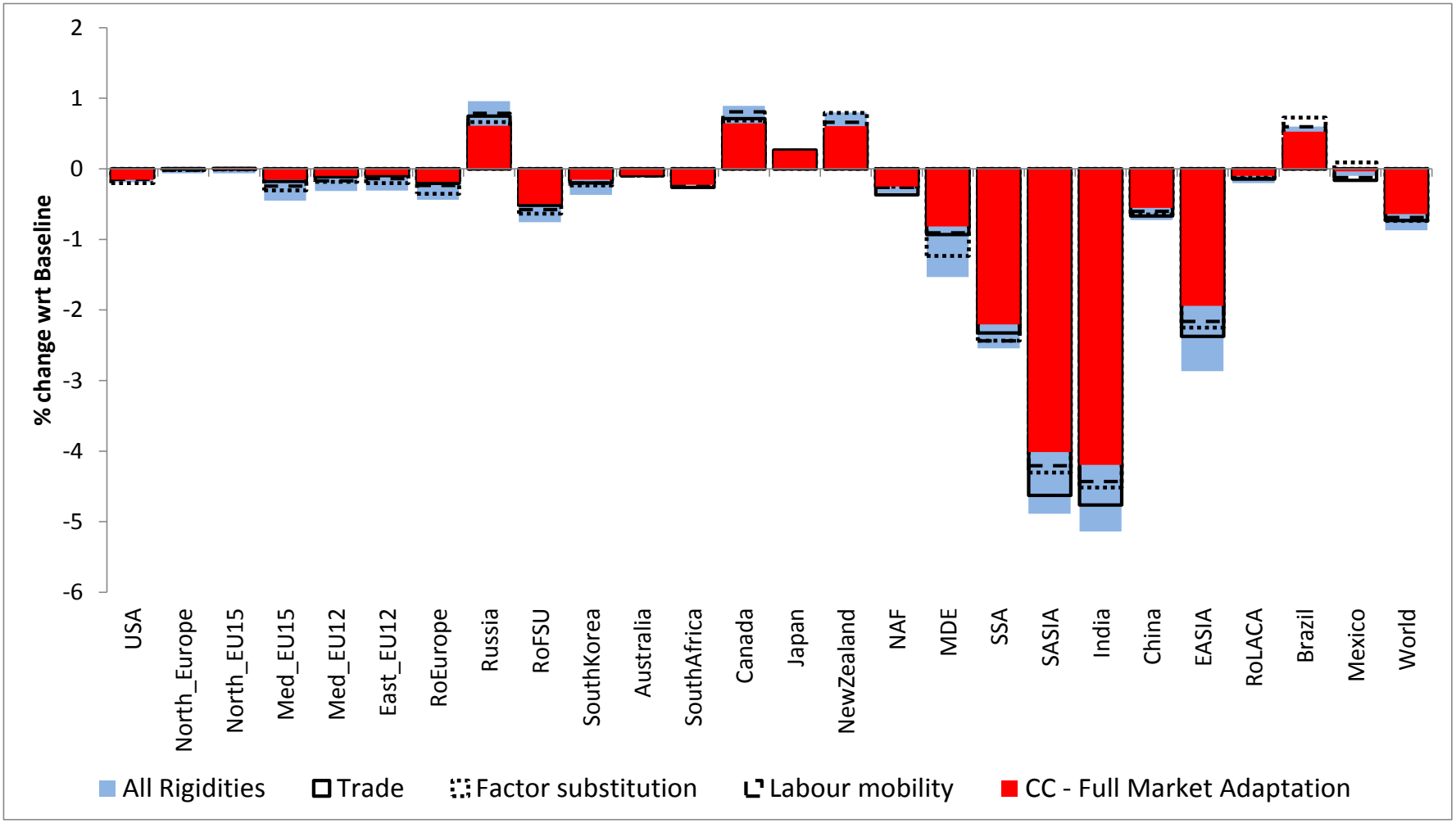
RCP 8.5 impacts on regional GDP with limited adaptation



Limiting adaptation tends to augment the original impact or damage

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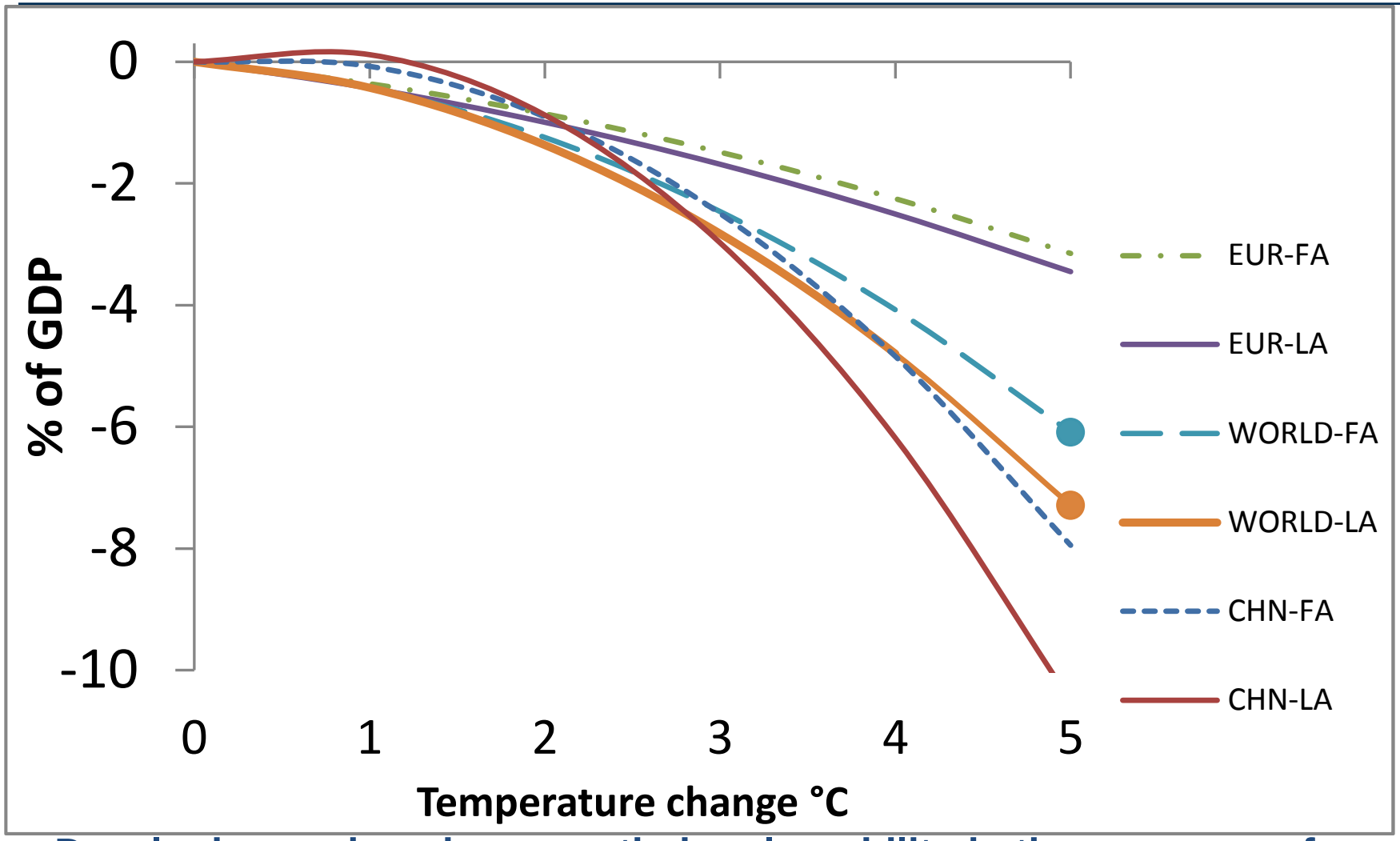
Reduced-forms with Full (FA) and Limited adaptation (LA)



Developing regions increase their vulnerability in the presence of limited adaptation

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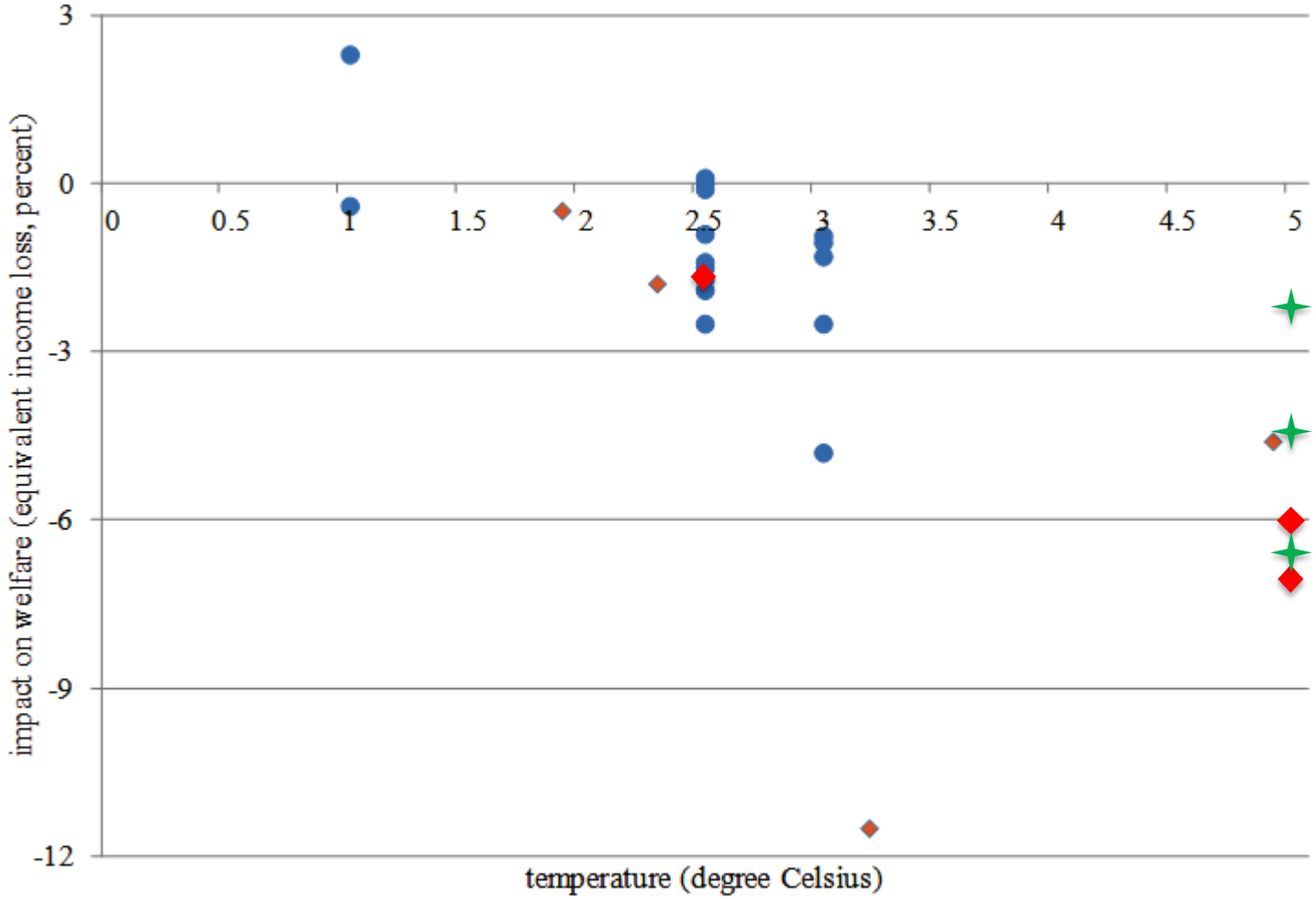
Quick model comparison



Sources: figure from IPCC AR5, * from Stern (2013)

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7. Conclusions (1)

- ✓ In 2050 total costs roughly amount to 0.64% of GWP for RCP 8.5 (2.5° C increase).
- ✓ Aggregate figures hide important regional and sectoral asymmetries.
- ✓ Higher vulnerability of developing countries to climate change impacts. (South Asia and India loose more than 4% of their GDP, Eastern Asia and Sub Saharan Africa roughly 2% of their GDP in 2050 in RCP 8.5).
- ✓ Even though some developed regions may end up with a higher GDP due to climate change, there are vulnerable sectors within those economies which will experience losses of 5% of their value added (or even more).
- ✓ Introducing rigidities in market adjustments increases climate change costs to 0.87% of GWP (roughly 30%), but does not change substantively the picture.

7. Conclusions (2)

✓In the shorter term, trade is a more important source of impact smoothing, in the longer term it is the degree of substitutability across primary factors.

✓ When the comparison is “even” CGE models do not provide lower estimates of climate change damages compared to “hard linked” IA models.

✓More research is needed, at least:

- ✓ Investigate the role of the social economic context (the structure of the economy) in impact determination
- ✓ Better define the range of uncertainties on key parameters
- ✓ More observations to calibrate the reduced-form damage functions (very limited knowledge “beyond 3° C”)

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Thanks!

This research project has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under the grant agreement n° 266992 (Global IQ)

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