Welfare implications of increasing spatial resolution in national CGE models for climate change impact assessment

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Outline

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- **Methodology Description**
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Motivations

Computable General Equilibrium (CGE) models are increasingly used for the economic evaluation of different climate and environmental impacts (Darwin and Tol, 2001; Bigano et al., 2008; Aaheim et al., 2010; Eboli et al., 2010; Ciscar et al., 2011; Bosello et al., 2012)

The sub-national detail is not common in CGE. However, climate impacts can be heterogenous even within countries

Objective

Objective 1: evaluating the **welfare implications** of **increasing** the **spatial resolution** of a **CGE** model when combined with **sub-national level impacts of climatic change** on sectoral Gross Value Added (GVA) derived through an econometric estimation

Objective 2: explaining the importance of **intra-national trade** (flows of imports and exports between sub-national units) and **capital/labour re-location** across regions. These economic channels are absent in the national version of the CGE

Methodology: the database of the CGE model

The global CGE is based on the Global Trade Analysis Project (GTAP) 8 database (Narayanan et al., 2012) a series of Social Accounting Matrices (SAMs) for 140 countries or group of countries for the base year 2007.

We split the national SAM of **Italy** in the GTAP 8 database into 20 SAMs, one for each NUTS-2 Italian region using information on sectoral value added from ISTAT and EUROSTAT (Bosello and Standardi, 2015).

We include only t**hree macro-economic sectors in the CGE: 1) agriculture, 2) industry, and 3) services**. This is to match the sectoral detail of the econometric analysis.

Methodology: the theoretical structure of CGE model

The theoretical structure of our CGE is neo-classical and based on the GTAP model (Hertel, 1997).

Main assumptions are:

- the competitive structure of the markets,
- the representative agents (firms, households and factors),
- the full use of resources.

In the macro-economic closure, the difference between regional savings and investments is equal to the trade balance and the investments are savings driven.

Methodology: inter and intra-national trade in the CGE

$$\min_{D_{i,c},I_{i,c}} \; D_{i,c} \cdot PD_{i,c} + I_{i,c} \cdot PI_{i,c}$$

$$s.t.\ Cons_{i,c} = g(D_{i,c}, I_{i,c}, \sigma_{ARM\ c}) \qquad \sigma_{ARM\ c} \geq 0$$

$$\min_{IMP_{i,1,c} \ldots IMP_{i,N,c}} \; \sum_{r*}^{N} IMP_{i,c*,c} \cdot PIMP_{i,c*,c}$$

$$s.t.\ I_{i,r} = g(IMP_{i,1,c}, \ldots, IMP_{i,N,c}, \sigma_{IMP\ c*,c}) \qquad \sigma_{IMP\ c*,c} \geq 0$$

where *Cons*, *D*, *I*, *PD* and *PI* are total and domestic consumption, aggregate imports, and the associated prices in sector *i* and country *c*, $\sigma_{ARM\ c}$ is the elasticity of substitution between domestic and imported product. *IMP* and *PIMP* are imports from country *c** to country *c* and the associated prices, $\sigma_{IMP\ c*,c}$ is the el. of sub. between imports coming from different countries. In the regionalized CGE we have:

$$\sigma_{ARM\ r} = 10 \cdot \sigma_{ARM\ c} \;,\; \sigma_{IMP\ r*,r} = 10 \cdot \sigma_{IMP\ c*,c}$$

where *r* is the sub-national index.

Methodology: geographical mobility of factors in the CGE

In the national version of the CGE model, capital and labor cannot move outside the country but in the regionalized version, an elasticity of substitution (σ_L, σ_K) regulates the movements of labor and capital across the Italian regions:

$$\max_{L_1 \dots L_N} \sum_r^N L_r \cdot PL_r$$

$$s.t.\ L_{Italy} = g(L_1, .., L_{N,}, \sigma_L) \qquad \sigma_L \leq 0$$

$$\max_{K_1 \dots K_N} \sum_r^N K_r \cdot PK_r$$

$$s.t.\ K_{Italy} = g(K_1, \dots, K_{N,}, \sigma_K) \qquad \sigma_K \leq 0$$

L, *K*, *PL* and *PK* are the regional supply of labor and capital and the associated prices, σ_L and σ_K represent the elasticity of transformation for inter-regional mobility of labor and capital, respectively. For this key parameters we conduct a sensitivity analysis:

σ_L = σ_K = (0, -30, -60, -90 and -120)

Methodology: econometric estimation

In a first step we use EUROSTAT data on sectoral GVA for the twenty Italian regions between 2000 – 2017.

The fixed-effects panel regression is:

$$lny_{rti} = f(C) + \alpha_r + \gamma_t + \theta_{1r}t + \theta_{2r}t^2$$

$$where\ f(C) = \beta_1 T + \beta_2 T^2 + \varphi tdev + \delta_1 prec + \delta_2 prec^2 + \mu WSDI$$

lny_{rti} is the log of GVA in region r in year t for sector i.
f(C) is the non-linear relationship between the temperature and productivity, controlled for by including both the linear (*T*) and squared-term of mean temperature (T^2);
short-run temperature shock ($tdev$);
total annual precipitation (*prec*) and its second-degree polynomial ($prec^2$);
Warm Spell Duration Index (*WSDI*);
Specification also include region α_r and year γ_t specific fixed-effects, and a quadratic time trend $\theta_{1r}t + \theta_{2r}t^2$ to capture non-linear technological changes.

Methodology: econometric estimation

In the second step, we combine our spatial non-linear econometric estimates with gridded climate data from four different regional climate models (KNMI RACMO22E, IPSL-CM5A-MR, MPI-ESM-LR, and CNRM-CM5) and future warming scenarios (RCP 8.5) to estimate the loss in productivity due to future climate change.

We define current and future climate as the mean of the climatic variables between 1986-2005 (historical) and 2050-2070 (future).

Methodology: linking the econometric analysis and the CGE

To link the econometric estimations to the macro-economic model we use the Total Factor Productivity (*TFP*) of the *GVA* function in the CGE model:

$$GVA_{i,r} = TFP_{i,r} \cdot h(L_{i,r}, K_{i,r,}, Land_{i,r,} NR_{i,r,} \sigma_{VA\,i}) \qquad \sigma_{VA\,i} > 0$$

where *h* is a Constant Return to Scale (CRS) CES function. *L*, *K*, *Land* and *NR* represent labor, physical capital, land and natural resources used in the production process. σ_{VA} is the sector-specific elasticity of substitution between the primary factors. Its values are based on the GTAP default setting (Narayanan et al., 2012).

We perform a comparative static analysis.

Results: econometric analysis

	(1)	(2)
	Agriculture	Industry
Spatial lag of agricultural GVA	0.789***	
	(0.000)	
Spatial lag of industrial GVA		0.899***
		(0.000)
WSDI	0.001***	0.001**
	(0.000)	(0.036)
Temperature deviation	-0.027**	-0.054***
	(0.031)	(0.001)
Total precipitation	0.116***	0.153***
	(0.004)	(0.004)
Total precipitation-squared	-0.019***	-0.024***
	(0.006)	(0.008)
Mean temperature	0.054***	0.078**
	(0.004)	(0.014)
Mean temperature-squared	-0.002*	-0.002***
	(0.084)	(0.009)
Spatial lag of WSDI	-0.003***	-0.003***
	(0.000)	(0.000)
Spatial lag of temperature deviation	0.004	0.016
	(0.812)	(0.422)
Spatial lag of total precipitation	0.018	0.015
	(0.755)	(0.850)
Spatial lag of total precipitation-squared	-0.006	-0.006
	(0.605)	(0.684)
Spatial lag of mean temperature	0.049**	0.097*
	(0.034)	(0.096)
Spatial lag of mean temperature-squared	-0.002**	-0.003*
	(0.021)	(0.052)
Constant	-5.453***	-6.875***
	(0.000)	(0.000)
Observations	236	236
R-squared	0.691	0.703
Number of regions	20	20

Results: econometric analysis and climate projections

The percentage change in GVA due to climate change in 2070 under RCP 8.5 is translated as a TFP impact in the Value added function of the CGE for agriculture and industry.

Percentage change in GVA due to climate change in 2070 under RCP 8.5

Regions	Agriculture	Industry
Piemonte	-13.68	-8.40
Valle d'Aosta	10.80	17.37
Lombardia	-13.26	-9.00
Trentino-AA	0.31	5.73
Veneto	-14.40	-11.17
Friuli-VG	-11.79	-7.59
Liguria	-12.63	-11.85
Emilia-Romagna	-16.47	-15.64
Toscana	-16.69	-16.06
Umbria	-18.05	-15.90
Marche	-16.46	-16.09
Lazio	-15.94	-15.79
Abruzzo	-18.60	-14.82
Molise	-19.20	-17.65
Campania	-16.69	-16.52
Puglia	-14.82	-19.90
Basilicata	-20.43	-19.64
Calabria	-15.36	-17.61
Sicily	-18.54	-19.17
Sardegna	-15.78	-18.70
Italy	-15.16	-12.39

Results: CGE results

Equivalent Variation (EV) of Italy in the different versions of the model (national vs regional) and for different values of the elasticity regulating the mobility of primary factors

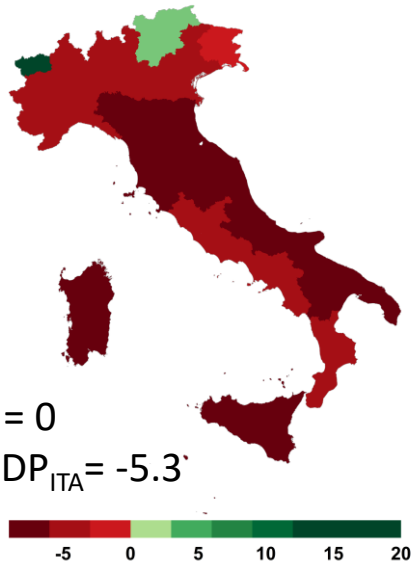
	National CGE	Regional CGE	Regional CGE	Regional CGE	Regional CGE	Regional CGE
		($\sigma_L = \sigma_K = 0$)	($\sigma_L = \sigma_K = -30$)	($\sigma_L = \sigma_K = -60$)	($\sigma_L = \sigma_K = -90$)	($\sigma_L = \sigma_K = -120$)
EV -2007 Mil $	-116706	-118625	-21814	-88567	-57752	-36134

GDP loss of Italy in the different versions of the model (national vs regional) and for different values of the elasticity regulating the mobility of primary factors

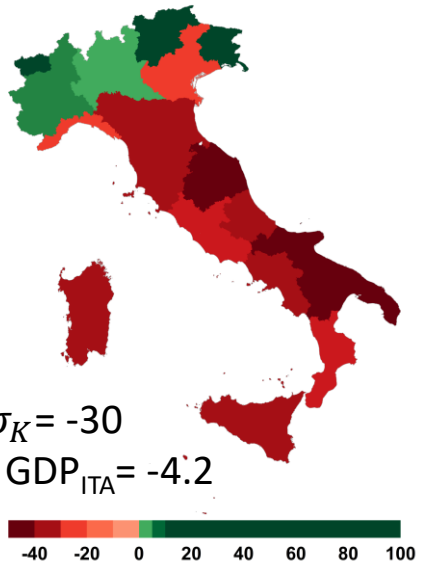
	National CGE	Regional CGE	Regional CGE	Regional CGE	Regional CGE	Regional CGE
		($\sigma_L = \sigma_K = 0$)	($\sigma_L = \sigma_K = -30$)	($\sigma_L = \sigma_K = -60$)	($\sigma_L = \sigma_K = -90$)	($\sigma_L = \sigma_K = -120$)
GDP loss - % Ch.	-5.30	-5.31	-4.18	-2.71	-1.63	-0.89

Results: CGE results

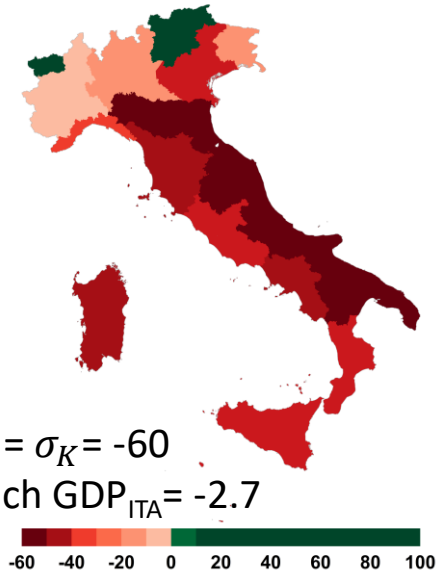
% GDP Changes for different values of factors mobility (σ_L, σ_K)



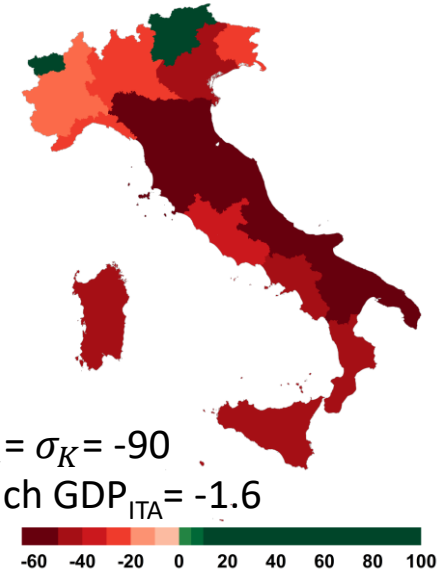
$\sigma_L = \sigma_K = 0$
% ch GDP_{ITA} = -5.3



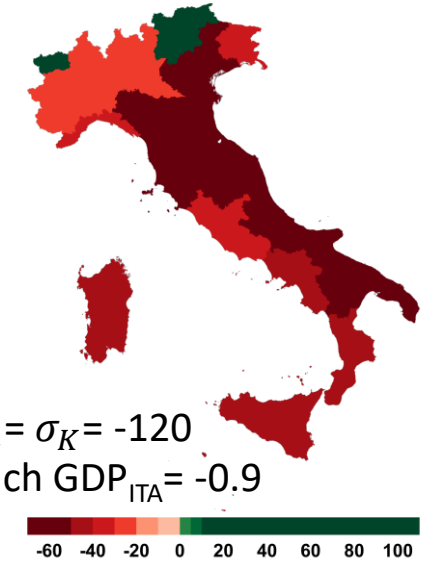
$\sigma_L = \sigma_K = -30$
% ch GDP_{ITA} = -4.2



$\sigma_L = \sigma_K = -60$
% ch GDP_{ITA} = -2.7



$\sigma_L = \sigma_K = -90$
% ch GDP_{ITA} = -1.6



$\sigma_L = \sigma_K = -120$
% ch GDP_{ITA} = -0.9

Results: CGE results

% change in the regional supply of labor and capital for different level of factors mobility

	($\sigma_L = \sigma_K = -30$)		($\sigma_L = \sigma_K = -60$)		($\sigma_L = \sigma_K = -90$)		($\sigma_L = \sigma_K = -120$)	
	Labour	**Capital**	**Labour**	**Capital**	**Labour**	**Capital**	**Labour**	**Capital**
Piemonte	**13.7**	**11.7**	-2.3	-3.7	-11.9	-13.2	-17.5	-18.7
Valle d'Aosta	**2626.4**	**2408.8**	**7155.5**	**6521.2**	**10546.7**	**9543.9**	**12770.8**	**11501.1**
Lombardia	**7.8**	**6.0**	-8.1	-9.1	-17.8	-18.6	-23.4	-24.1
Trentino-AA	**406.4**	**383.1**	**523.7**	**485.7**	**496.1**	**453.3**	**452.8**	**409.5**
Veneto	-13.8	-14.1	-32.3	-32.8	-42.1	-42.8	-47.5	-48.3
Friuli-VG	**16.1**	**12.8**	-6.5	-9.8	-20.5	-23.8	-28.3	-31.5
Liguria	-10.7	-10.7	-19.6	-20.5	-24.6	-26.0	-27.5	-29.3
Emilia-Romagna	-35.4	-34.4	-48.5	-48.6	-54.8	-55.4	-58.3	-59.2
Toscana	-32.7	-31.2	-44.1	-43.9	-49.9	-50.2	-53.2	-53.8
Umbria	-37.7	-36.3	-49.5	-49.1	-55.0	-55.2	-58.1	-58.5
Marche	-38.1	-36.3	-50.7	-50.1	-56.6	-56.6	-59.9	-60.2
Lazio	-20.1	-19.9	-26.9	-28.2	-30.7	-32.7	-32.9	-35.4
Abruzzo	-35.4	-35.0	-49.9	-50.5	-56.7	-57.7	-60.4	-61.6
Molise	-40.9	-40.0	-53.0	-53.5	-58.6	-59.7	-61.8	-63.1
Campania	-27.0	-27.1	-36.9	-38.2	-41.9	-43.8	-44.8	-47.1
Puglia	-36.9	-35.0	-46.4	-46.0	-50.9	-51.3	-53.5	-54.3
Basilicata	-38.4	-39.4	-49.0	-51.2	-54.3	-57.0	-57.4	-60.2
Calabria	-23.7	-25.3	-32.9	-36.1	-37.8	-41.7	-40.7	-45.0
Sicilia	-25.2	-26.0	-33.0	-35.3	-36.9	-40.0	-39.1	-42.7
Sardegna	-29.6	-32.4	-36.5	-40.7	-39.6	-44.5	-41.3	-46.6

Results: economic explanation

The intra-national trade of goods is crucial as it allows the regional consumers to shift demand of products to those areas where products can be produced at a cheaper price. This results in an increase in the demand for primary factors from firms and an increase in the prices of labor and capital, which attract units of labor and capital to the more productive areas.

If the spatial mobility of labor and capital is high, the benefit for the national GDP can be relevant.

Conclusions

We provide numeric evidence on the welfare implications of increasing the spatial resolution in a national CGE model when combined with econometric estimates of climate change impacts on TFP.

We describe the theoretical economic reasons of such implications. The main result from our analysis is that the country-level version of the CGE neglects intra-national market channels that are important in case of asymmetric climate change effects within the national territory.

These asymmetric effects of climate are likely to occur not only in large countries such US, China, India, and Russia but also in medium sized countries such as Italy.

Further research

As for further development, it would be worthy to increase the sectoral detail along with differentiated impacts between labor, capital, land, and natural resources to capture the inter-factor dimension.

Policy implications: if free markets for both goods and factors are important to achieve an efficient re-allocation of labor and capital within a country as a consequence of climate change, it is likely to be even more important at the global level where the climate impacts are expected to be much more heterogenous.

Thanks

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