Assessing macro-economic effects of climate impacts on energy demand in EU sub-national regions

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Outline

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- **Experiment design: baselines, impact modelling and energy inputs trends**
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Motivations

The impact of climatic stressors on energy demand have been rather extensively researched (De Cian and Wing, 2017; De Cian et al., 2013; Howell and Rogner, 2014; Schaeffer, 2012; Bazilian et al., 2011). However, sub-national impact assessment of climate change on energy demand in Europe is lacking in the existing literature.

European policy makers are increasingly interested in having a more detailed spatial representation about the future macro-economic impacts coming from these climatic shifts in the energy consumption patterns.

Objective

In this work we try to meet these policy needs by carrying out a **macro-economic assessment** of energy demand impacts at the sub-national level for the Nomenclature of Territorial Units for Statistics (NUTS) EU regions.

We use the ICES CGE model (Parrado and DeCian, 2014), whose regional coverage has been extended to the sub-county NUTS2 and NUTS1 EU regions for this work.

Methodology: data sources

We start from the Global Trade Analysis Project (GTAP) 8 database (Narayanan et al., 2012)

From the national SAMs of the European Union available in the GTAP data, we use sub-national information from Eurostat (Economic Accounts for Agriculture, 2018; Structural Business Statistics, 2018; Gross value added at basic prices by NUTS 3 regions, 2018) to get a regionalized database at the NUTS2-1 level.

We use information from the World Electric Power Plants Database (WEPP) (PLATTS, 2014) to increase the technological detail in the electricity sector at the NUTS-1/2 level. Using the WEPP information we were able to split the electricity sector of GTAP in 7 new sectors: **transmission & distribution, nuclear, fossil power generation, wind, hydropower, solar, other renewables**.

Methodology: creating and balancing the sub-national SAMs

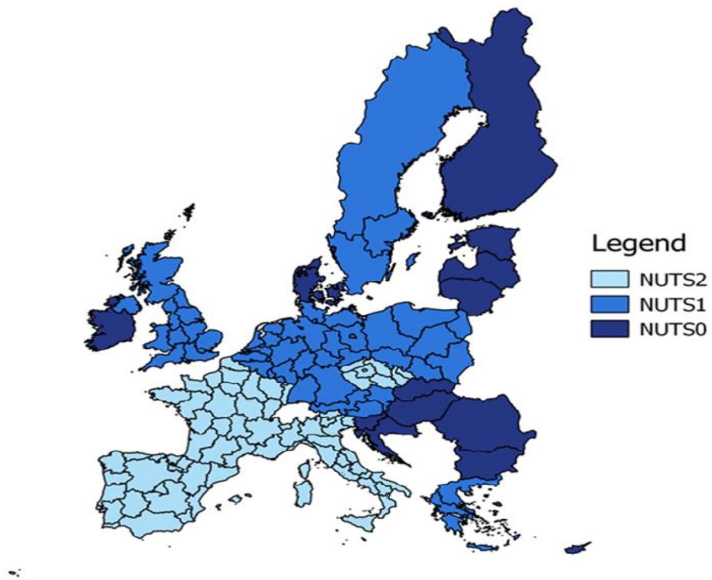
We use the methodology in Bosello and Standardi (2018) to obtain and balance the regionalized SAMs. The methodology is applied in the following steps:

- For every sector we split remuneration of labour, capital, land and natural resources available at the country level in the GTAP database, according the to regional shares of valued added from the Eurostat sub-national information.

- We rely on the so-called Simple Locations Quotients (SLQs) (Miller and Blair, 1985; Bonfiglio and Chelli, 2008; Bonfiglio, 2008) to obtain final and intermediate demand (domestic and imported) at the sub-country level

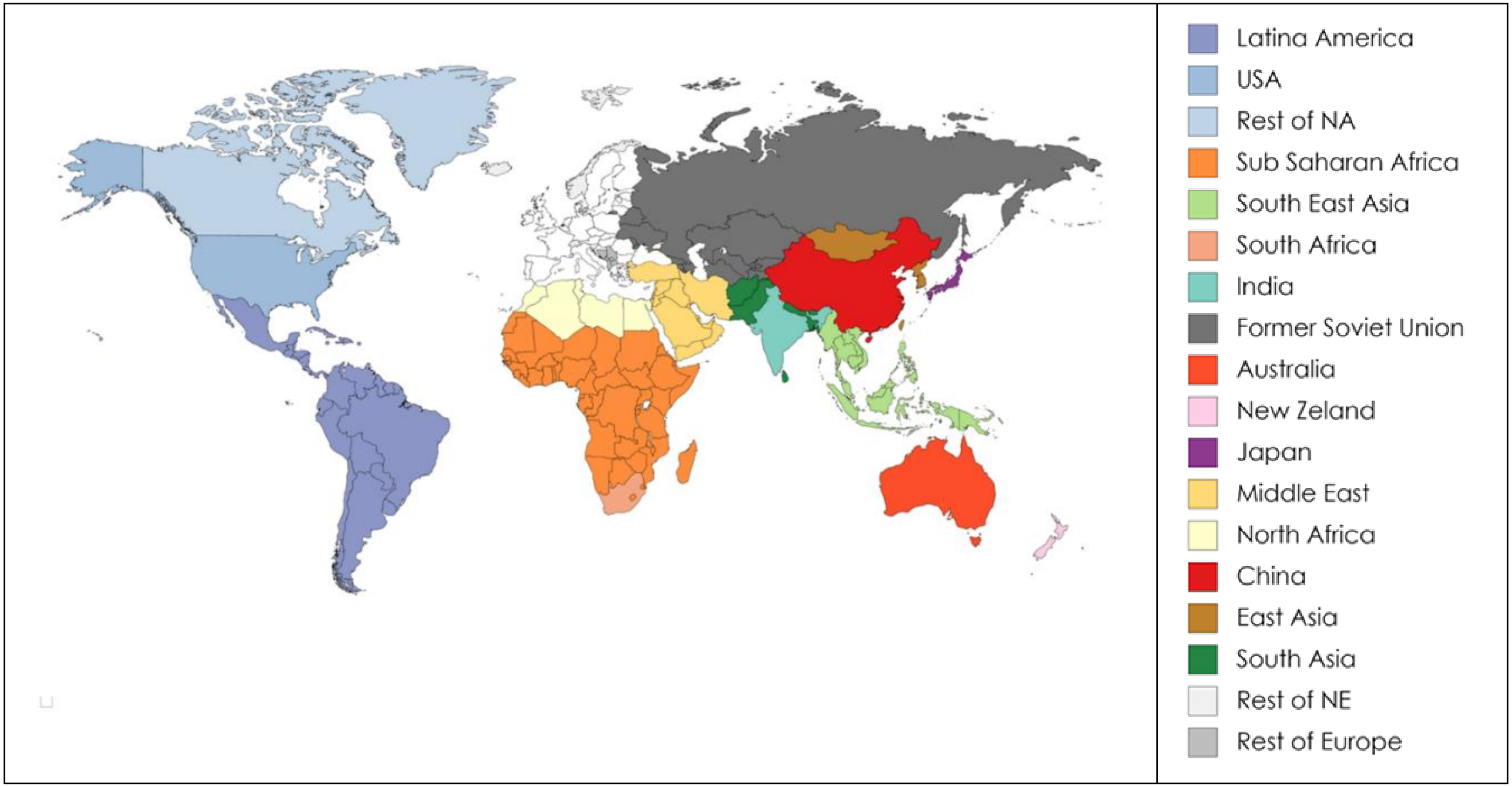
- We follow a gravitational approach based on the kilometric road distance between each couple of capital cities for regions within the country. We adjust the trade flows across sub-national regions by using the RAS statistical method (Bacharach, 1970) to make them consistent with the aggregate intra-national exports and imports obtained through the SLQs.

Methodology: final geographical aggregation (Eu28)



Country	Number of Regions	NUTS level
Austria	3	NUTS1
Belgium	3	NUTS1
Bulgaria	1	NUTS0
Cyprus	1	NUTS0
Czech Republic	8	NUTS2
Germany	16	NUTS1
Denmark	1	NUTS0
Estonia	1	NUTS0
Spain	17	NUTS2
Finland	1	NUTS0
France	22	NUTS2
Greece	4	NUTS1
Hungary	1	NUTS0
Croatia	1	NUTS0
Ireland	1	NUTS0
Italy	20	NUTS2
Lithuania	1	NUTS0
Luxembourg	1	NUTS0
Latvia	1	NUTS0
Malta	1	NUTS0
Netherlands	4	NUTS1
Poland	6	NUTS1
Portugal	5	NUTS2
Romania	1	NUTS0
Sweden	3	NUTS1
Slovenia	1	NUTS0
Slovakia	1	NUTS0
United Kingdom	12	NUTS1
Total	**138**	

Methodology: final geographical aggregation (Rest of the World)

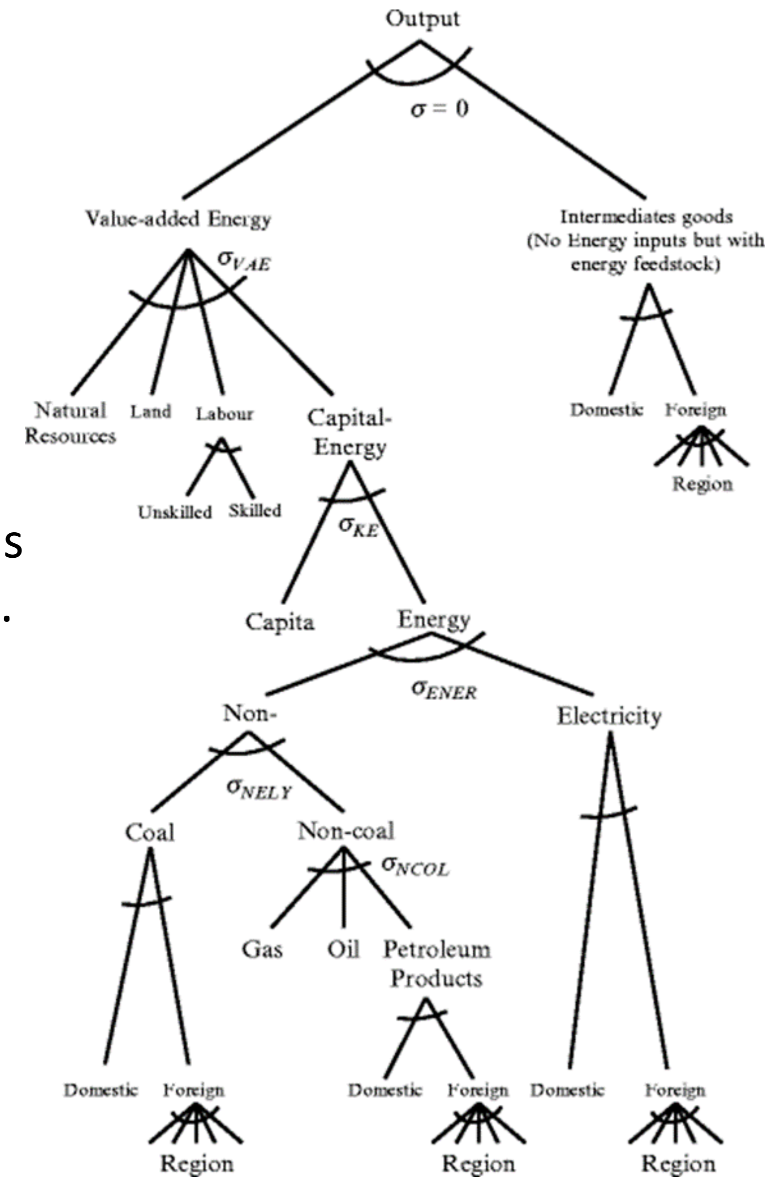


Methodology: final sectoral aggregation

1	Veg. & Fruits	13	Wind
2	Other Crops	14	Hydropower
3	Livestock	15	Solar
4	Timber	16	Oth. Renewabl.
5	Fishery	17	Heavy industry
6	Coal	18	Construction
7	Oil	19	Light indusry
8	Gas	20	Transport Road
9	Oil Products	21	Transport Water
10	Tr. & Dist.	22	Transport Air
11	Nuclear	23	Services
12	Fossil Power	24	Public Services

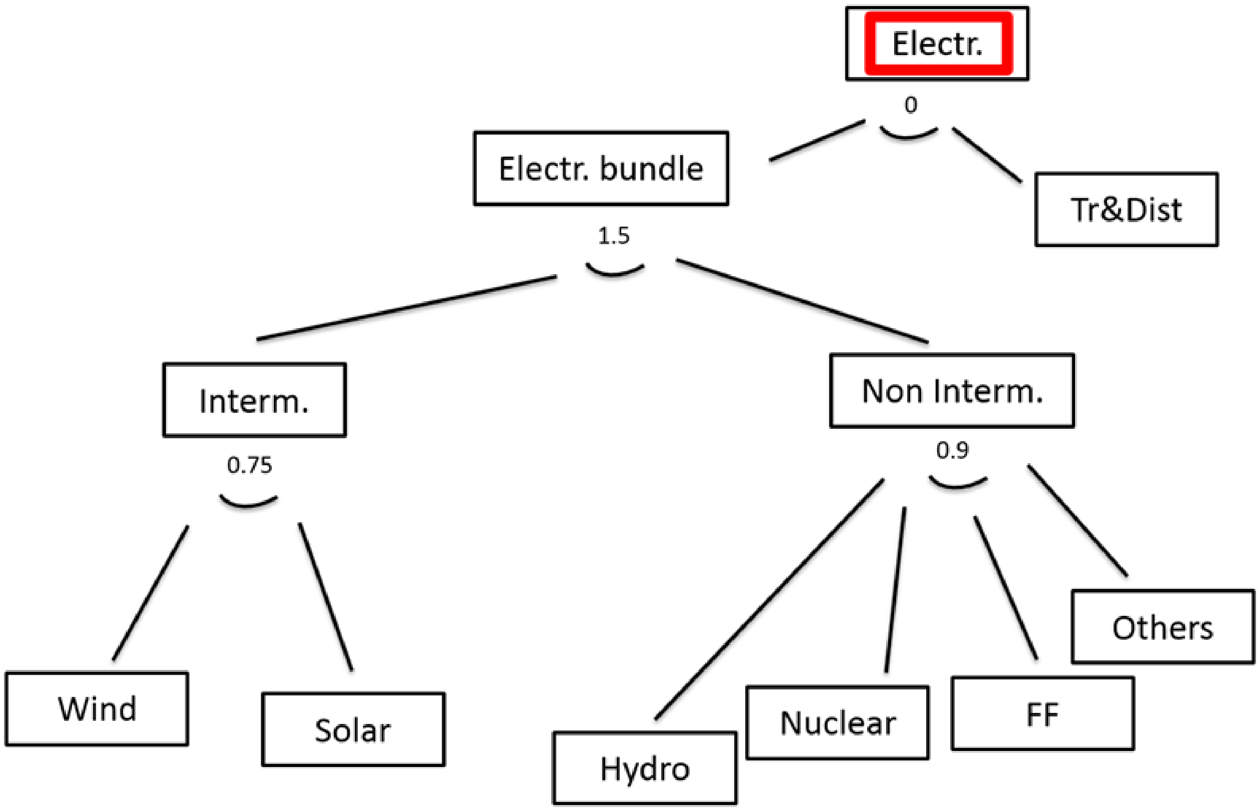
Methodology: model description

The supply side of ICES is based on GTAP-E model.



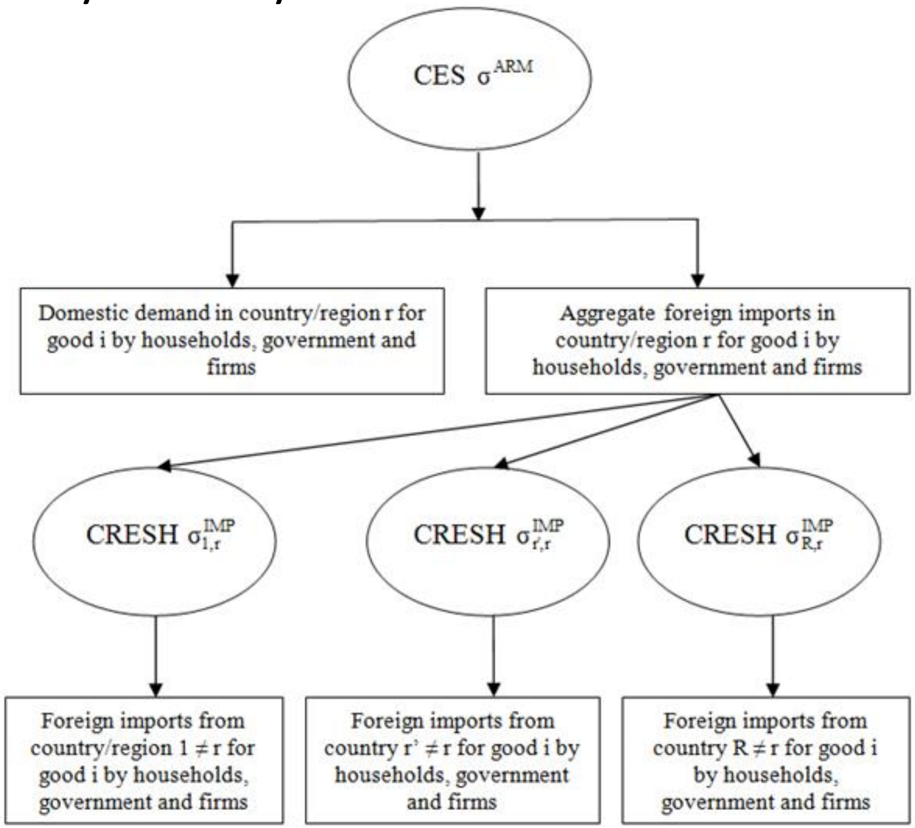
Methodology: model description

We further detail the part related to the electricity tree. This is done consistently with the database expansion for the power generation sector using the WEPP information at the sub-country level.



Methodology: model description

We follow the GTAP double nest approach but we employ in the lower nest a Cresh function (Hanoch, 1971; Pant, 2007) which allows for more flexibility in the choice of the bi-lateral substitution for each couple of spatial units. For RoW countries we keep the original values of the Armington elasticities. For sub-country regions we increase the elasticity value by 50%.



Experiment design: baselines

To examine a wide spectrum of socio-economic and climatic characteristics, the macroeconomic assessment has been performed using nine baseline scenarios based on combinations of the Representative Concentration Pathways (RCP) and the Shared Socioeconomic Pathways (SSP). The impact assessment is run from 2015 to 2070.

	RCP2.6	RCP4.5	RCP6.0	RCP8.5
SSP1	●	●		
SSP2	●	●	●	
SSP3	●	●		
SSP5				●

Experiment design: baselines

- We assume that sub-national regions follow the country projections available from the SSP database, we replicate GDP and population projections
- Then we further detail the RCP-SSP combination according to different socio-economic and technological characteristics in the table below (the higher the number of asterisks the higher the level of the associated variable)

	Fossil fuel prices	Efficiency in clean energy production	Substitutability between electric and non-electric	Trade openness (Armington)	Climate policy (carbon tax)
SSP1-RCP2.6	*	******	****	**	****
SSP1-RCP4.5	*	****	****	**	-
SSP2-RCP2.6	**	*****	****	**	***
SSP2-RCP4.5	**	***	***	**	-
SSP2-RCP6.0	**	**	**	**	-
SSP3-RCP2.6	***	***	**	*	**
SSP3-RCP4.5	***	**	*	*	-
SSP5-RCP4.5	****	**	*	**	*
SSP5-RCP8.5	****	*	*	**	-

Experiment design: impact modelling

- Future trends in regional energy demand are obtained combining the econometrically estimated elasticities (De Cian and Sue Wing, 2017) with high-resolution ensemble-mean temperature projections from four Regional Climate Models (RCMs): KNMI RACMO22E, IPSL-CM5A-MR, MPI-ESM-LR, and CNRM-CM5.

- In the CGE model this translates in implementing **12 different impacts**, i.e. the number of energy carriers (**electricity, petroleum products, and natural gas**) times the number of economic activities (**agriculture, industry, services and residential**). This has been done for each RCP scenario.

Experiment design: impact modelling

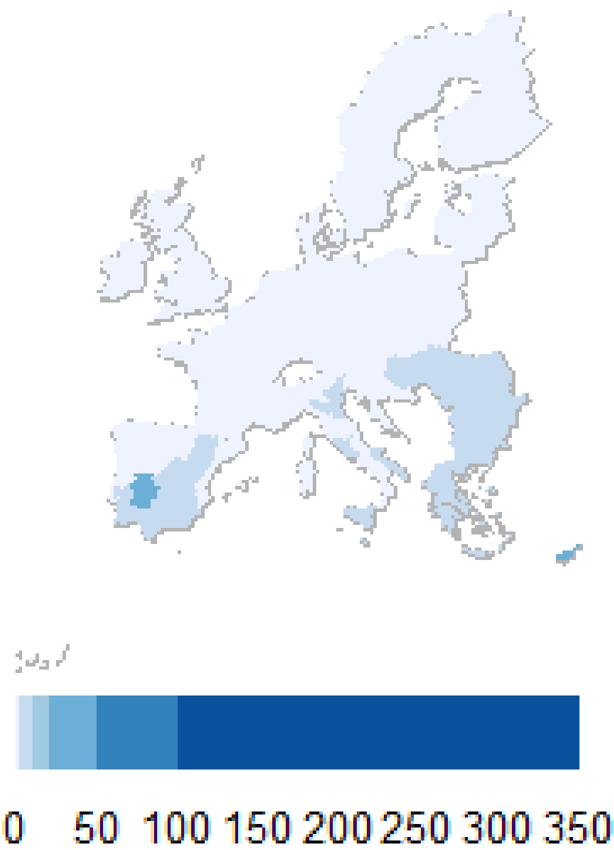
- To implement changes in energy demand in the agriculture, industry and services sectors we use the energy efficiency in those sectors. The underlying assumption is that the representative firm becomes more (less) efficient if climate change will reduce (increase) the energy demand for a given energy input and will satisfy a given amount of energy demand using less (more) energy inputs.

- Energy demand shifts in the residential sector are implemented imposing exogenous shocks to the household energy expenditure while keeping fixed the household budget constraint. This implies a re-adjustment of household consumption across all consumption items.

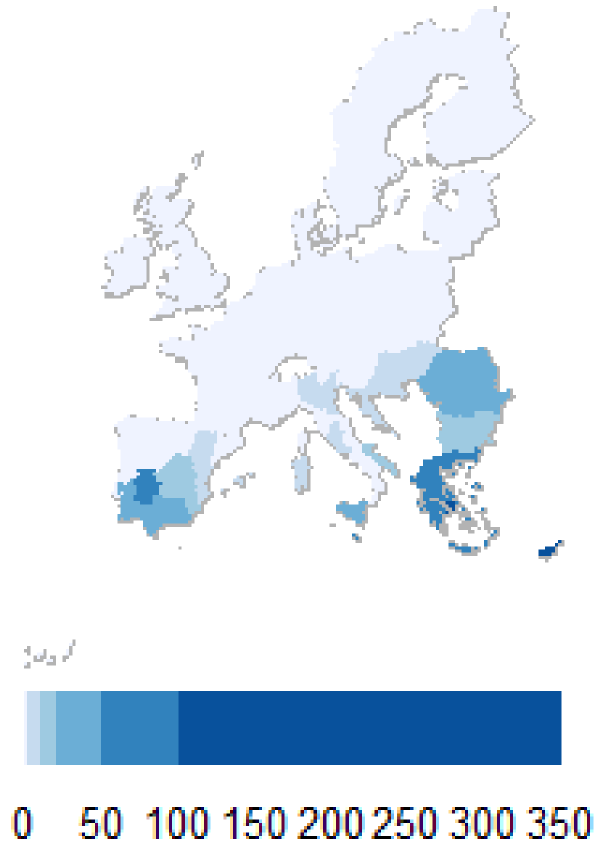
Experiment design: energy inputs trends

Gas demand from industrial sector (% Ch. In 2070)

RCP2.6

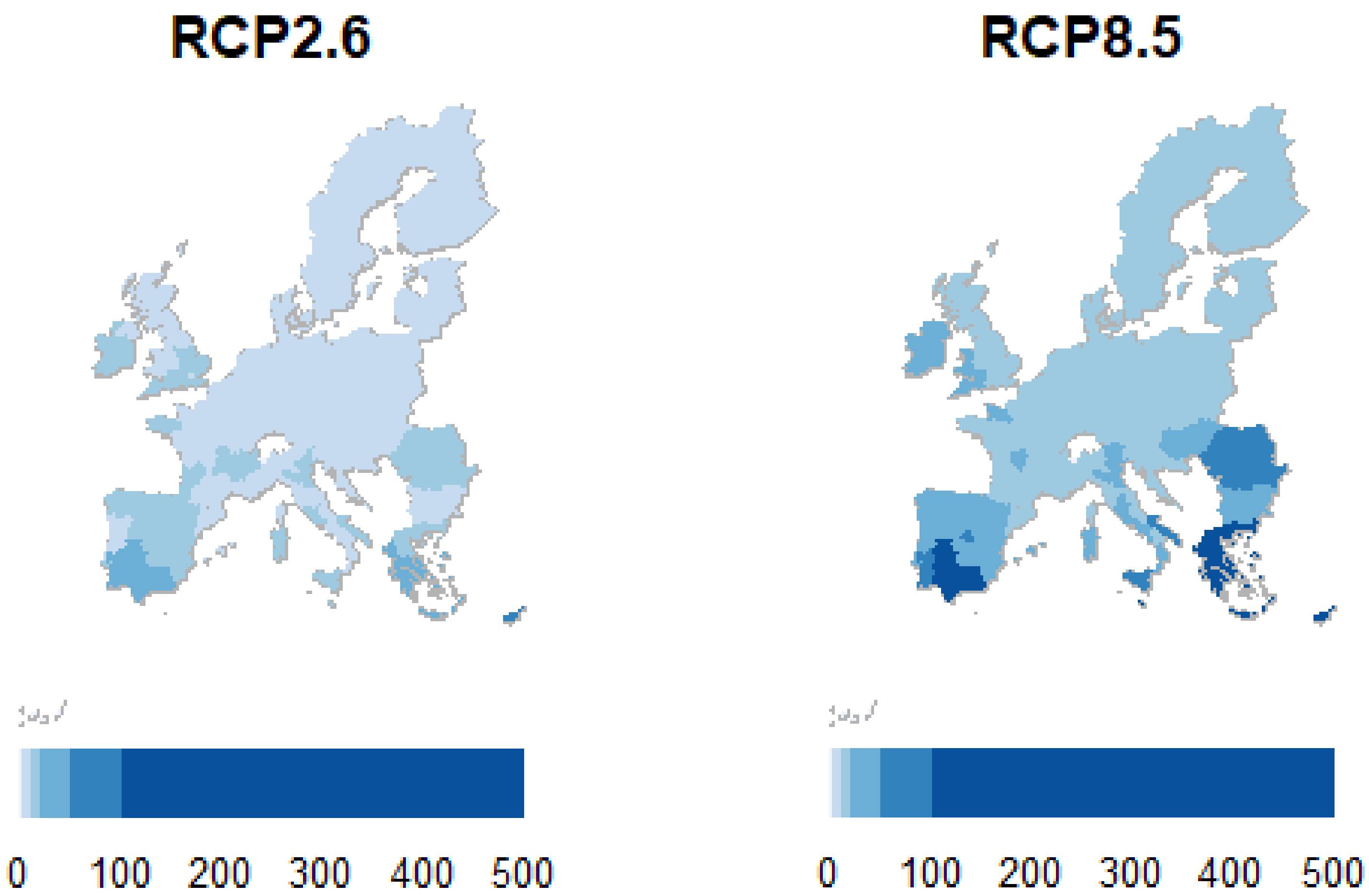


RCP8.5



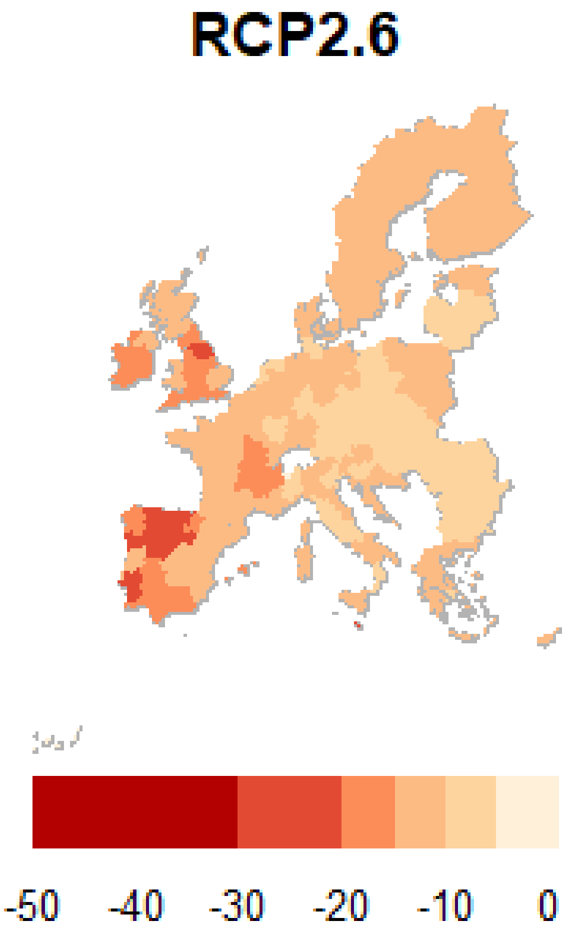
Experiment design: energy inputs trends

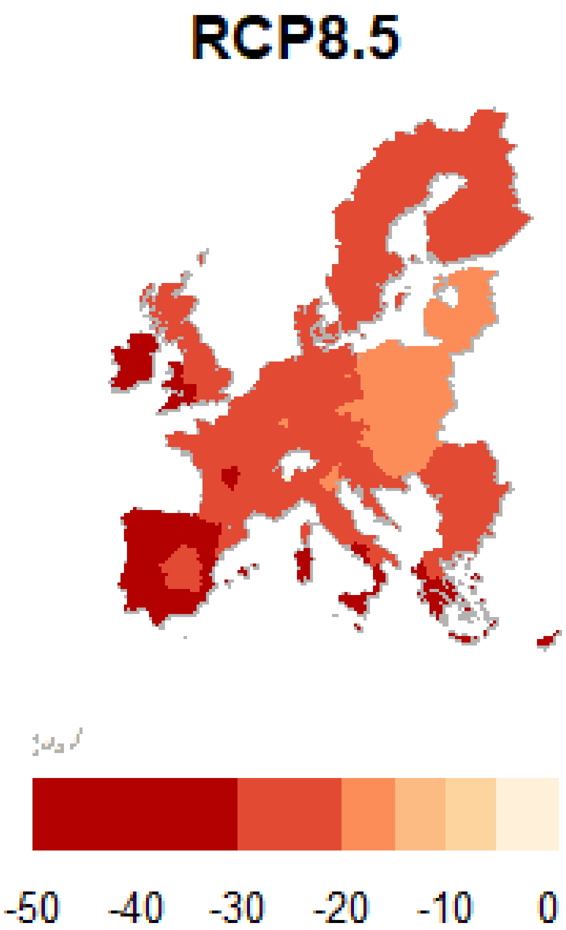
Electricity demand from service sector (% Ch. In 2070)



Experiment design: energy inputs trends

Oil demand from service sector (% Ch. In 2070)

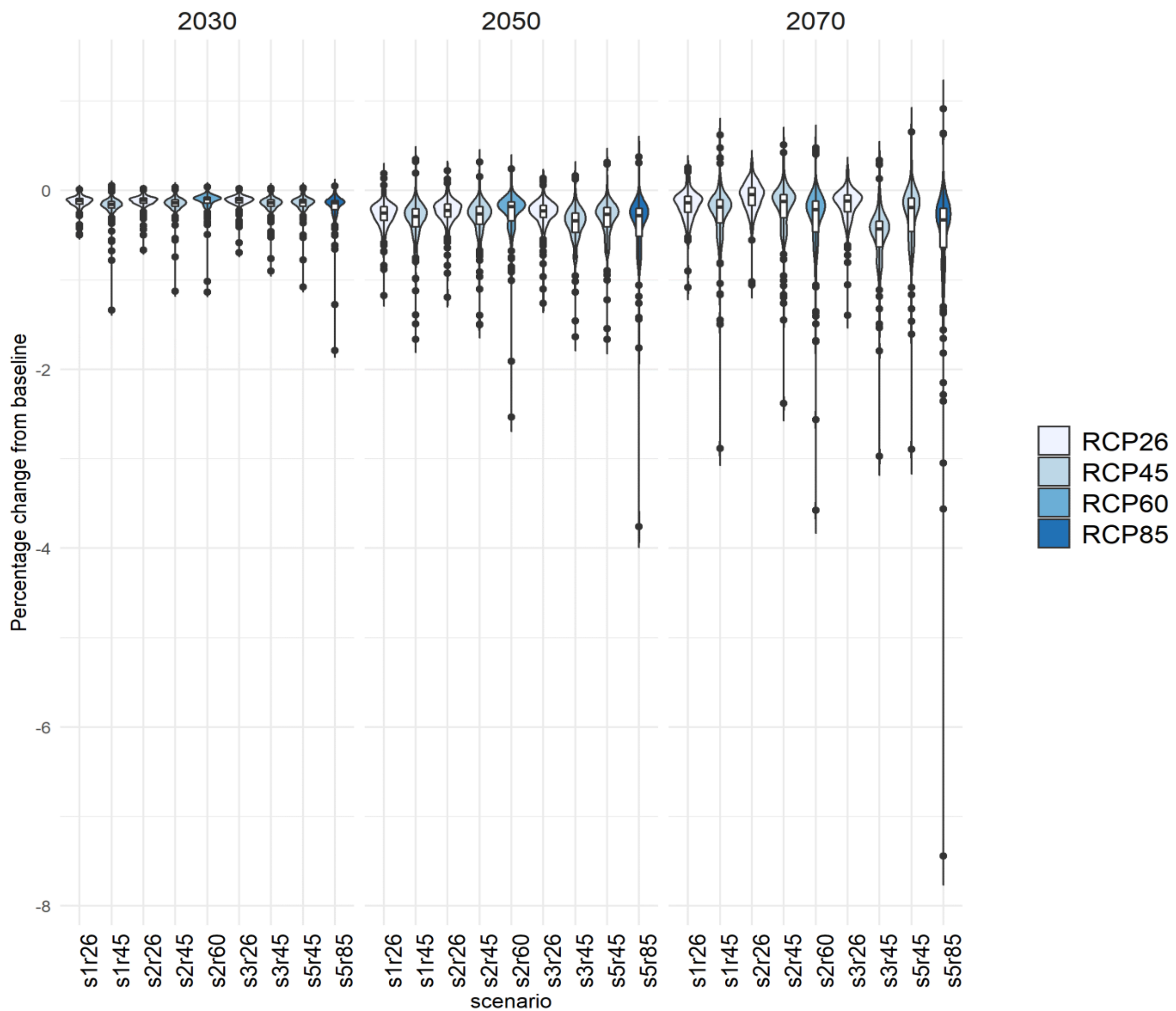




Results: GDP % Ch. compared to the baselines

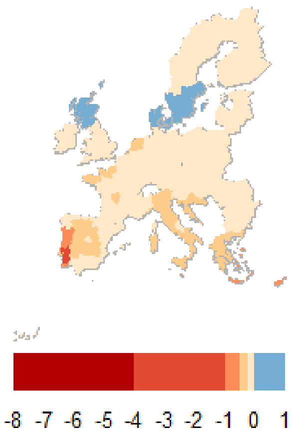
EU28	2050	2070
SSP1-RCP2.6	-0.26	-0.15
SSP1-RCP4.5	-0.30	-0.21
SSP2-RCP2.6	-0.22	-0.04
SSP2-RCP4.5	-0.27	-0.13
SSP2-RCP6.0	-0.20	-0.24
SSP3-RCP2.6	-0.22	-0.11
SSP3-RCP4.5	-0.35	-0.45
SSP5-RCP4.5	-0.29	-0.21
SSP5-RCP8.5	-0.33	-0.41

Results: GDP % Ch. compared to the baselines

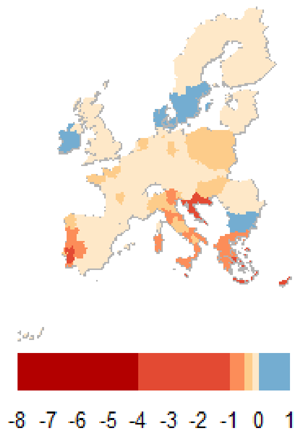


Results: GDP % Ch. compared to the baselines in 2070

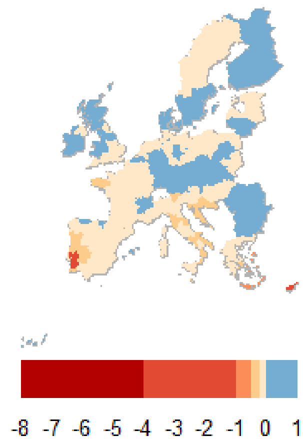
SSP1-RCP2.6



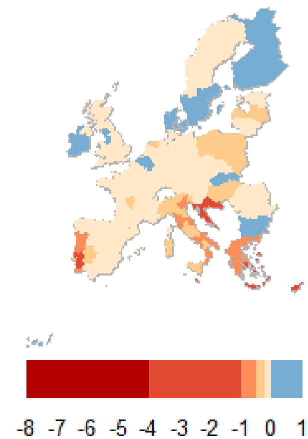
SSP1-RCP4.5



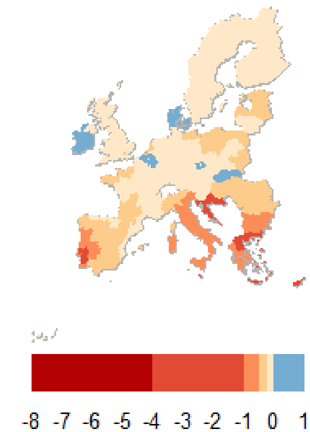
SSP2-RCP2.6



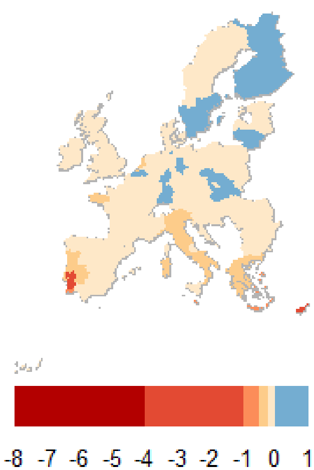
SSP2-RCP4.5



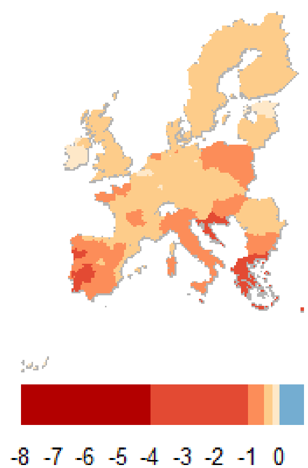
SSP2-RCP6.0



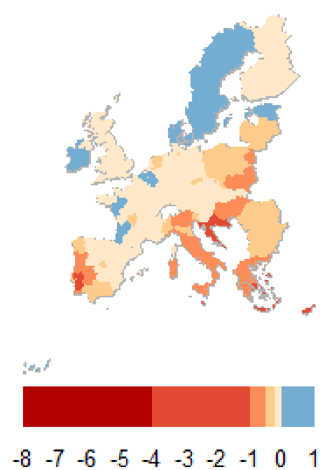
SSP3-RCP2.6



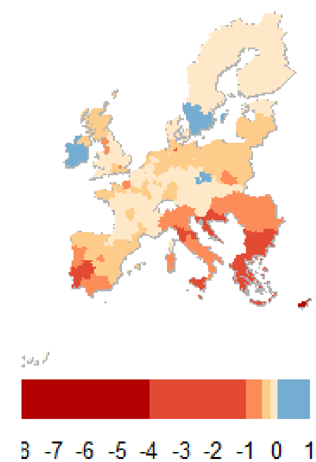
SSP3-RCP4.5



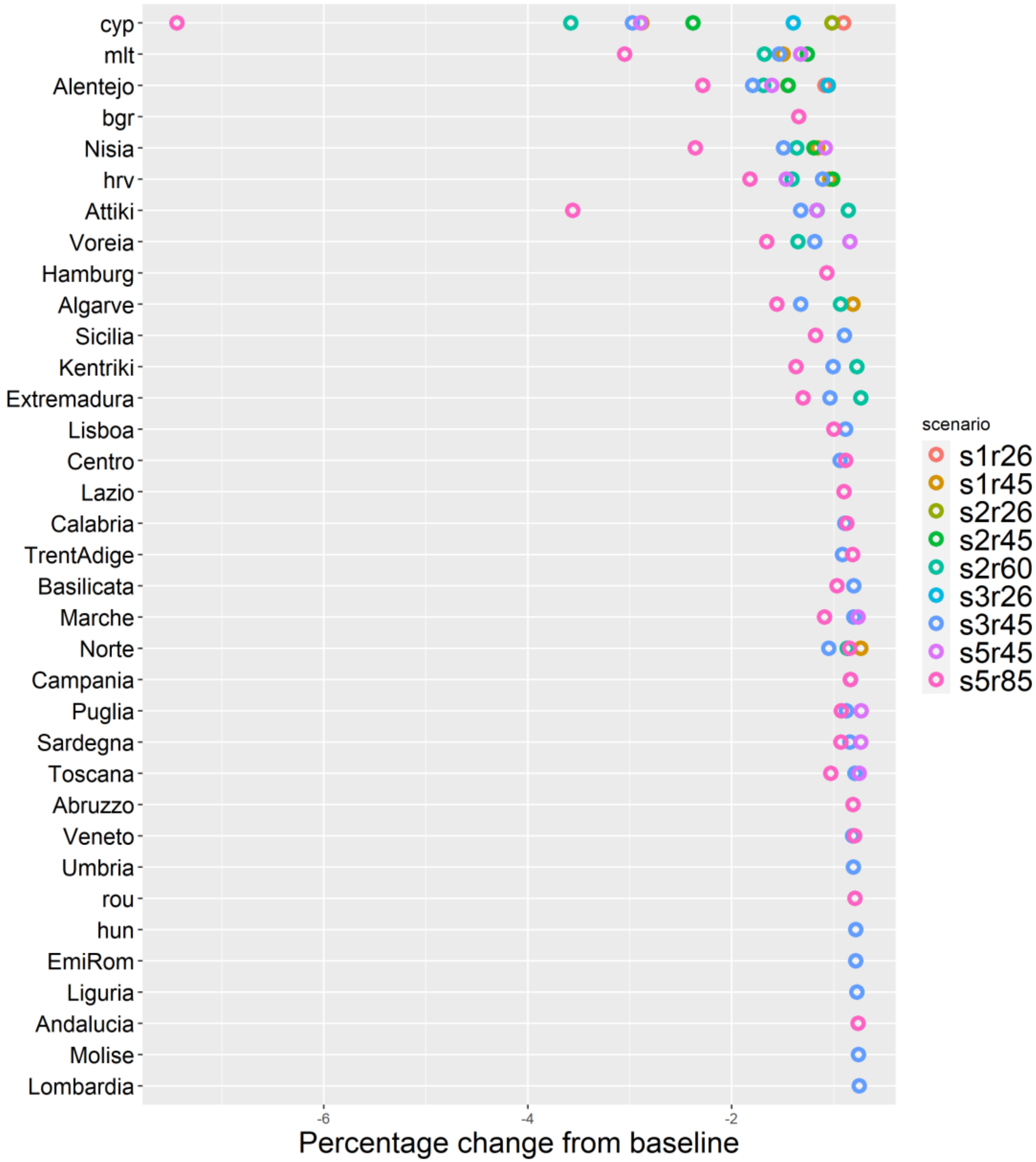
SSP5-RCP4.5



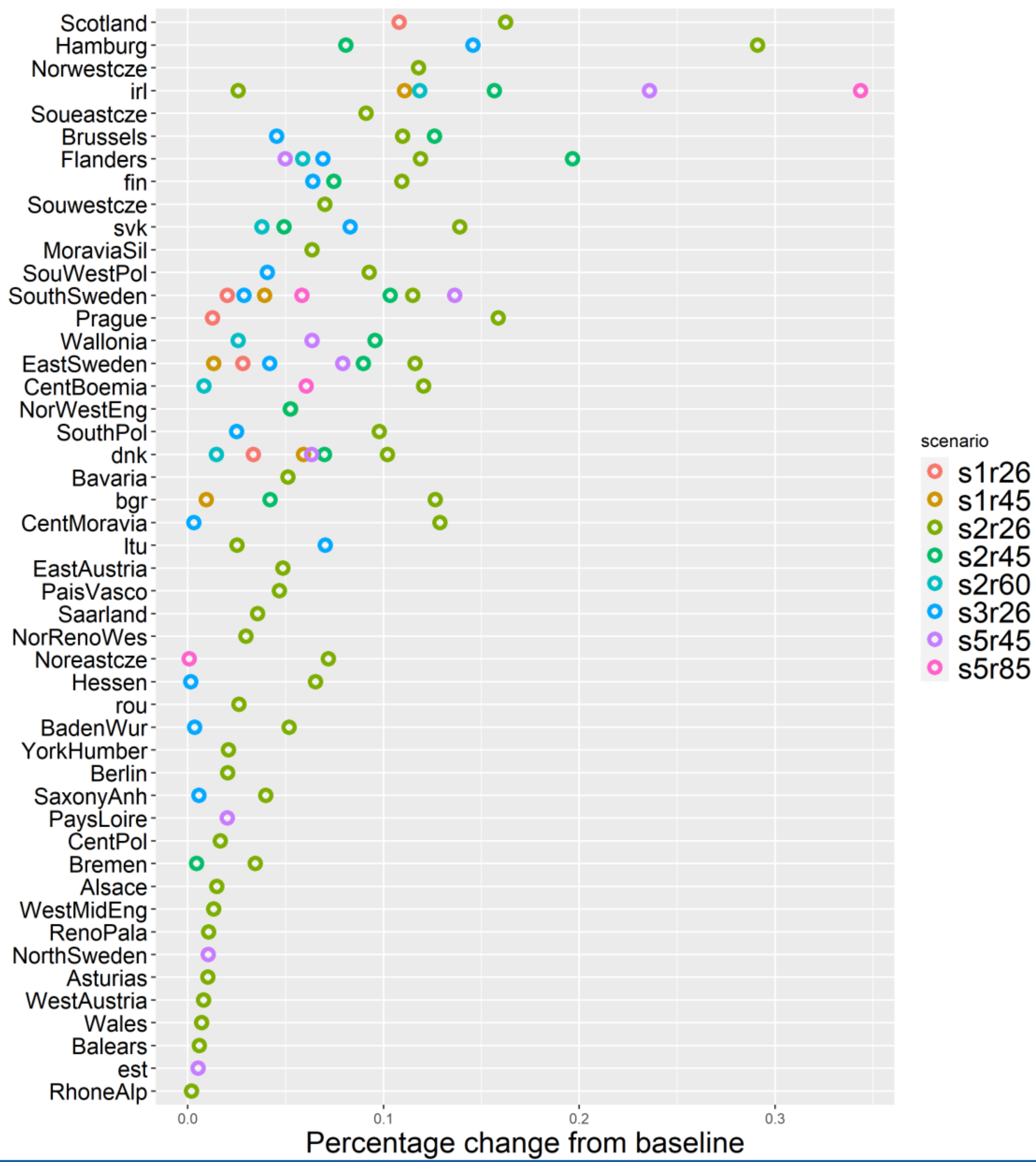
SSP5-RCP8.5



Results: GDP % Ch. compared to the baselines (**looser regions**)



Results: GDP % Ch. compared to the baselines (**winner regions**)



Conclusions

- Negative macroeconomic effects of climate impacts on energy demand may not be negligible in regions located in Southern Europe. By 2070 especially in SSP5-RCP8.5 and SSP3-RCP4.5 these negative effects can be bigger than 1% of GDP with a peak of -7.5% in Cyprus. The analysis also shows the importance of mitigation policies to reduce the adverse macro-economic effects.
- Even if the energy demand impact coming from the econometric estimation is essentially linked to a specific RCP, the socio-economic dimension is also important. For example, the combination SSP3-RCP4.5 shows the worst economic outcomes for EU28.
- As a policy implication, it is important that Southern European countries immediately start to invest in more efficient cooling technologies and implement appropriate climate policy to reduce greenhouse gas emissions.

Further research

- Improving and better contextualize the modelling of climate impacts on energy demand for the representative household (so far these impacts are only re-distributive within the household's budget constraint)

- Refining further the baselines scenarios (convergence of GDP per capita within countries according to the different SSPs, different degrees of labour mobility within EU, checks on prices and consumption shares)

Thanks

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