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Summary

This paper describes a methodology to develop a Computable General Equilibrium model with a sub-national detail starting from a global database and model presenting the country-level as the highest resolution. This procedure is demonstratively applied to Italy, but can be transferred to any country/macro-region, provided regional data availability. Increasing the spatial resolution of a CGE model can be particularly useful to capture local specificities not only in response to given policy shocks, but also to environmental impacts, as, for instance, those originated by climate change, which are highly differentiated spatially. Conceptual and practical issues are treated: we use an innovative method to estimate bilateral trade flows across sub-national areas and analyse the implications of different assumptions on both factor and good intra-country mobility. We carry out a simple experiment to test the robustness of our regionalized structure.

Keywords: CGE Models, Regional Economics

JEL Classification: C68, D58, R11, R12, R13

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A sub-national CGE model for Italy

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Abstract

This paper describes a methodology to develop a Computable General Equilibrium model with a sub-national detail starting from a global database and model presenting the country-level as the highest resolution. This procedure is demonstratively applied to Italy, but can be transferred to any country/macro-region, provided regional data availability. Increasing the spatial resolution of a CGE model can be particularly useful to capture local specificities not only in response to given policy shocks, but also to environmental impacts, as, for instance, those originated by climate change, which are highly differentiated spatially. Conceptual and practical issues are treated: we use an innovative method to estimate bilateral trade flows across sub-national areas and analyse the implications of different assumptions on both factor and good intra-country mobility. We carry out a simple experiment to test the robustness of our regionalized structure.

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Summary

1. Introduction

Computable General Equilibrium models translate the Walrasian general equilibrium paradigm from theory into an operational description of real-life economies (Shoven and Walley, 1992). Over the years their use spread rapidly across the academia, international and national institutions. Indeed with their explicit representation of international and intersectoral trade-flows they are particularly suited to address policy relevant facts like tax reforms (see e.g. Shoven and Whalley, 1984; Bovenberg, 1987; Powell and Snape, 1993; Jorgenson, 1997; Dixon, 2001;), trade liberalization (see e.g. Anderson et al., 2005a; Anderson et al., 2005b; Bouet et al., 2005; François et al, 1995; Harrison et al., 1997; Hertel and Keeney, 2005), implementation of carbon and energy taxes for environmental purposes (see e.g. EC 2008; EC 2010; Böhringer et al., 2009, 2010, 2012). Recently, they have been increasingly applied to the study of economic consequences of climate change impacts (see e.g. 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 typical investigation unit of CGE models is the country, whose economic system is represented as a set of interacting sectors or industries. Sub national differences are usually overlooked.

Nevertheless, more rule than exception, countries present huge social-economic differences across their administrative units. It is thus reasonable to assume that each can be affected quite differently by a given policy shock.

At the same time, there are also situations in which different areas of a country are hit by different shocks. This is for instance the case of climate change impacts, that can be highly differentiated geographically.

Tracing these sub national effects is thus particularly important not only to gain a better grasp of the distributional implication of a given policy or impact, but also to get a more realistic estimation of the aggregate effect at the country level. In fact, specificities and interactions across sub national entities could be non-neutral in its determination.

One interesting extension of CGE models is thus their development into "sub-national" versions.

Nonetheless, few such CGE models exist. This is mainly due to the difficulty to create mutually consistent social accounting matrices for a large number of sub-national regions. Among these: Peter et al. (1996) developed the MRF (*Multi Regional Forecasting*) model to simulate tax/environmental policy for the Australian economy; Jean and Laborde (2004) developed the DREAM-MIRAGE (*Deep Regional Economic Analysis Model – Modelling International Relationships in Applied General Equilibrium*) model for Europe taking into account 119 NUTS (*Nomenclature of Territorial Units for Statistics*) 1 regions; Canning and Tsigas (2000) built a model for eight macro-regions of the USA.

Furthermore, some CGE models exist presenting a spatially resolved description of the agricultural sector. Examples of this type are CAPRI-GTAP (*Common Agricultural Policy Regional Impact Analysis – Global Trade Analysis Project*) (Jansson et al., 2009), CAPSIM (*China's Agricultural Policy Simulation Model*) (Yang et al., 2011), GTAP-AEZ (*Global Trade Analysis Project – AgroEcological Zones*) (Hertel et al., 2009; Lee et al., 2009) and the ICES-AEZ (*Intertemporal Computable Equilibrium System – AgroEcological Zones*) (Michetti and Parrado, 2012).[1]

Against this background, we describe a methodology to build a sub-national version of a CGE model and database presenting originally the country as the highest detail. Our reference is the

[1] For a brief survey of the literature on sub-national CGE global models see section 2 in Perali et al., (2012). For an extensive literature, see Rodriguez (2007).

GTAP model (Hertel, 1997). This procedure is applied demonstratively to Italy; however, it can be easily transferred to other countries provided data availability. At this stage, we split the Italian economic system in 10 sectors and 3 macro-regions (North, Centre, South). In a next step, the model will be extended to all 20 Italian regions and 57 GTAP sectors.

Regionalization implies two work phases: one on the database, and another on the model structure.

The first consists in the creation of sub-national Social Accounting Matrices accounting for sectoral interactions within sub national areas and of each of these with the rest of the world. The major challenge in this is the estimation of the intra national trade flows due to the usual lack of data of this kind. A typical solution is to use a gravitational approach (Horridge and Wittwer, 2010; Dixon et al. 2012). This method assumes that trade between two regions depends positively on their sectoral production and negatively on their distance. Nevertheless, this is only an approximation because other variables play a role in the determination of the bilateral trade.

We propose an alternative and innovative approach. We combine two sources of information: transport data and economic production data both from ISTAT (*Italian National Statistical Institute*).This method is likely to increase the data realism because transport information represents actual flows.

The second task requires modifying the functional structure of the model especially to introduce a different degree of factors and goods mobility within and between country borders. In fact, both goods and factors are expected to move easier within the country than between countries.

To test the performance of our regionalized CGE model we carry out a simple experiment (a uniform 20% decrease in the productivity of all primary factors in Italy) and we compare the results coming from the standard country-level model with our modified sub-national version. We also perform some sensitivity tests on the elasticity of substitution parameters.

The paper is organized as follows. Section 2 presents the database construction and the estimation strategy to obtain trade flows across sub-national regions. Section 3 describes the model improvement for the factors and goods market. Section 4 lays out the results of the experiment and sensitivity analysis. Section 5 concludes and sketches some ideas for future research.

2. Database development

To test and illustrate the methodology, we purposefully keep the sectoral and country disaggregation of our model simple. Italy is detailed in its Northern, Central and Southern macro regions. The global economic system is just split in “Europe” and Rest of the World (Table 1). Sectors are 10 (Table 2)**.**

Our starting point is the GTAP 7 database (Narayanan and Walmsley, 2008), consisting of 57 sectors and 113 countries or groups of countries. The reference year is 2004.

Data on value added, labour and land input for the 20 Italian regions and 40 production sectors derive from ISTAT (Conti Economici Regionali, Anni 1995-2009; Agricoltura e Zootecnia; Valore Aggiunto ai Prezzi di Base dell’Agricoltura per Regione, Anni 1980-2011). ISTAT also reports bilateral flows in physical volume (tons) by mode of transportation (truck, rail, water and air) for the 20 Italian regions (Trasporto Merci su Strada, 2008-2009; Trasporto Aereo, 2003-2009; Trasporto Marittimo, 2005-2008; Trasporto Ferroviario, 2004-2009), but for a smaller number of sectors (just 10 agricultural/industrial sectors).[2]

[2] For the moment, we use the overall amount of carried goods as a proxy in the service sectors.

Table 1: regional detail of the CGE model

Acronym	Description
North	Northern Italy: Aosta-Valley, Emilia-Romagna, Friuli-Venezia Giulia, Liguria, Lombardy, Piedmont, Trentino-South Tyrol, Veneto
Centre	Central Italy: Lazio, Marche, Tuscany, Umbria
South	Southern Italy: Abruzzi, Apulia, Basilicata, Campania, Calabria, Molise, Sardinia, Sicily
EU	Rest of European Union (27 countries except Italy)
ROW	All remaining countries in the world

Table 2: sectoral detail of the CGE model

Acronym	Description
GrainsCrops	Grains and crops
MeatLstk	Livestock meat products
Extraction	Mining and extraction
ProcFood	Processed food
TextWapp	Textiles and clothing
LightMnfc	Light manufacturing
HeavyMnfc	Heavy manufacturing
Util_Cons	Utilities and construction
TransComm	Transport and communication
OthServices	Other services

2.1 Splitting the production side

In a CGE model, the production side is determined by the value of what is produced of every good and service as well as by the amount of primary factors and intermediates needed to produce them.

The first step consists thus in detailing these data, originally available at the country level, to the new regional scope.

To do this, first, we match the 40 ISTAT sectors with the 10 macro-sectors chosen in our aggregation. Then, the regional shares of value added, labour and land computed from ISTAT data are used to distribute the respective GTAP Italian data across the three Italian macro-regions. Note that two more primary factors appear in the GTAP database: capital and natural resources. The respective regional shares are not retrievable from ISTAT. Those of capital are then computed as a difference between value added and labour, while those of natural resources are proxied by the sub-national share of value added.

It is then assumed that intermediate inputs of origin sector *i* in the destination sector *j* are distributed according to the value added share in the origin sector. For example, the economic value of the agricultural goods, which the Northern Italian manufactures purchase, is determined upon the agricultural value added share in the sub-national region.

2.2 Estimation of trade flows across sub-national regions

The second step, consisting in the determination of the bilateral trade flows across sub-national regions, is the most challenging. These data are very often missing. To overcome the problem the procedure usually adopted is the so-called gravitational approach as in Horridge and Wittwer (2010) and Dixon *et al.* (2012). By this method, the bilateral intra-country trade flows are estimated using a gravity equation as in the Newtonian physics. It accounts for the sectoral production in the origin and destination regions as attractors and the distance between them as friction. This procedure appealing for simplicity is very likely to introduce distortions and inconsistencies as it overlooks the many factors determining trade flows.

Some alternative approaches exist. For example, Chintrakarn and Millimet (2006) and Canning and Tsigas (2000) use transport data for United States to obtain trade flows across member States. Dubé and Lemelin (2005) also use transport data to estimate the trade flows across three sub-national regions of Quebec. In addition, they integrate this information with economic data about aggregate sub-national exports and imports and apply a cross-entropy optimisation method to make the two types of information consistent.

ISTAT does provide transport information. Therefore, we also prefer to use transport data to depict bilateral flows rather than the gravitational approach because the former seems to represent more effectively the actual flows of commodity within a country. Following Dubé and Lemelin (2005), we adjust the trade flows across sub-national regions by the RAS statistical method (Deming and Stephan, 1940; Bacharach, 1970) to increase the consistency of transportation flows with the production data.[3]

In practice, the procedure is the following. Consider the share matrix **Π** represented in Table 3. Afterwards, vectors and matrices are in bold type.

In matrix **Π,** the rows represent the origin, and the columns the destination sub-national regions. Its general element π_{od} , where $0 \leq \pi_{od} \leq 1$, is computed dividing the physical volume of good transferred from origin to destination region, by the total physical amount of carried goods within Italy. This implies that, we have 10 different **Π**, one for each sector. As our procedure is valid for all the sectors, for sake of algebraic simplicity we do not consider a sector index in the rest of the sub-section.

Table 3: Components of Matrix Π

	North	Centre	South	Tot
North	π_{11}	π_{12}	π_{13}	$\Pi_{1.}$
Centre	π_{21}	π_{22}	π_{23}	$\Pi_{2.}$
South	π_{31}	π_{32}	π_{33}	$\Pi_{3.}$
Tot	$\Pi_{.1}$	$\Pi_{.2}$	$\Pi_{.3}$	1

Denoting Y_{ITA} the Italian sectoral production sold countrywide that is the value of sectoral production sold domestically, D the sub-national demand (excluded demand for foreign goods), EXP the sub-national exports towards the other sub-national regions, IMP the sub-national imports from the other sub-national regions, EXPAG the aggregate sub-national exports towards the rest of Italy and IMPAG the aggregate sub-national imports from the rest of Italy, we compute these variables for, say, sub-national region Centre, applying the following formulas:

[3] The RAS abbreviation stems from the names of the vectors (R and S) and matrix (A) used by Bacharach in the original formulation of the algorithm. According to McDougall (1999) RAS is a type of cross-entropy optimization method and it should be preferred in the absence of information about variation in column structure or row structure of the matrix.

$$
\begin{aligned}
&(\pi_{12}+\pi_{22}+\pi_{32})\cdot Y_{ITA} = D_{Centre}\\
&\pi_{21}\cdot Y_{ITA} = EXP_{Centre, North}\\
&\pi_{23}\cdot Y_{ITA} = EXP_{Centre, South}\\
&(\pi_{21}+\pi_{23})\cdot Y_{ITA} = EXPAG_{Centre}\\
&\pi_{12}\cdot Y_{ITA} = IMP_{North, Centre}\\
&\pi_{32}\cdot Y_{ITA} = IMP_{South, Centre}\\
&(\pi_{12}+\pi_{32})\cdot Y_{ITA} = IMPAG_{Centre}
\end{aligned}
\qquad \text{(eq. sys. 1)}
$$

We apply the same procedure for each sub-national region.

Now, it well may happen that the regional production that can be inferred from equation system 1 by applying:

$$
\begin{aligned}
&Y_{North} = D_{North} + EXPAG_{North} - IMPAG_{North}\\
&Y_{Centre} = D_{Centre} + EXPAG_{Centre} - IMPAG_{Centre}\\
&Y_{South} = D_{South} + EXPAG_{South} - IMPAG_{South}
\end{aligned}
\qquad \text{(eq. sys 2)}
$$

does not coincide with the production value reported by statistical sources.

The required adjustment takes place through the bi-proportional RAS method. Consider the bilateral trade matrix:

$$\mathbf{A} = \mathbf{\Pi}\ Y_{ITA}$$

of size 3 x 3, where we put $\pi_{11} = \pi_{22} = \pi_{33} = 0$. In matrix **A,** the general element is a_{od} where row *o* represents the origin and column *d* the destination sub-national region respectively. We also have a target vector of row totals **E** (aggregate sub-national exports to the rest of Italy, size 3 x 1) and a target vector of column totals **M** (aggregate sub-national imports from the rest of Italy, size 3 x 1). Targets are computed using the ISTAT information about economic production (Y_{North}, Y_{Center} and Y_{South}) according to the following equations:

$$
\begin{aligned}
&E_{North} = Y_{North} - D_{North} + IMPAG_{North}\\
&E_{Centre} = Y_{Centre} - D_{Centre} + IMPAG_{Centre}\\
&E_{South} = Y_{South} - D_{South} + IMPAG_{South}\\
&M_{North} = D_{North} + EXPAG_{North} - Y_{North}\\
&M_{Centre} = D_{Centre} + EXPAG_{Centre} - Y_{Centre}\\
&M_{South} = D_{South} + EXPAG_{South} - Y_{South}
\end{aligned}
\qquad \text{(eq. sys. 3)}
$$

The RAS method attempts to find a new matrix **B** such that:

$$
\begin{aligned}
&\sum_{o} b_{od} = M_d\\
&\sum_{d} b_{od} = E_o
\end{aligned}
$$

where b_{od}, e_o and m_d are, respectively, the general element of matrix **B**, vector **E** and vector **M**.

The new matrix **B** is related to the original **A** via the iterative procedure:

$$b_{od} = (rm)_o \cdot (cm)_d \cdot a_{od}$$

where $(rm)_o$ is the multiplier of row *o* and $(cm)_d$ is the multiplier of column *d*.

For this initial application, we split the Italian exports towards EU and rest of the world and Italian imports from EU and rest of the world using the sectoral sub-national share of value added.[4]

Applying our methodology, we are able to derive the value of production (Table 4) and the inter-regional trade (Table 5). In Table 5, as usual the row represents the origin sub-national region and the column the destination sub-national region, respectively.[5]

Table 4: value of production (2004 million $)

	North	Center	South
GrainsCrops	19071	6474	15728
MeatLstk	21496	7673	16770
Extraction	6020	2460	2540
ProcFood	67922	19816	33721
TextWapp	53410	18474	16218
LightMnfc	220166	60921	56170
HeavyMnfc	336396	89888	95704
Util_Cons	134259	45670	59645
TransComm	295638	117664	128158
OthServices	485927	221315	266259

[4] We are aware that this assumption is very strong because import and export patterns are different. Nevertheless, we use it only in this methodological paper. We remove it in the 20 regions version of the model where additional data from ISTAT on sub-national foreign exports and imports are available.

[5] Few numbers in the extraction and processed food sectors seem to be not realistic. This could depend on the interaction between the RAS adjustment procedure and the very rough sectoral and geographical aggregation adopted at this stage. However, given the lack of real bilateral trade data at the sub-national level we are not able to assess properly the reliability of these results.

Table 5: Bilateral trade flows (2004 million $)

GrainCrops	North	Centre	South	EU	ROW	Tot exp
North		823	2417	1607	375	5222
Centre	457		1059	598	139	2253
South	814	482		1532	357	3185
EU	1486	553	1417			
ROW	1772	659	1689			
Tot imp	4529	2517	6583			

MeatLstk	North	Centre	South	EU	ROW	Tot exp
North		1232	2669	744	191	4836
Centre	896		1355	277	71	2599
South	694	363		709	182	1948
EU	2855	1063	2723			
ROW	573	213	546			
Tot imp	5018	2871	7292			

Extraction	North	Centre	South	EU	ROW	Tot exp
North		756	1764	347	267	3135
Centre	21		1297	125	96	1540
South	11	977		97	74	1159
EU	1508	544	420			
ROW	17894	6454	4987			
Tot imp	19433	8730	8468			

ProcFood	North	Centre	South	EU	ROW	Tot exp
North		15	738	6820	4151	11723
Centre	323		5824	1492	908	8547
South	6690	3712		2344	1427	14173
EU	9426	2062	3240			
ROW	2703	591	929			
Tot imp	19142	6380	10731			

TextWapp	North	Centre	South	EU	ROW	Tot exp
North		830	1428	11909	8403	22569
Centre	1342		1421	3848	2715	9325
South	2595	2370		2565	1810	9340
EU	6311	2039	1359			
ROW	6459	2087	1391			
Tot imp	16707	7326	5599			

LightMnfc	North	Centre	South	EU	ROW	Tot exp
North		3203	951	40748	23137	68040
Centre	12042		6265	9757	5540	33603
South	6629	12855		6887	3911	30281
EU	41018	9821	6933			
ROW	15985	3827	2702			
Tot imp	75673	29707	16850			

HeavyMnfc	North	Centre	South	EU	ROW	Tot exp
North		4539	6084	69036	53278	132938
Centre	22728		8637	14585	11256	57206
South	16511	13814		13613	10506	54444
EU	74000	15634	14592			
ROW	39295	8302	7748			
Tot imp	152534	42288	37061			

Util_Cons	North	Centre	South	EU	ROW	Tot exp
North		7480	12099	620	473	20673
Centre	1497		5769	239	182	7687
South	5318	1697		334	255	7603
EU	1672	643	900			
ROW	1661	639	895			
Tot imp	10148	10459	19663			

TransComm	North	Centre	South	EU	ROW	Tot exp
North		15181	4611	10323	7275	37389
Centre	10456		7134	4397	3098	25085
South	3847	6655	0	4397	3098	17998
EU	9391	4000	4000			
ROW	8312	3540	3540			
Tot imp	32006	29377	19284			

OthServices	North	Centre	South	EU	ROW	Tot exp
North		28079	8625	11507	7027	55237
Centre	17767		16923	5523	3373	43587
South	6175	14746		5984	3654	30558
EU	10219	4905	5314			
ROW	7846	3766	4080			
Tot imp	42007	51496	34942			

3. Changes in the model structure

In standard CGE models primary factors of production like labour and capital are mobile across sectors, within the country or macro-region and do not usually move, across countries[6]. There are CGE models, like GTAP, which also include land among primary factors. Land does not move physically, but can be used for different purposes, namely to grow different crops. It is a "sluggish" factor of production as there are constraints in land uses captured by an elasticity of transformation parameter which determines the land supply in each agricultural sector. This sectoral mobility of primary input is clearly technological/sectoral rather than spatial. The issue is slightly different for intermediates and final consumption goods. Both can be imported and thus are "mobile" across countries. However, in the CGE framework, to prevent unrealistic specialization phenomena and trade overflows that could warp the results of the model, the Armington assumption (1969) is introduced. It postulates imperfect substitutability between homologue domestic and imported goods. The values of the Armington elasticity are set by econometric estimations, which are carried out at the national level.

When, as in our case, the spatial detail of the CGE model is increased, it would be unrealistic to simply transfer to sub national entities the same parameterization used in the national model.

Both intra national primary factor mobility and intra and extra regional goods' and intermediates' substitution require additional assumptions.

As to the first point it is reasonable to assume some, but not perfect, degree of factor mobility across regions within a country.

As to the second point some imperfect substitution between goods produced in different regions must be introduced. If not, unrealistic full specialization or trade flows could be observed also at the regional levels. Following the empirical evidence that trade is bigger within than between countries given the same distance - the so-called border effect (McCallum, 1995) - these Armington elasticities should be higher intra than inter country.

3.1 Mobility in factors market

The value added in the standard GTAP model originates from five primary factors: land, natural resources, unskilled labour, skilled labour and capital. All the sectors use labour and capital while only some use land and natural resources (agriculture and mining-related sectors, respectively). Land and natural resources supply is sluggish across sectors while labour and capital are perfectly mobile. All the primary factors are spatially immobile. For our sub-national context, we assume the following:

1) Primary factors sectoral mobility does not change.
2) Land and natural resources remain spatially immobile at the sub-national level.
3) Sub-national unskilled labour, skilled labour and capital supply is geographically sluggish within Italian regions and still immobile with respect to the rest of Europe and the rest of the world.

The third assumption is new with respect to the standard GTAP model. It is implemented through a CET (*Constant Elasticity of Transformation*) function: as a result, workers and capital can move outside the Italian region they belong to in response to economic shocks.[7]

[6] More sophisticated CGE models can in fact model labor or capital flows across countries.
[7] Note this intra-country mobility is lower than that implicitly assumed by the National model, but larger than that that the same model assumes inter-country.

First order conditions of the CET supply function and the formula to determine the national price of the endowment (shadow price) are given in the equations 1-6, where QL, QH, QK, PL, PH, and PK represent, respectively, the quantity of supplied unskilled labour, skilled labour, capital and the associated prices. ITA and *r* are, respectively, the unique Italian aggregate index and the sub-national index. The parameters σ_L, σ_H and σ_K are the elasticity of substitution of the endowment supply, they are a measure of geographical mobility. Increasing the absolute value of these parameters means increasing the factors mobility within Italy. At this very first stage, we make the hypothesis that $\sigma_L = \sigma_H = \sigma_K$.

$$QL_r = QL_{ITA}\left(\frac{PL_{ITA}}{PL_r}\right)^{\sigma_L} \quad \text{with } \sigma_L < 0 \tag{1}$$

$$\sum_r QL_r PL_r = QL_{ITA} PL_{ITA} \tag{2}$$

$$QH_r = QH_{ITA}\left(\frac{PH_{ITA}}{PH_r}\right)^{\sigma_H} \quad \text{with } \sigma_H < 0 \tag{3}$$

$$\sum_r QH_r PH_r = QH_{ITA} PH_{ITA} \tag{4}$$

$$QK_r = QK_{ITA}\left(\frac{PK_{ITA}}{PK_r}\right)^{\sigma_K} \quad \text{with } \sigma_K < 0 \tag{5}$$

$$\sum_r QK_r PK_r = QK_{ITA} PK_{ITA} \tag{6}$$

3.2 The trade structure across sub-national regions

In the standard GTAP model the demand side is composed by private consumption, government spending and intermediate goods[8]. The demand tree follows a double nest (Figure 1). The first nest links domestic demand and aggregate foreign imports of a specific commodity (irrespective of origin country) for each agent (households, government, firms). The second nest differentiates foreign imports according to the geographical origin. The second model improvement thus consists in modifying that tree in order to make sub-national products closer substitutes among them than the foreign products.

To achieve this goal we insert two additional bundles for each sub-national region keeping unchanged the structure for the rest of Europe and the rest of the world. Figure 2 illustrates the new demand tree.

[8] These are not exclusive. Of course, economic agents can also employ their income alternatively; namely, firms will buy some amount of primary factors (that have the specific treatment highlighted in the previous section) and households will allocate some share of income to savings. However, treatment of primary factors and savings are not affected by the model improvement explained here. It only applies to commodities/goods producible both domestically and abroad.

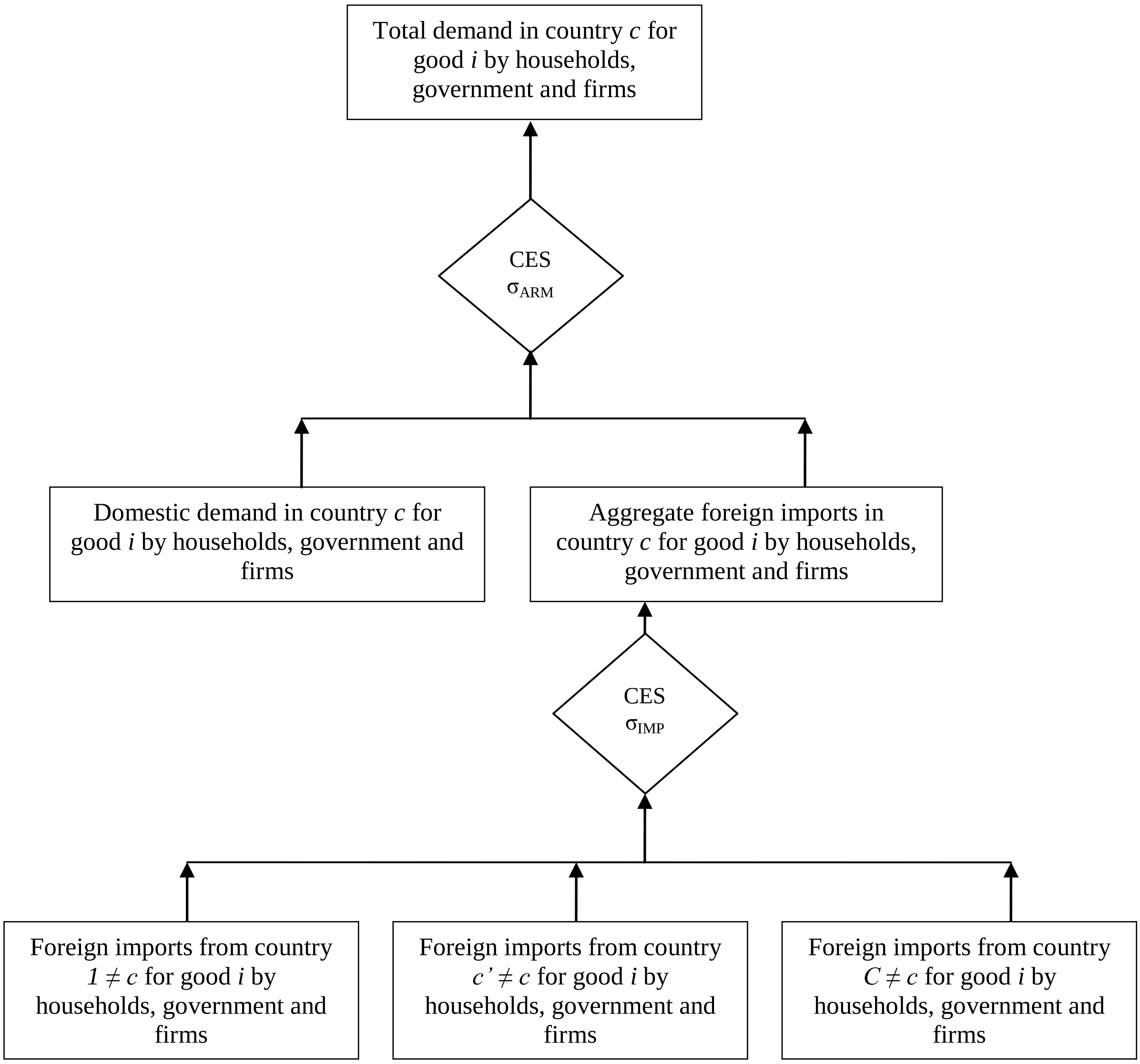

Figure 1 – GTAP standard commodity demand structure

Source: Hertel (1997)

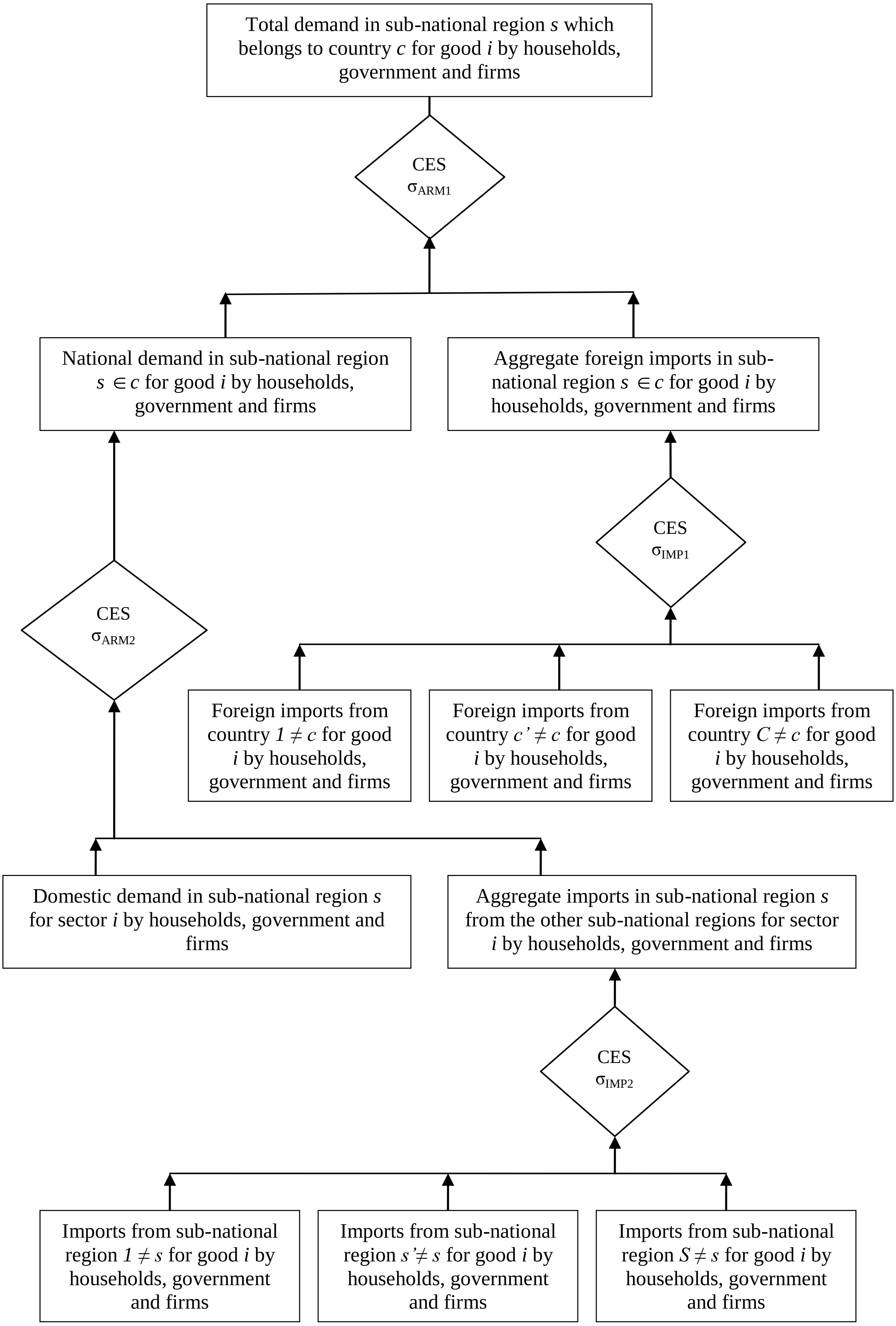

Figure 2 – GTAP sub-national commodity demand structure

Compared to the national CGE version, Figure 2 depicts two further bundles because the "national" demand in the sub-national regions is broken in two parts. The upper bundle links domestic demand and aggregate intra-national imports while the lower bundle differentiates the imports with respect to the origin sub-national region. We insert consistently four additional parameters σ_{ARM1}, σ_{IMP1}, σ_{ARM2} and σ_{IMP2}. Two relations characterises the four parameters:

$$\sigma_{ARM} = \sigma_{ARM1} < \sigma_{ARM2}$$

$$\sigma_{IMP} = \sigma_{IMP1} < \sigma_{IMP2}$$

where σ_{ARM} and σ_{IMP} are the Armington eleasticities in the standard GTAP model represented in Figure 1. We use CES (*constant elasticity of substitution*) functions to model the inter-national and intra-national bundles. As the following equations apply to all sectors in the same manner, for sake of algebraic simplicity we do not consider a sector index in the rest of the sub-section.

Starting from private consumption, QC, QCD and QCM, represent, respectively, the quantity of total, domestic and imported private goods in the country or group of countries, represented by index *c*. QCU, QCDU and QCMU are, respectively, total, national and international imported private goods in the sub-national region *r* (the suffix U stands for upper bundle). QCDL and QCML represent the domestic and intra-national imported private goods in the sub-national region (the suffix L stands for lower bundle). PC, PCD, PCM, PCU, PCDU, PCMU, PCDL and PCML are the associated prices.

The equations 7-12 show the mathematics behind the old trade structure for countries in Figure 1 and the new trade structure in Figure 2 for sub-national regions:

$$QCD_c = QC_c\left(\frac{PC_c}{PCD_c}\right)^{\sigma_{ARM}} \quad \text{with}\ \sigma_{ARM} > 0 \qquad (7)$$

$$QCM_c = QC_c\left(\frac{PC_c}{PCM_c}\right)^{\sigma_{ARM}} \quad \text{with}\ \sigma_{ARM} > 0 \qquad (8)$$

$$QCDU_r = QCU_r\left(\frac{PCU_r}{PCDU_r}\right)^{\sigma_{ARM1}} \quad \text{with}\ \sigma_{ARM1} > 0 \qquad (9)$$

$$QCMU_r = QCU_r\left(\frac{PCU_r}{PCMU_r}\right)^{\sigma_{ARM1}} \quad \text{with}\ \sigma_{ARM1} > 0 \qquad (10)$$

$$QCDL_r = QCDU_r\left(\frac{PCDU_r}{PCDL_r}\right)^{\sigma_{ARM2}} \quad \text{with}\ \sigma_{ARM2} > 0 \qquad (11)$$

$$QCML_r = QCDU_r\left(\frac{PCDU_r}{PCML_r}\right)^{\sigma_{ARM2}} \quad \text{with}\ \sigma_{ARM2} > 0 \qquad (12)$$

QG, QGD and QGM, represent, respectively, the quantity of total, domestic and imported goods purchased by government in the country or group of countries. QGU, QGDU and QGMU are, respectively, total, national and international imported goods purchased by government in the sub-national region. QGDL and QGML represent the domestic and intra-national imported government goods purchased by the government in the sub-national region. PG, PGD, PGM, PGU, PGDU, PGMU, PGDL and PGML are the associated prices.

The equations 13-18 describe the new tree for the government demand:

$$QGD_c = QG_c\left(\frac{PG_c}{PGD_c}\right)^{\sigma_{ARM}} \quad \text{with}\,\sigma_{ARM} > 0 \tag{13}$$

$$QGM_c = QG_c\left(\frac{PG_c}{PGM_c}\right)^{\sigma_{ARM}} \quad \text{with}\,\sigma_{ARM} > 0 \tag{14}$$

$$QGDU_r = QGU_r\left(\frac{PGU_r}{PGDU_r}\right)^{\sigma_{ARM1}} \quad \text{with}\,\sigma_{ARM1} > 0 \tag{15}$$

$$QGMU_r = QGU_r\left(\frac{PGU_r}{PGMU_r}\right)^{\sigma_{ARM1}} \quad \text{with}\,\sigma_{ARM1} > 0 \tag{16}$$

$$QGDL_r = QGDU_r\left(\frac{PGDU_r}{PGDL_r}\right)^{\sigma_{ARM2}} \quad \text{with}\,\sigma_{ARM2} > 0 \tag{17}$$

$$QGML_r = QGDU_r\left(\frac{PGDU_r}{PGML_r}\right)^{\sigma_{ARM2}} \quad \text{with}\,\sigma_{ARM2} > 0 \tag{18}$$

Finally, QI, QID and QIM, represent, respectively, the quantity of total, domestic and imported intermediate goods in the country or group of countries. QIU, QIDU and QIMU are, respectively, total, national and international imported intermediate goods in the sub-national region. QIDL and QIML represent the domestic and intra-national imported intermediate goods in the sub-national region. PI, PID, PIM, PIU, PIDU, PIMU, PIDL and PIML are the associated prices.

The equations 19-24 present the demand for intermediate goods:

$$QID_c = QI_c\left(\frac{PI_c}{PID_c}\right)^{\sigma_{ARM1}} \quad \text{with}\,\sigma_{ARM} > 0 \tag{19}$$

$$QIM_c = QI_c\left(\frac{PI_c}{PIM_c}\right)^{\sigma_{ARM1}} \quad \text{with}\,\sigma_{ARM} > 0 \tag{20}$$

$$QIDU_r = QIU_r\left(\frac{PIU_r}{PIDU_r}\right)^{\sigma_{ARM1}} \quad \text{with}\,\sigma_{ARM1} > 0 \tag{21}$$

$$QIMU_r = QIU_r\left(\frac{PIU_r}{PIMU_r}\right)^{\sigma_{ARM1}} \quad \text{with}\,\sigma_{ARM1} > 0 \tag{22}$$

$$QIDL_r = QIDU_r\left(\frac{PIDU_r}{PIDL_r}\right)^{\sigma_{ARM2}} \quad \text{with}\,\sigma_{ARM2} > 0 \tag{23}$$

$$QIML_r = QIDU_r\left(\frac{PIDU_r}{PIML_r}\right)^{\sigma_{ARM2}} \quad \text{with}\,\sigma_{ARM2} > 0 \tag{24}$$

The domestic demand is the sum of the three domestic demand components: private consumption, government spending and intermediate goods. QDS is the quantity of demanded domestic goods and PDS is the associated price. The equations are:

$$PDS_c QDS_c = PCD_c\, QCD_c + PGD_c QGD_c + PID_c QID_c \tag{25}$$

$$PDS_r QDS_r = PCDL_r QCDL_r + PGDL_r QGDL_r + PIDL_r QIDL_r \tag{26}$$

The imported demand is also the sum of the three imported demand components: private consumption, government spending and intermediate goods. QAI, QAIU and QAIL are, respectively, the quantity of aggregate imported goods in the country, the aggregate imported goods from abroad in the sub-national region and the aggregate imported goods from the other sub-national regions. PAI, PAIU and PAIL are the associated prices. The formulas are:

$$PAI_c QAI_c = PCM_c\, QCM_c + PGM_c QGM_c + PIM_c QIM_c \tag{27}$$

$$PAIU_r QAIU_r = PCMU_r QCMU_r + PGMU_r QGMU_r + PIMU_r QIMU_r \tag{28}$$

$$PAIL_r QAIL_r = PCML_r QCML_r + PGML_r QGML_r + PIML_r QIML_r \tag{29}$$

The additional sub-national nest for imports also requires modifying the structure of the bilateral trade flows. For countries in the rest of Europe and rest of the world, things do not change but for the Italian regions, we introduce two bundles. We use CES preferences to model these two nests. In the following equations QXS, QXSU and QXSL represent, respectively, the bilateral trade flows from country *d* to country *c*, the bilateral trade flows from country *c* to sub-national region *r*, the bilateral trade flows from sub-national region *s* to sub-national region *r*. PXS, PXSU and PXSL are the associated prices. The equations are reported below:

$$QXS_{dc} = QAI_c \left(\frac{PAI_c}{PXS_{dc}} \right)^{\sigma_{IMP}} \quad \text{with } \sigma_{IMP} > 0 \tag{30}$$

$$\sum_d QXS_{dc} PXS_{dc} = QAI_c PAI_c \tag{31}$$

$$QXSU_{cr} = QAIU_r \left(\frac{PAIU_r}{PXSU_{cr}} \right)^{\sigma_{IMP1}} \quad \text{with } \sigma_{IMP1} > 0 \tag{32}$$

$$\sum_c QXSU_{cr} PXSU_{cr} = QAIU_r PAIU_r \tag{33}$$

$$QXSL_{sr} = QAIL_r \left(\frac{PAIL_r}{PXSL_{sr}} \right)^{\sigma_{IMP2}} \quad \text{with } \sigma_{IMP2} > 0 \tag{34}$$

$$\sum_s QXSL_{sr} PXSL_{sr} = QAIL_r PAIL_r \tag{35}$$

4. Testing the model

This section tests the performance of our sub-national model.

A simple 20% uniform productivity loss in all primary factors through the Italian territory is imposed to the different model specifications summarized below:

- The **AI** (Aggregated Italy) model considers Italy as whole, rest of Europe and rest of the world. The theoretical structure and parameter values are those of the standard GTAP model. It is the benchmark.
- The **RI** (Regionalized Italy) model disentangles North, Centre and South of Italy, rest of Europe and rest of the world. However, in this model, Italian regions behave exactly as GTAP countries. They replicate at the regional level the original countrywide parameters. The RI model thus assumes immobile primary factors across Italian regions and the same imperfect good substitutability in intra-regional and international trade. It thus presents the lowest degree of market integration and flexibility at the sub-national level.
- The **RIMFM** (Regionalised Italy with geographical Mobility in Factors Market) is like RI, but adds sluggish mobility in factor markets within Italy for capital and labour. The supply elasticity is the same for all these primary factors ($\sigma_{FAC} = \sigma_K = \sigma_L = \sigma_H$). In our reference case, this parameter is set equal to -10.
- In the **RIARM** (Regionalised Italy with increased inter regional Armington elasticities) specification the geographical detail is as in RI and RIMFM, but we build the new trade structure to make products closer substitutes inside than outside the national borders. In addition, we put four additional parameters for the sub-national regions, σ_{ARM1}, σ_{ARM2}, σ_{IMP1}, and σ_{IMP2}. In the reference case, their values are set according to the following formulas:

  $\sigma_{ARM2} = 5\ \sigma_{ARM1}$ $\qquad \sigma_{ARM1} = \sigma_{ARM}$

  $\sigma_{IMP2} = 5\ \sigma_{IMP1}$ $\qquad \sigma_{IMP1} = \sigma_{IMP}$

  where σ_{ARM} and σ_{IMP} are the values adopted in the standard GTAP model.

- Finally, in the RIAFM (Regionalised Italy with both increased Armington and mobility in Factor Markets) model both changes in goods and factors market are incorporated. RIAFM is the full model with the highest degree of market integration and flexibility at the sub-national level.

In addition to the cross model comparison, we also carry out a sensitivity analysis on the following parameters adopted at the sub-national level:

i) Armington elasticity for intra-national trade, and
ii) CET elasticity for intra-national factor mobility.

4.1 Model comparison

Our comparison focuses on the per cent variations in real GDP and sectoral production (Table 6). As expected, GDP unambiguously decreases consequent the negative productivity shock on primary factors.

Considering Italy as a whole, a first result is that the aggregated country performance and sectoral production do not change excessively across the different model specifications. This points out a comforting robustness of our methodology.

Distributional effects across Italian macro-regions are more interesting. When GDP is concerned, the RI and the RIARM models present the more stable results (loss around 20%). This is consistent with these two specifications assuming no spatial mobility in primary factors. Basically the Italian regions are connected just by interregional import export of goods and services. Apparently, the higher substitutability in interregional goods with respect to international commodities introduced by the RIARM specification alters only marginally the results. These outcomes are replicated at the sectoral level, even though regional differences across the two specifications are slightly more visible especially in some sectors (Util_Cons, TextWapp and MeatLstk).

Table 6: model comparison (real GDP % variations wrt the basedata)

North	RI	RIMFM	RIARM	RIAFM
GDP	-20.48	-18.32	-20.52	-19.04
GrainsCrops	-12.34	-11.33	-11.48	-11.19
MeatLstk	-19.05	-17.38	-19.33	-18.25
Extraction	-18.81	-18.38	-18.11	-18.09
ProcFood	-16.89	-14.84	-16.46	-15.08
TextWapp	-7.70	-5.09	-6.69	-5.23
LightMnfc	-14.02	-11.37	-13.15	-11.61
HeavyMnfc	-11.62	-8.88	-10.50	-8.99
Util_Cons	-34.67	-33.16	-35.78	-34.41
TransComm	-20.23	-18.10	-20.41	-18.90
OthServices	-22.18	-20.03	-22.53	-20.97

Centre	RI	RIMFM	RIARM	RIAFM
GDP	-20.58	-21.50	-20.57	-21.31
GrainsCrops	-11.14	-11.80	-10.90	-11.31
MeatLstk	-16.59	-17.81	-15.82	-16.89
Extraction	-17.43	-17.97	-17.25	-17.51
ProcFood	-16.61	-17.94	-16.08	-16.99
TextWapp	-3.39	-4.82	-3.46	-4.26
LightMnfc	-12.58	-13.54	-13.22	-13.74
HeavyMnfc	-9.53	-10.38	-10.59	-11.00
Util_Cons	-39.51	-40.41	-39.17	-40.10
TransComm	-18.88	-19.80	-18.84	-19.60
OthServices	-20.97	-21.89	-20.85	-21.63

South	RI	RIMFM	RIARM	RIAFM
GDP	-20.63	-24.41	-20.58	-23.08
GrainsCrops	-9.61	-11.70	-10.55	-11.18
MeatLstk	-16.34	-20.04	-16.96	-19.10
Extraction	-16.35	-17.80	-16.89	-17.31
ProcFood	-15.74	-18.59	-17.37	-19.01
TextWapp	-0.90	-5.84	-2.40	-4.89
LightMnfc	-11.73	-16.24	-13.11	-15.53
HeavyMnfc	-7.38	-12.11	-8.90	-11.29
Util_Cons	-38.58	-41.39	-37.02	-39.54
TransComm	-18.49	-22.49	-18.50	-21.13
OthServices	-20.90	-24.89	-20.69	-23.39

Italy	RI	RIMFM	RIARM	RIAFM	AI
GDP	-20.54	-20.52	-20.54	-20.53	-20.54
GrainsCrops	-11.11	-11.54	-11.03	-11.20	-10.88
MeatLstk	-17.65	-18.42	-17.88	-18.33	-17.98
Extraction	-17.93	-18.16	-17.64	-17.78	-17.75
ProcFood	-16.52	-16.39	-16.65	-16.48	-16.66
TextWapp	-5.55	-5.17	-5.22	-4.97	-5.30
LightMnfc	-13.38	-12.57	-13.16	-12.65	-12.59
HeavyMnfc	-10.48	-9.73	-10.22	-9.76	-10.08
Util_Cons	-36.57	-36.59	-36.73	-36.77	-36.45
TransComm	-19.52	-19.51	-19.62	-19.58	-19.68
OthServices	-21.56	-21.78	-21.64	-21.78	-21.76

Re-distributional effects are more pronounced in the RIMFM and RIAFM models. The most important difference introduced is the primary-factor mobility. Now North is clearly advantaged by the more flexible labour and capital market (GDP loss is about 18%, 19% respectively) while South is penalized (GDP decrease is about 24%, 23% respectively). Factor mobility amplifies the difference between South and Centre/North regions as labour and capital move from South to North and Centre.

Uneven patterns across the Italian regions are also observed at the sectoral level, in particular in the Util_Cons and LightMnfc sectors and especially in the RIMFM specification, where the lower substitutability in consumption of goods coming from Italian regions fosters regional specialisation phenomena.

By comparing RIMFM and RIAFM specifications it is confirmed that the new Armington trade structure does not change much the pattern of the distributional effects.

4.2 Sensitivity analysis

In this section, we conduct a sensitivity analysis on the Armington and the CET elasticity in the sub-national endogenous supply of mobile primary factors. These two parameters are fundamental drivers of the model results. Moreover, there is limited quantitative support to their econometric estimation. This is a further motivation to justify a sensitivity test.

The sensitivity analysis is carried out on the last specification (RIAFM) that is comprehensive of all modifications.

Figure 3 represents Italian countrywide and regional GDP performances under four different assumptions on factors mobility, implemented varying the elasticity of transformation σ_{FAC} in the CET function. Armington elasticity is kept at the reference case. Factor mobility is increased according to the following scheme:

fac_1 → $\sigma_{FAC} = 0$
fac_2 → $\sigma_{FAC} = -10$
fac_3 → $\sigma_{FAC} = -100$
fac_4 → $\sigma_{FAC} = -1000$

where fac_1 represents no factor mobility case and fac_4 the maximum level of factor mobility. They are depicted on the horizontal axis.

In Figure 4 factor mobility is kept at the reference case ($\sigma_{FAC} = -10$) while we progressively increase the substitution across products (i.e., Armington elasticities) coming from different Italian regions using the formulas reported below (representing, respectively, low, medium-low, medium-high and high mobility in the goods market):

arm_1 → $\sigma_{ARM2} = \sigma_{ARM1}$, $\sigma_{IMP2} = \sigma_{IMP1}$
arm_2 → $\sigma_{ARM2} = 5\ \sigma_{ARM1}$, $\sigma_{IMP2} = 5\ \sigma_{IMP1}$
arm_3 → $\sigma_{ARM2} = 10\ \sigma_{ARM1}$, $\sigma_{IMP2} = 10\ \sigma_{IMP1}$
arm_4 → $\sigma_{ARM2} = 15\ \sigma_{ARM1}$, $\sigma_{IMP2} = 15\ \sigma_{IMP1}$

Finally, Figure 5 merges these different tests as follows:

arm_fac_1 → $\sigma_{ARM2} = \sigma_{ARM1}$, $\sigma_{IMP2} = \sigma_{IMP1}$, $\sigma_{FAC} = 0$
arm_fac_2 → $\sigma_{ARM2} = 5\ \sigma_{ARM1}$, $\sigma_{IMP2} = 5\ \sigma_{IMP1}$, $\sigma_{FAC} = -10$
arm_fac_3 → $\sigma_{ARM2} = 10\ \sigma_{ARM1}$, $\sigma_{IMP2} = 10\ \sigma_{IMP1}$, $\sigma_{FAC} = -100$
arm_fac_4 → $\sigma_{ARM2} = 15\ \sigma_{ARM1}$, $\sigma_{IMP2} = 15\ \sigma_{IMP1}$, $\sigma_{FAC} = -1000$

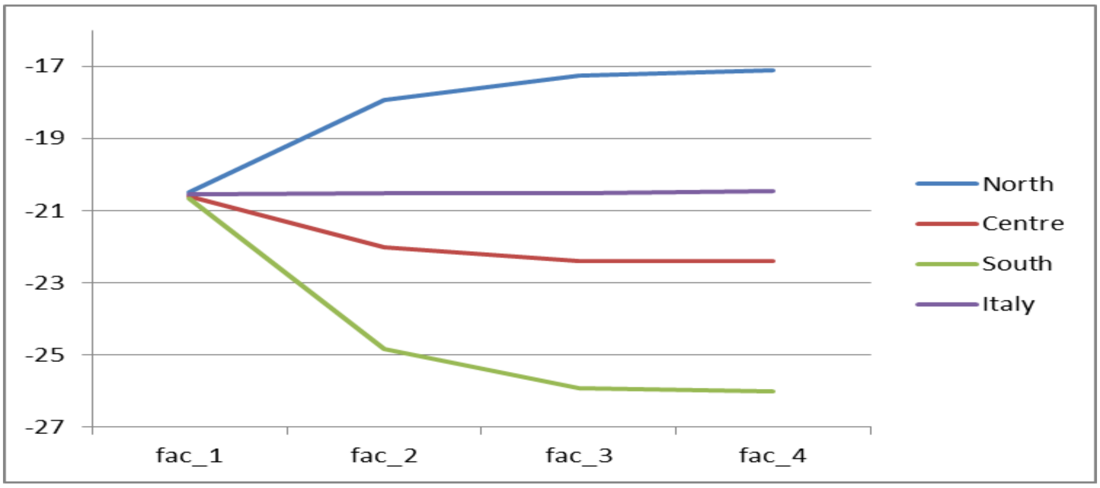

Figure 3: real GDP % variations wrt the basedata (factors mobility component)

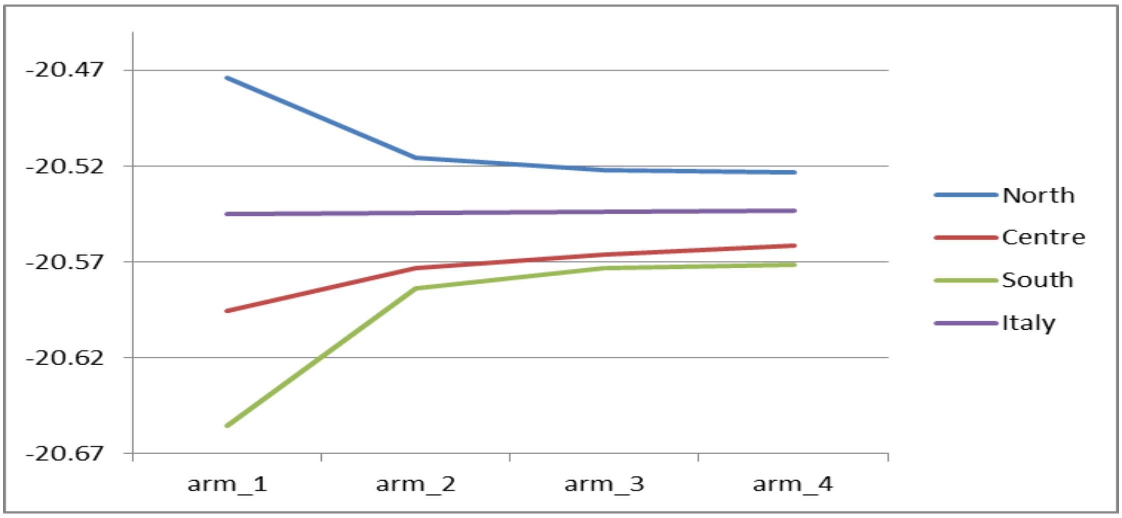

Figure 4: real GDP % variations wrt the basedata (Armington component)

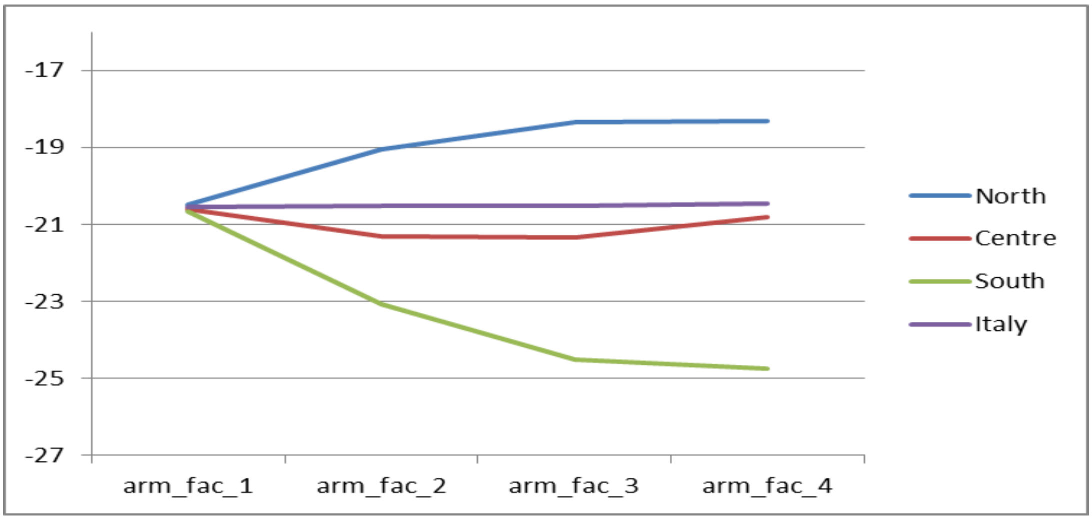

Figure 5: real GDP % var wrt the basedata (factors mobility and Armington components)

The aim is to disentangle the mobility factor component (Figure 3), the sub-national Armington component (Figure 4) and finally to analyse their interaction (Figure 5).

It is immediately evident that increasing factors mobility amplifies the sub-national divergences while increasing product substitution in consumption triggers a convergence process. However, it is worth noting that the first effect dominates the second (comparing the scales on the vertical axis in Figures 3 and 4) at least considering the overall effect on real GDP.

Accordingly, when the two effects are compounded in Figure 5, we can still note an increased divergence due to the prevailing dynamic related to the CET parameter, but smaller than that of Figure 3 due to the counterbalancing effect of the Armington elasticity.

This said, the interaction between the Armington and CET elasticities is not necessarily trivial. For instance Centre Italy in Figure 5 changes its slope compared to Figure 3 due to the products substitutability effect. In other words, if factors mobility seems important for magnitudes, Armington elasticity can still affect the direction of changes.

Table 7 reports sensitivity analysis results for sectors, which confirms those already observed for GDP. Moving toward a more flexible and integrated economic environment, the sectoral performances tend to diverge across regions, but this is due to the prevalence of the factor mobility effect over the good substitutability effect.

Finally, the above-mentioned dynamics depends also on the type of shock analyzed. Affecting uniformly all the primary factors, as we did, means for instance to decrease the importance of all the heterogeneity stemming from the standard framework of comparative advantages based on different regional endowments. Shocking primary factors one-by-one would on the contrary amplify the redistribution process across regions due to regional differences in factor intensity (the well known Rybczyski theorem (Rybczyski, 1955)).

Table 7: sensitivity on elasticity parameters (real GDP % variations wrt the basedata)

North	arm_fac_1	arm_fac_2	arm_fac_3	arm_fac_4		Centre	arm_fac_1	arm_fac_2	arm_fac_3	arm_fac_4
GDP	-20.47	-19.04	-18.35	-18.32		GDP	-20.60	-21.31	-21.34	-20.82
GrainsCrops	-12.10	-11.19	-11.12	-11.18		GrainsCrops	-10.30	-11.31	-11.64	-11.77
MeatLstk	-19.31	-18.25	-17.76	-17.73		MeatLstk	-16.52	-16.89	-16.70	-16.12
Extraction	-18.54	-18.09	-18.07	-18.03		Extraction	-16.66	-17.51	-17.65	-17.62
ProcFood	-16.83	-15.08	-14.00	-13.53		ProcFood	-16.64	-16.99	-16.32	-15.08
TextWapp	-7.37	-5.23	-4.66	-4.71		TextWapp	-2.17	-4.26	-4.24	-3.64
LightMnfc	-13.73	-11.61	-10.94	-10.94		LightMnfc	-12.59	-13.74	-13.54	-12.91
HeavyMnfc	-11.27	-8.99	-8.29	-8.28		HeavyMnfc	-9.70	-11.00	-11.09	-10.78
Util_Cons	-34.93	-34.41	-33.97	-34.15		Util_Cons	-39.86	-40.10	-40.19	-39.73
TransComm	-20.29	-18.90	-18.20	-18.17		TransComm	-18.88	-19.60	-19.64	-19.12
OthServices	-22.30	-20.97	-20.21	-20.15		OthServices	-20.97	-21.63	-21.68	-21.16

South	arm_fac_1	arm_fac_2	arm_fac_3	arm_fac_4		Italy	arm_fac_1	arm_fac_2	arm_fac_3	arm_fac_4
GDP	-20.66	-23.08	-24.50	-24.75		GDP	-20.54	-20.53	-20.52	-20.46
GrainsCrops	-9.01	-11.18	-11.64	-11.73		GrainsCrops	-10.64	-11.20	-11.40	-11.48
MeatLstk	-16.08	-19.10	-20.65	-21.08		MeatLstk	-17.67	-18.33	-18.64	-18.68
Extraction	-15.67	-17.31	-17.56	-17.56		Extraction	-17.46	-17.78	-17.86	-17.83
ProcFood	-16.00	-19.01	-21.31	-22.82		ProcFood	-16.57	-16.48	-16.41	-16.36
TextWapp	-0.93	-4.89	-6.15	-6.14		TextWapp	-5.09	-4.97	-4.85	-4.75
LightMnfc	-12.06	-15.53	-16.89	-17.03		LightMnfc	-13.24	-12.65	-12.40	-12.31
HeavyMnfc	-7.60	-11.29	-12.48	-12.44		HeavyMnfc	-10.32	-9.76	-9.54	-9.47
Util_Cons	-38.94	-39.54	-40.51	-40.38		Util_Cons	-36.87	-36.77	-36.79	-36.76
TransComm	-18.44	-21.13	-22.60	-22.85		TransComm	-19.54	-19.58	-19.56	-19.48
OthServices	-20.85	-23.39	-24.96	-25.27		OthServices	-21.60	-21.78	-21.84	-21.78

5. Conclusions and further research

In this paper, we describe a methodology to develop a sub-national CGE model starting from a national model and database. This methodology, rooted in the mainstream literature, adds some elements to increase the realism of the analysis. It uses both transport information and economic data in a consistent statistical framework via the RAS method to obtain a sub-national database for Italy. Moreover, the model improvements allow for intra-national goods and factor mobility (with respect the complete mobility of country-scaled models) without affecting the internal consistency of advanced CGE models.

We run a number of simulations testing the same shock (a 20% uniform productivity loss in all primary factors) on different versions of the model, varying in flexibility of the Italian economic system. The distributional effects at the sub-national level show clearly diverging patterns both at the sectoral and GDP level, which are driven by the interregional mobility in the factors market, while different degrees of substitutability in consumption of goods from different Italian regions play a minor role.

A sensitivity analysis on the newly introduced elasticity parameters confirms the abovementioned results: while increasing factor mobility across Italian regions increases the divergence of regional performances, higher substitutability in consumption decreases it. The former effect dominates the latter. Nonetheless this last can influence the direction of the former.

Finally, the welfare outcomes measured in terms of GDP loss improve when moving toward more flexible and integrated markets at the sub-country level, suggesting a higher capacity of Italian sub-national agents to react to changes in relative market prices (market-driven or autonomous adaptation feature typical of CGE models) when affecting all the factors in a uniform manner.

Further research involves both the database and the model. Concerning the database, the next step is the extension of this first version concerning 3 macro-regions and 10 sectors to the 20 Italian regions and 57 sectors. With regard to the modelling part, we will test the model on real shocks (e.g. those consequent extreme natural events such as floods) to improve the model parameterization.

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