The role of spatial and technological details for energy/carbon mitigation impacts assessment in Computable General Equilibrium models

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Outline

- **Introduction:** motivations, objective and case study
- **Methodology:** the Base and Tech model
- **Experiment design**
- **Results and Economic interpretation**
- **Conclusions and further research**

Introduction: motivations

Computable General Equilibrium (**CGE**) modelling has been widely used to quantify the cost of mitigation (Babatunde et al., 2017) because this tool is able to capture not only the overall effect on welfare but also the distribution of these effects across sectors, technologies and regions.

However, there are large empirical **uncertainties** surrounding the modelling of carbon mitigation policies, although models are usually built with the same source of data and similar parameterization Pearce (2012).

In a recent work taking **Italy** as a case study Standardi, Cai and Yeh (2017) highlight the importance of systematically examining the impacts of **technological and spatial details** for the predictions of mitigation costs in CGE modelling.

Introduction: the case study – European Union

GTAP 9 (Aguiar er al., 2016) **database** is collection of Social Accounting Matrixes (SAMs) for 140 regions and 57 sectors in the world. Disaggregation of the electricity sector in 8 technologies: Coal Power, Oil Power, Gas Power, Nuclear, Wind, Solar, Hydro, Others. **Reference year 2011**.

GTAP 8 (Narayanan et al., 2012) **database** is collection of Social Accounting Matrixes (SAMs) for 129 regions and 57 sectors. To disaggregate the electricity sector into different technologies we complement the GTAP 8 database with data from IEA (International Energy Agency) and EIA (Energy Information Administration). **Reference year 2007**.

The sub-national study by Standardi, Cai and Yeh (2017) used the **GTAP 8** database integrated with information from ISTAT, TERNA and ENEA to disaggregate the Italian economy and the electricity sector into different technologies. **Reference year 2007**.

Introduction: objective

Objective: verifying if the results at the supra-national level are robust for different databases and reference years and consistent with those at the sub-national level by Standardi, Cai and Yeh (2017).

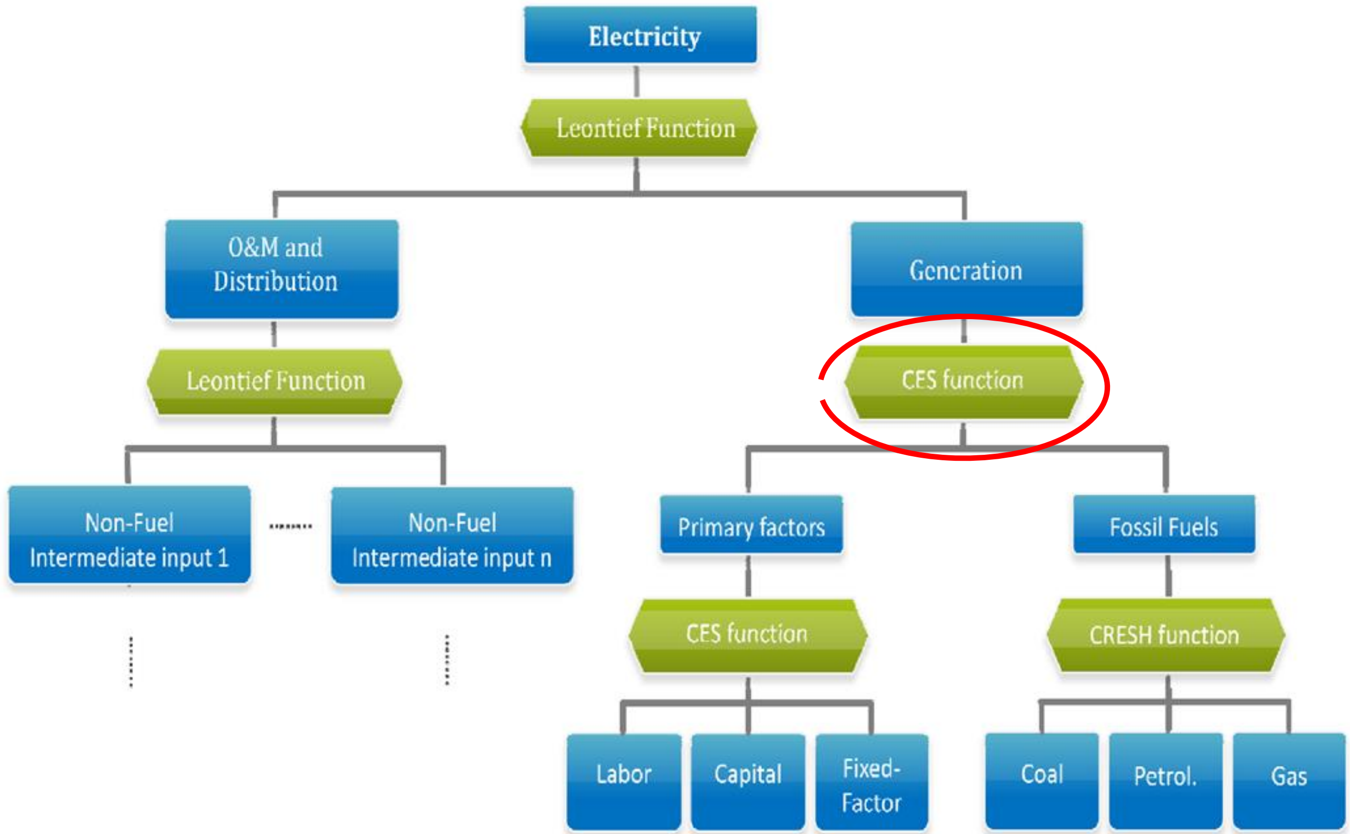
Methodology: the basic structure of Base and Tech models

Neo-classical framework: investments are saving driven, factors are fully employed, markets are competitive, a representative firm maximizes profits under a technological constraint in each region and sector, a representative regional household maximizes utility under a budget constrain in each region.

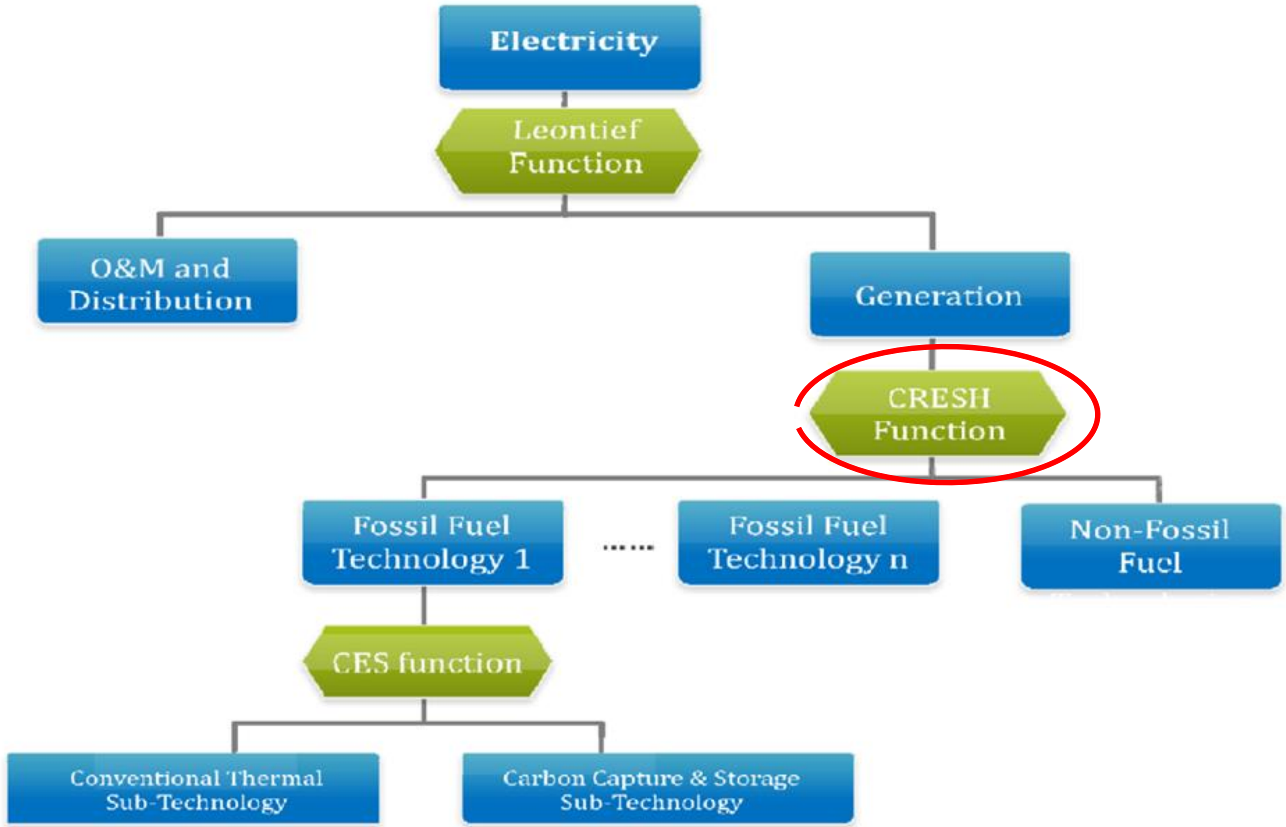
In the basic setting all prices and quantities are endogenous in the CGE except the numeraire and the endowments of the primary factors (natural resources, capital, labor) in the region. Productivities and subsidies/taxes are exogenous.

Base and **Tech** models have been developed by Cai and Arora (2015).

Methodology: electricity sector in the Base model



Methodology: electricity sector in the Tech model



Experiment design: economic sectors and technologies

Economic sectors in Base and Tech models
Coal
Oil
Gas
Coal and oil products
Electricity
Iron and Steel
Nonferrous metals
Chemical, rubber, plastic products
Other mining
Nonmetallic minerals
Land transport
Water Transport
Air transport
Crops
Livestock
Fishing and Forestry
Processed Food
Services

Technologies in the electricity sector of Tech
Coal Power Generation
Oil Power Generation
Gas Power Generation
Nuclear
Wind
Solar
Hydro
Others

Experiment design: three spatial aggregations

Eu1 (single Europe)

Eu3 (North, South, East Europe)

Eu27 (27 countries)

Experiment design: the six configurations

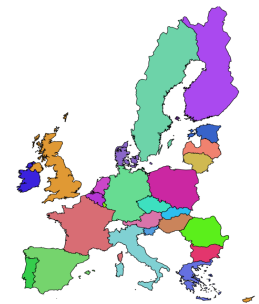
1) Base-Eu1

No technology

2) Base-Eu3

No technology

2) Base-Eu27

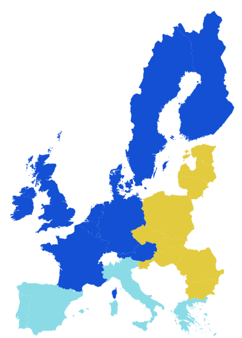


No technology

4) Tech-Eu1

Coal Power, Oil Power,
Gas Power, Nuclear, Wind,
Solar, Hydro, Others

5) Tech-Eu3



Coal Power, Oil Power,
Gas Power, Nuclear, Wind,
Solar, Hydro, Others

6) Tech-Eu27

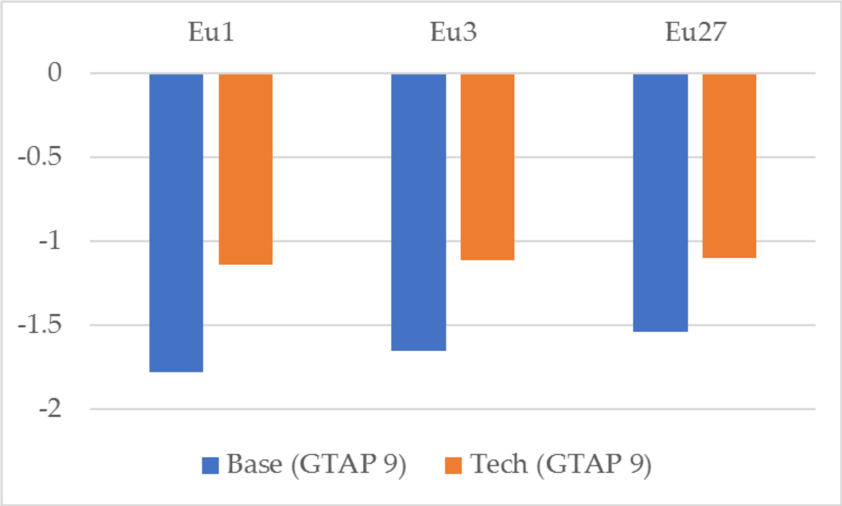
Coal Power, Oil Power,
Gas Power, Nuclear, Wind,
Solar, Hydro, Others

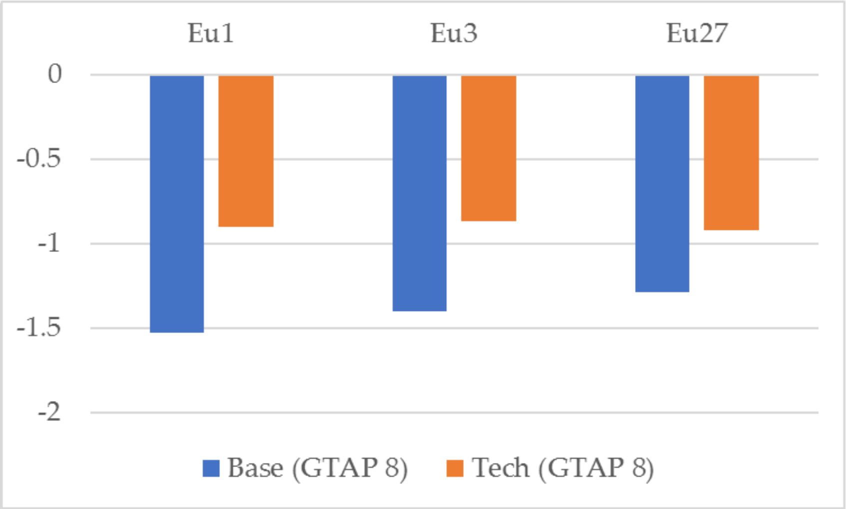
The Experiment

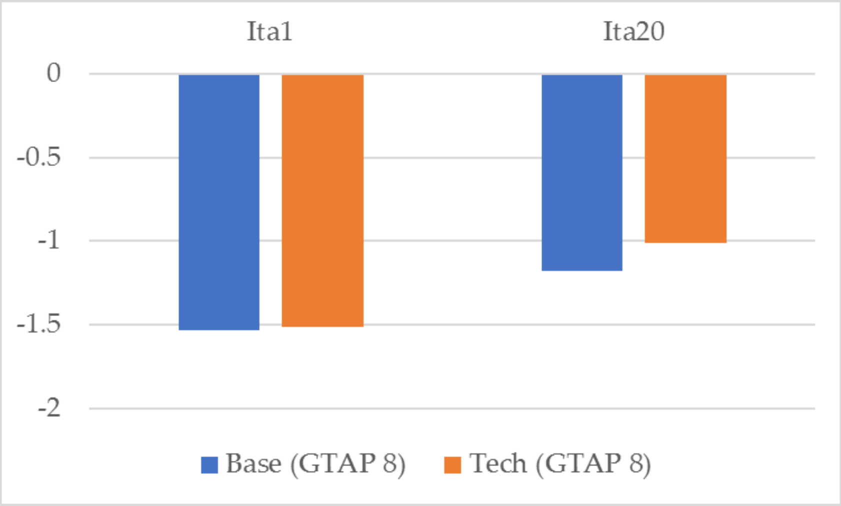
- **20%** CO_2 emission reduction target in EU achieved by a **uniform carbon tax**.
- Comparative static exercise
- Comparing results coming from different geographical and technological aggregations
- Comparing results of two different databases: GTAP 8 (reference year 2007) and GTAP 9 (reference year 2011)
- Verifying if results are consistent with the sub-national experiment (Standardi, Cai and Yeh, 2017)

Results of the Experiment

Mitigation Costs (% GDP Ch.) to achieve a 20% CO_2 emission reduction in EU and Italy for different levels of spatial and technological details







Results of the Experiment

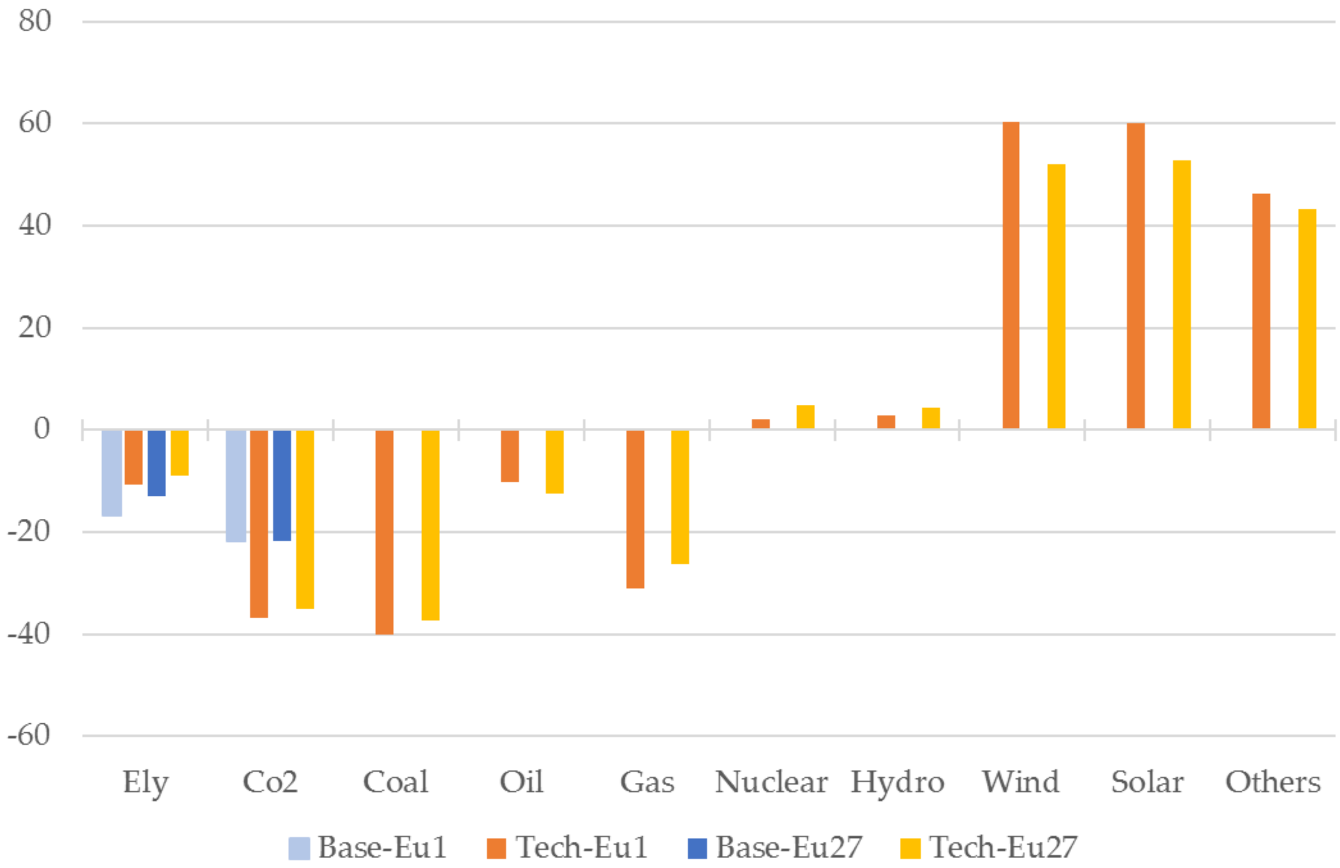
% Changes of GDP and % changes of economic production and CO2 emission in the electricity power generation. Between brackets absolute economic losses (2011 Bln $ in GTAP 9 and 2007 Bln $ in GTAP 8).

	GTAP-9 ref. year 2011			GTAP-8 ref. year 2007		
	Elec. Prod.	**CO2 ely**	**GDP**	**Elec. Prod.**	**CO2 ely**	**GDP**
Base-Eu1	-16.66 (-94)	-21.68	-1.78 (-313)	-16.96 (-88)	-22.94	-1.53 (-260)
Base-Eu3	-16.04 (-90)	-22.19	-1.65 (-291)	-15.76 (-82)	-23.10	-1.40 (-238)
Base-Eu27	-13.08 (-74)	-21.81	-1.54 (-271)	-13.17 (-68)	-22.38	-1.29 (-220)
Tech-Eu1	-10.69 (-60)	-36.75	-1.14 (-200)	-10.14 (-53)	-36.10	-0.90 (-153)
Tech-Eu3	-10.56 (-59)	-36.49	-1.11 (-195)	-9.82 (-51)	-35.23	-0.87 (-148)
Tech-Eu27	-8.96 (-51)	-35.07	-1.10 (-193)	-9.18 (-48)	-32.83	-0.92 (-156)

	GTAP-8 Italy ref. year 2007		
	Elec. Prod.	**CO2 ely**	**GDP**
Base-Ita1	-18.1 (-13)	-21.2	-1.53 (-33)
Base-Ita20	-11.7 (-8)	-25.7	-1.18 (-25)
Tech-Ita1	-17.3 (-12)	-27.9	-1.51 (-32)
Tech-Ita20	-10.1 (-7)	-33.8	-1.01 (-21)

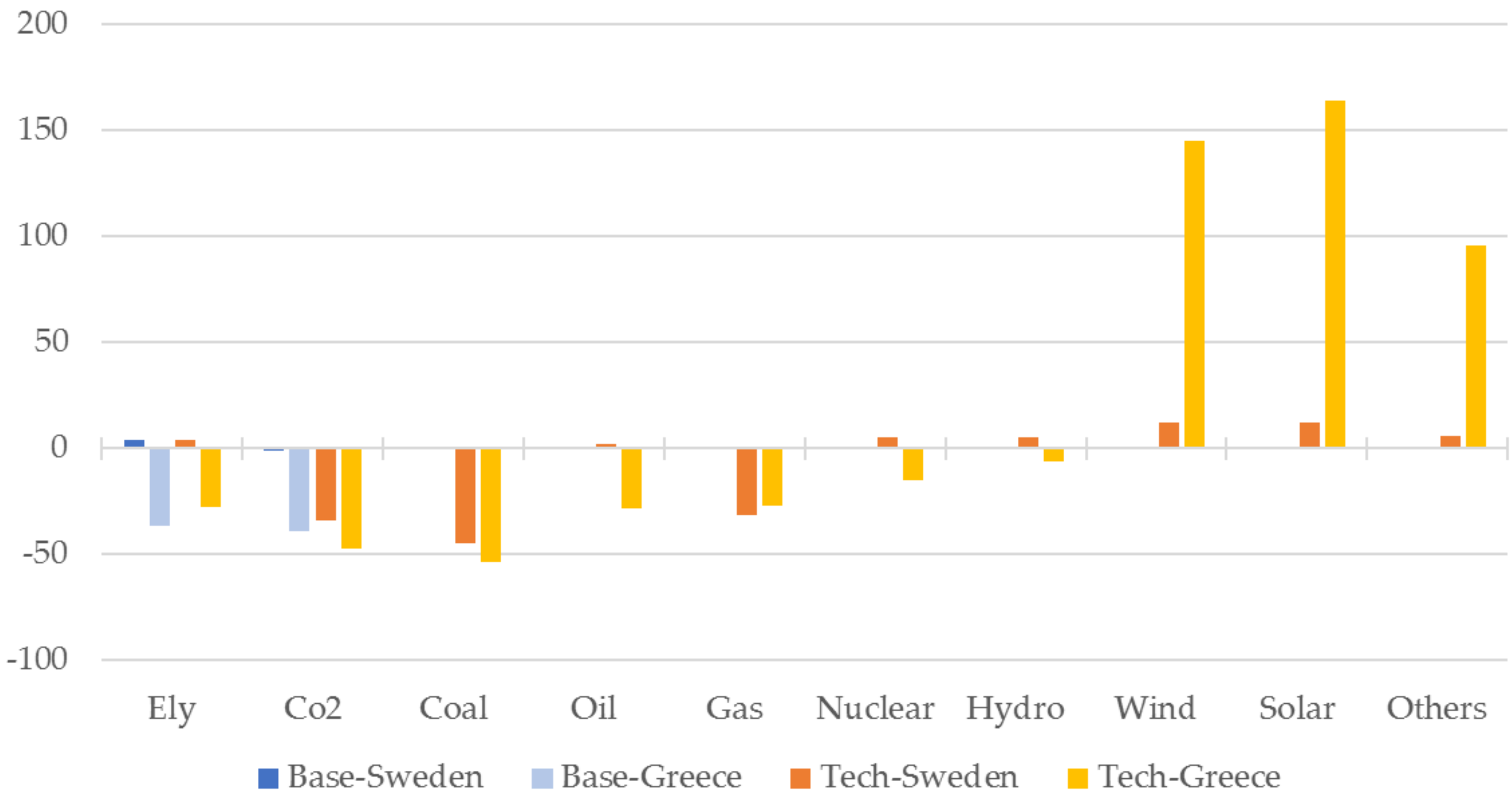
Results of the Experiment

% Changes in technology power generation, electricity and Co2 emissions in Base-Eu1, Tech-Eu1, Base-Eu-27 and Tech-Eu27 (GTAP 9, ref. year 2011)



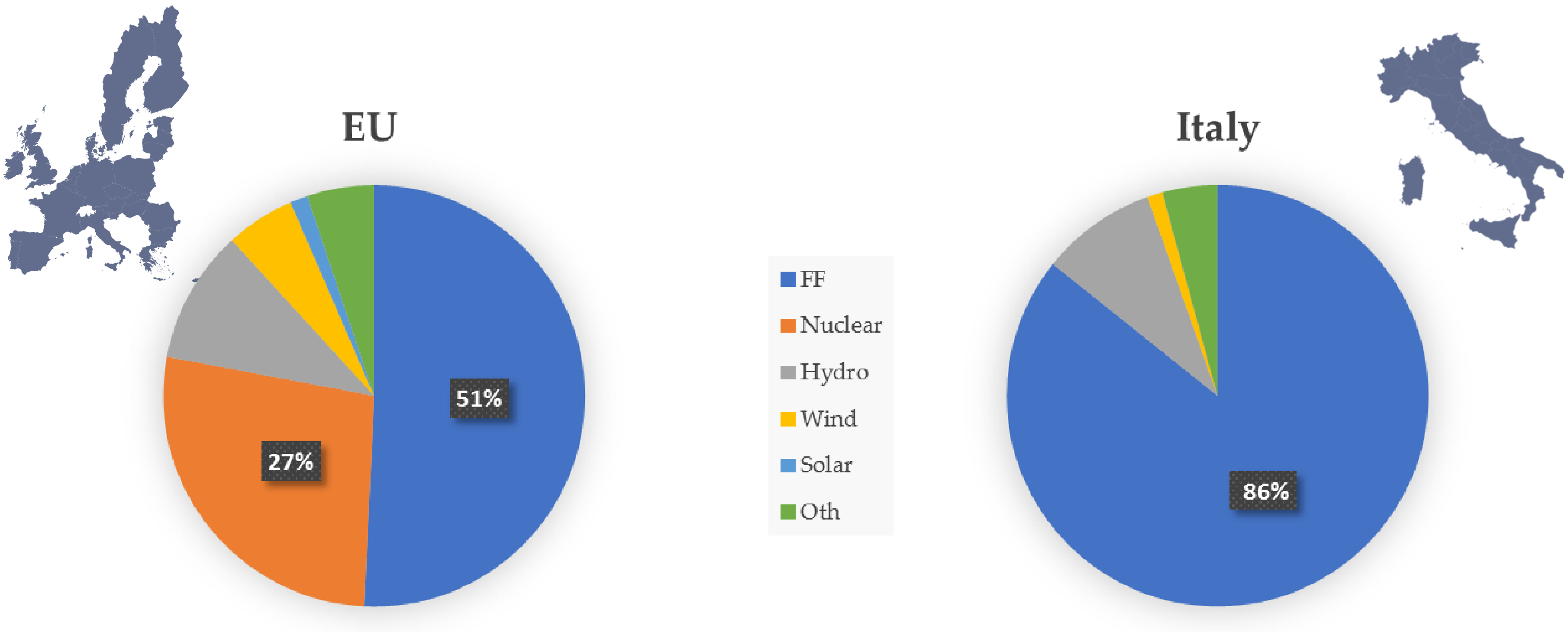
Results of the Experiment

% Changes in technology power generation, electricity and Co2 emissions in Base-Eu27 and Tech-Eu27 (GTAP 9, ref. year 2011) for Greece and Sweden



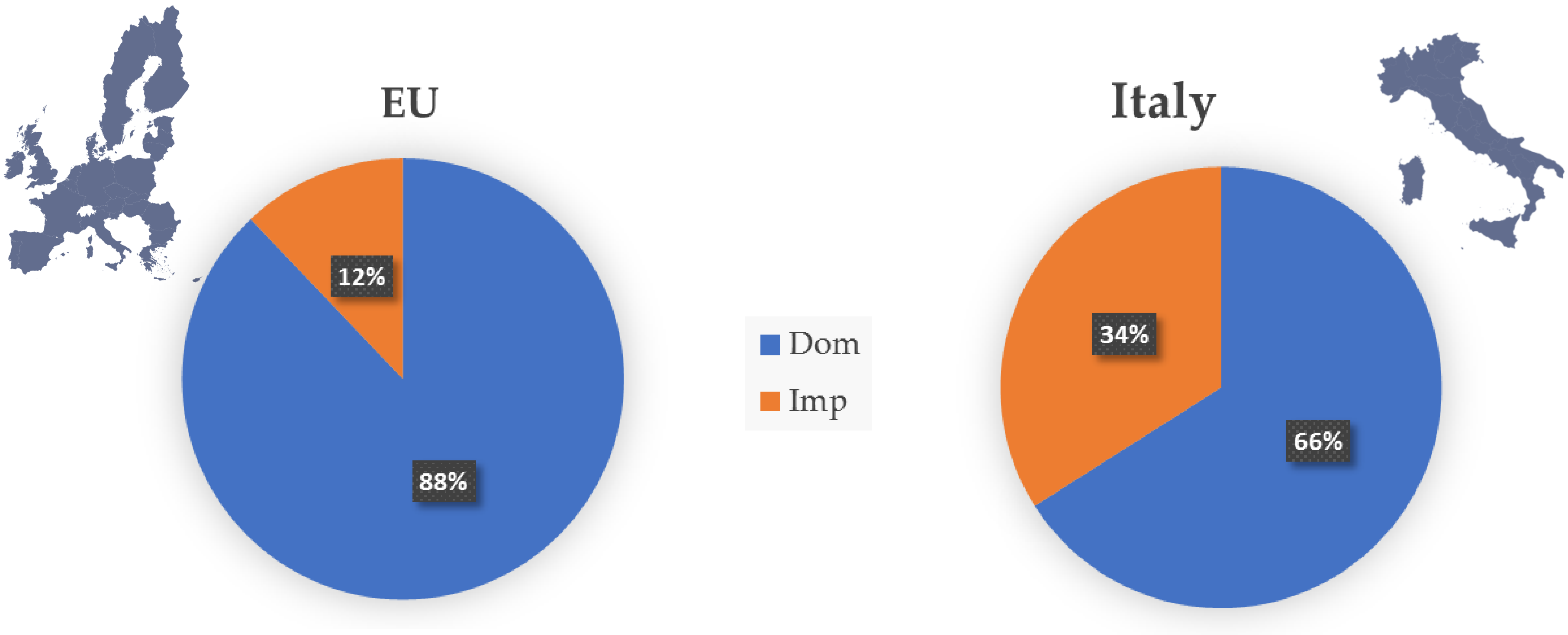
Economic interpretation: comparison with the sub-national study

Portfolio of power generation technologies in EU (GTAP 9 - 2011) and Italy (GTAP 8 -2007)



Economic interpretation: comparison with the sub-national study

Imported and domestic trade within EU (GTAP 9 - 2011) and within Italy (GTAP 8 -2007)



Conclusions

- For a given parametrization and taking EU as an example, increasing the technological and regional details can substantially decrease the economic loss of a de-carbonization pathway in CGE models.

- Overall the EU findings confirm those of the previous study for Italy by Standardi, Cai and Yeh (2017). However the importance of the spatial and technological components differ between the two studies.

- **Technological heterogeneity** in the electricity sector and **trade between countries/regions** provides opportunities to reduce the costs of a climate policy.

Further research

- Assessment of other big economies such as **USA**, **China**, **Russia**, **India**, **Brazil, Australia and Canada** would be useful.

- Further research could consist in carrying out a comparison with other modelling framework (linear programming, Markal models etc) usually used in the energy modelling community where factors other than trade and comparative advantages could be important.

Thanks

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