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Sensitivity of Climate Abatement Costs Estimates to Technological and Regional Details: A Case Study of European Union

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Motivations

The European Union (EU) has put in place ambitious policies to control GHG emissions, develop renewable energies and improve energy efficiencies, with the aim of reducing emissions by 40% from the 1990 level by the end of 2030.

Economic models (such as CGE) are widely used to assess the mitigation costs of a climate policy. However, results from models vary greatly, and they are sometimes contradictory. This could be largely due to differences in technological and geographical scales of models.

To better advise policy makers, it is important to understand sensitivity of models to these differences, and to resolve uncertainties surrounding estimates of climate policy impacts.

Using CGE models as a case study

Global Trade Analysis Project (**GTAP**) model and database (Hertel, 1997).

- **Representative household** maximizing consumption utility in each region
- **Representative firm** minimizing costs in each region and sector
- **Production** technology uses **primary inputs** (labor, capital, land, natural resources) and **intermediate input**.
- **Fully employed** primary inputs and **perfectly competitive** markets.
- Countries and regions mainly interact by **trade** and **investment**.

CTAP vs. CTEM models

CTAP and **CTEM** are two neo-classical global CGE models (Cai and Arora, 2015)

The **CTAP** model considers the electricity sector as characterized by a unique technology

- Imposing a carbon price will result in a shift toward higher share costs of labor and capital, and less fossil fuels, mimicking the transition toward cleaner technologies.

CTEM breaks the **electricity** sector of **CTAP** in **10** technologies:

1. Coal, **2**. Oil, **3**. Gas, **4**. Nuclear, **5**. Hydro, **6**. Wind, **7**. Solar, **8**. Biomass, **9**. Waste, **10**. Geothermal, Wave, and other renewables

Four Models of Different Tech & Spatial Details
Italy case study

Step 1. From **CTAP-1** to **CTEM-1**: increasing the number of technologies keeping Italy as a whole.

Step 2. From **CTAP-1** to **CTAP-20**: increasing the number of regions (**20** Italian regions).

Step 3. **CTAP-1** to **CTEM-20**: increasing the number of technologies and regions.

Step 4. From **CTEM-20** to **CTEM-20Lab**: modelling labor mobility between Italian regions.

20% CO2 emission reduction target in Italy achieved by a **national uniform carbon tax**.

Italy Case Study - Carbon prices and GDP loss

Carbon price to achieve a 20% national CO_2 emission reduction in Italy and the estimated effects of disaggregating regions and electric technologies.

	$ per ton of CO_2	Effect of tech disaggregation	Effect of regional disaggregation	Effect of adding labor mobility
CTAP-1	208			
CTEM-1	177	−14.9%		
CTAP-20	148		−28.8%	
CTEM-20	124	−40.4%		
CTEM-20Lab	123	−40.9%		

Mitigation cost to achieve a 20% national CO_2 emission reduction in Italy and the estimated effects of disaggregating regions and electric technologies.

	GDP loss (in 2007 billion US$)	Effect of tech disaggregation	Effect of regional disaggregation	Effect of adding labor mobility
CTAP-1	32.31			
CTEM-1	31.90	−1.3%		
CTAP-20	25.00		−22.6%	
CTEM-20	21.41	−33.7%		
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Italy Case Study - Key Findings

- Taking Italy as an example, not considering the technological and regional details can result in higher estimates of the necessary carbon price and economic loss of a de-carbonization pathway by up to 40% in CGE models.

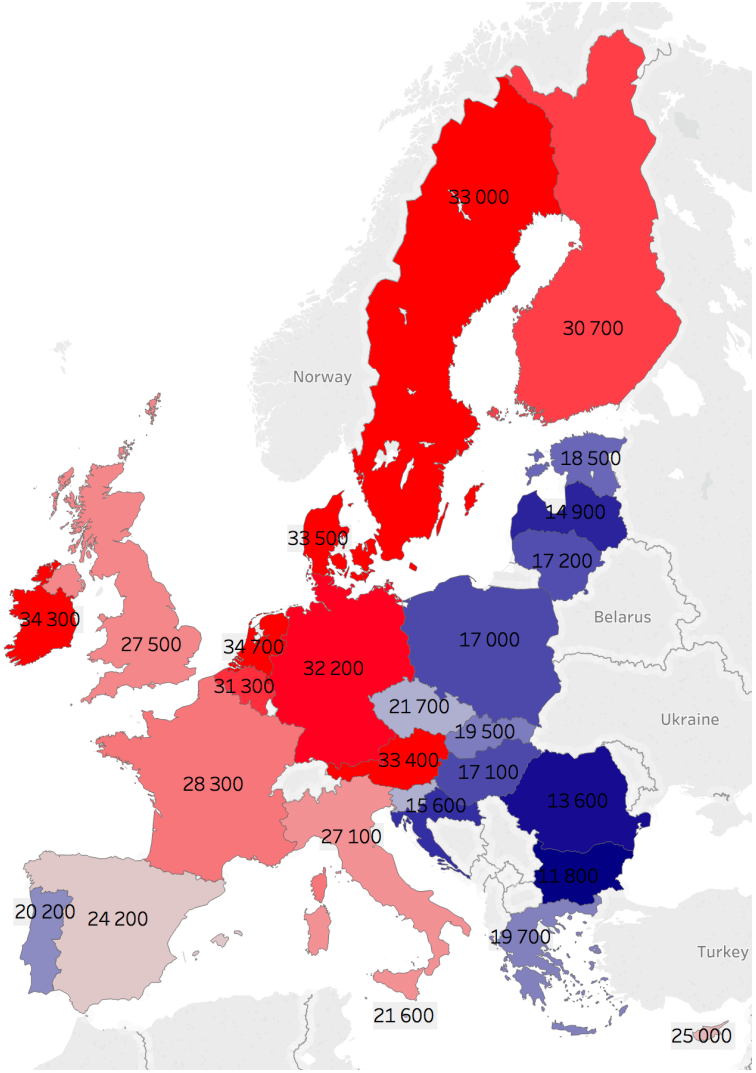
- The effect of representing regional details appears to be far more important than the effect of representing the details of electricity technology in both estimates.

New Research Questions using EU Case Study

Q1: Are the findings robust when applied to different country/super-national geographical areas?

Q2: How to achieve consistent estimates regardless of the levels of technological and spatial details?

A case study of the European Union



Countries within EU27

GDP (PPP) per capita Source: Eurostat for 2011

EU Models of Different Tech & Spatial Details

- One region, without and with technological details [CTAP-EU1 and CTEM-EU1]
- Three regions, North, South and East without and with technological detail [CTAP-EU3 and CTEM-EU3]
- Seventeen geographical areas, without and with technological detail [CTAP-EU17 and CTEM-EU17]
- Every country is considered, without and with technological detail [CTAP-EU27 and CTEM-EU27]

Estimates of Carbon Price

	$ per ton of CO2	Effect of regional disaggregation	Effect of tech disaggregation	Effect of both
CTAP-EU1	361.54			
CTEM-EU1	191.26		-47%	
CTAP-EU3	340.46	-6%		
CTEM-EU3	185.51	-3%	-46%	-49%
CTAP-EU27	306.48	-10%		
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- The directions of results are consistent with the Italian sub-national modeling exercise (Standardi et al., 2017).
- Comparing the most and the least aggregated models (CTAP-EU1 and CTEM-EU27), estimated C price is around 50% smaller using the model with the most detailed spatial and technological details.

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- Comparing the most and the least aggregated models (CTAP-EU1 and CTEM-EU27), estimated C price is around 50% smaller using the model with the most detailed spatial and technological details.
  - But, in the EU experiment the technological details appear to be far more important than the geographical details in affecting the estimates of carbon prices and GDP losses.
  - The impacts of regional disaggregation diminish as more regions or more technological details (shaded red in the previous slide) are added.

Q2 : How to achieve consistent estimates across diff levels of technological and spatial details?

Adjusting the elasticity of substitution

CTAP model:

- ESVF (electricity): the substitution elasticity between value added and the energy composite.
- 0.1 in the standard CTAP model

CTEM model:

- ESUBE: the elasticity of substitution between technologies.

Sensitivity analysis of elasticity of substitution

*Assume **CTEM-EU28** has the "true" estimates*

	$ per ton of CO2	GDP loss (%)	ESVF(ely)	ESUBE
CTAP-EU1	210	-1.10	5.8*ESVF	n.a.
CTAP-EU3	214	-1.10	5*ESVF	n.a.
CTAP-EU27	208	-1.10	4.5*ESVF	n.a.
CTEM-EU1	182	-1.10	0	1.1*ESUBE
CTEM-EU3	183	-1.10	0	1.03*ESUBE
CTEM-EU28	174	-1.10	0	1*ESUBE

- The adjustment of ESVF (electricity) is quite large (4.5 – 5.8×) of the default value of 0.1 in order to get the same GDP losses of CTEM-28.
- The adjustments of ESUBE is quite mild, consistent with earlier observations that spatial resolution has less effects in models with high technology resolutions.

Remaining Questions

- Understanding why at the sub-national level the regional component becomes more important than the technological details,
  - keeping in mind that the database at the subnational level has been estimated and is not observed directly as in the case of the country database (possible bias introduced with the regionalization technique).
- Econometric estimations of ESVF and ESUBE at different regional scales would be very important to reduce uncertainty

Thank you for your attention

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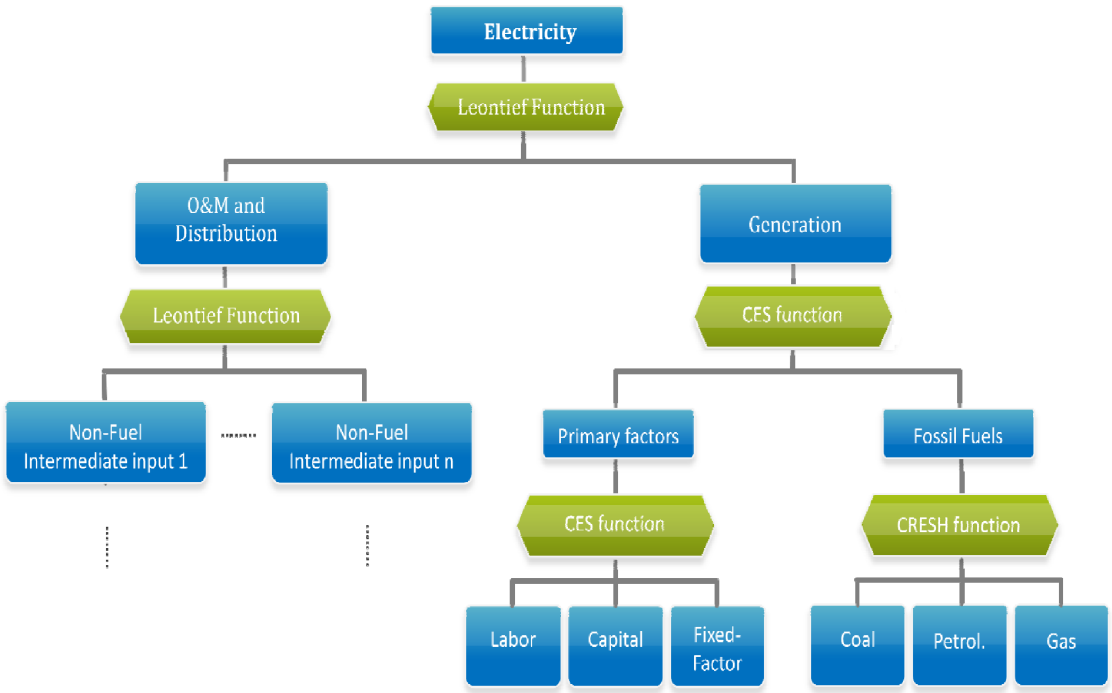
Back Up Slides

Methodology: electricity sector in CTAP



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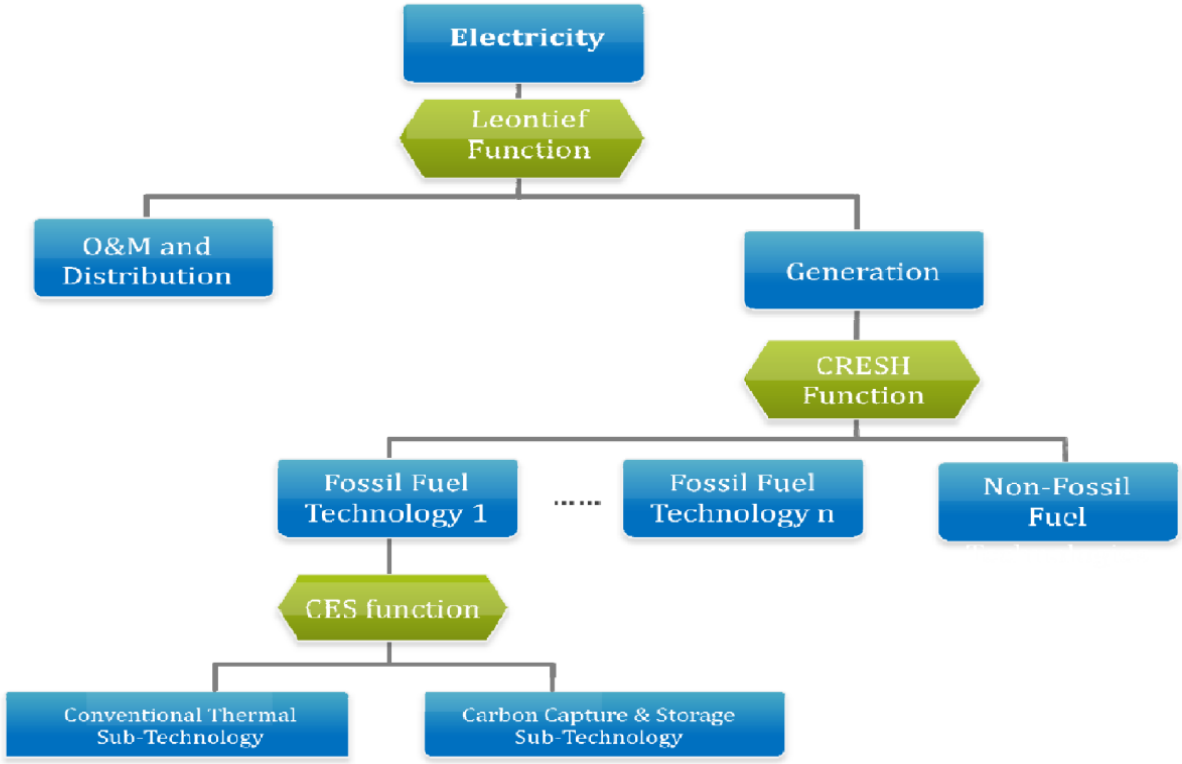
Methodology: electricity sector in CTEM



Italy Case Study - Sandardi (2017)
Electricity production loss

Reduction of power generation due to a 20% national CO_2 emission reduction in Italy and the estimated effects of disaggregating regions and electric technologies.

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- Adding electric technology details allows for the shift of electricity production from fossil fuels to renewable technologies.
- In CTAP-1, the technological shift is proxied by the shift toward higher share costs of labor and capital and less oil, coal and gas.
  - This does not reflect the different cost structures and fossil fuel dependence of various regions, and does not allow the model to explore their potential in absorbing the impacts of carbon pricing.
  - Predicts high reduction of power generation