

A sub-national version of the GTAP model for Italy

Gabriele Standardi^{a,b} Francesco Bosello^{a,b,c} Fabio Eboli^{a,b}

^a CMCC – EuroMediterranean Center on Climate Change

^b FEEM – Fondazione Eni Enrico Mattei

^c University of Milan

Corresponding author: gabriele.standardi@feem.it

Abstract

We develop a sub-national version of the GTAP model for Italy. The upgraded model allows assessing more properly the trade and environmental policies and/or shocks, whose effects can be largely different within a country. We use an innovative method to estimate bilateral trade flows across sub-national regions. In addition, the theoretical structure is modified in order to incorporate the possibility of an increasing spatial mobility in both factors and goods market at sub-country level. We carry out a simple experiment to test the robustness of our model. Results are consistent with the standard CGE assumptions; moving towards more competitive and integrated markets a negative shock results in a lower loss in terms of welfare.

1. Introduction

In this paper we describe the methodology to build a sub-national version of the GTAP model. GTAP stands for *global trade analysis project*, it is a widespread model and database among CGE (*computable general equilibrium*) modellers. It performs economic analysis of trade and environmental policies or assesses the economic consequences of climate change impacts. This work is an application to Italy. However, the methodology can be applied to other countries according to the data availability at the sub-country level. In this first version, we work with 10 sectors and three Italian macro-regions (North, Centre, South). As a next step, the model will be extended to all 20 Italian regions and 57 GTAP sectors. At this stage, the aim is not to have a realistic picture of the policy effects but rather to understand how the model works from an economic point of view and its potential contribution.

The motivations for such a work are important. First, few global CGE models exist at the sub-national level due to the difficulty to create mutually consistent social accounting matrixes for a large number of sub-national regions.¹ Nevertheless, the trade and environmental policies decided at the world level may raise significant effects also at sub-country level, highlighting distributional issues that require consistent and differentiated policy actions.

Second, concerning issues such as climate change, a more detailed geographical localization represents an important tool to assess more properly the economic consequences of physical impacts. For example, given a physical impact at the local level, the economic effects are likely to be stronger in a specific sub-national region but it could also be interesting to analyse to what extent they interact with other regions within a country and also the rest of the world. The potential to impose differentiated shocks within a country constitutes one of the main strengths in this type of model.

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).

In order to regionalize GTAP at sub-country level, the methodological approach implies two main tasks to be developed/accomplished. The first one is the database development and second one the model improvement.

Regarding the first task, the major effort in building a sub-national CGE database consists in estimating the trade flows across sub-national regions. Due to the lack of data, this is usually done through a gravitational approach as in Horridge and Wittwer (2010) and Dixon *et al.* (2012).

We propose an alternative and innovative approach. We combine in a consistent way two sources of information: transport data and economic production data both from ISTAT (*Italian National Statistical Institute*).

The second task requires modifying the theoretical structure of the model to take into account two different degrees of factors and goods mobility (national and sub-national). In fact, both goods and factors are expected to move easier within the country than between countries.

In order to have a validation of the different specifications we carry out a simple experiment (a uniform world decrease by 20% in land productivity) and we compare the results coming from the GTAP model and our modified sub-national versions. Results on welfare are robust with respect to the standard GTAP model and consistent with the CGE neoclassical framework (welfare improves when moving towards more competitive and integrated markets). The sensitivity analysis on elasticity parameters also shows consistent economic results.

The paper is organized as follows. Section 2 presents data 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

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

Concerning the sub-national sources, we collect data from ISTAT, which provides two types of information. For the first type of information, data on value added, labour and land for the 20 Italian regions and 40 sectors covering all the economic system are available.

For the second type of information, ISTAT reports bilateral flows of carried goods (tons) by mode of transportation (truck, rail, water and air) for the 20 Italian regions. However, limitations in terms of sector coverage (data available only for 10 agricultural/industrial sectors) and measurement unit (volume rather than economic value) exist.²

It is worth noting that this is mainly a methodological work. For this reason, we keep the sectoral and geographical aggregation simple with only 10 sectors and three Italian sub-national regions (North, Centre and South). The other GTAP countries are included in two large groups, European Union and Rest of the World.

We follow a two-steps procedure to derive the sub-national database for Italy described, respectively, in sub-sections 2.1 and 2.2. All the data refer to 2004, the base year in GTAP 7.

2.1 Splitting the production side

The first step consists in splitting the Italian production using the ISTAT information about economic production.

Practically, the statistical procedure is the following. First, we match the 40 ISTAT sectors with the 10 GTAP sectors chosen in our aggregation. Then we distribute the Italian value added and

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

primary factors in GTAP across the three Italian macro-regions using the shares of ISTAT for value added labour and land. Capital is computed as a difference between value added and labour. For sectors, which use also natural resources (another primary factor in GTAP) we take the sub-national share of value added in those sector as a proxy.

The sub-regional input-output tables are derived assuming 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 Italian manufactures purchase in Italy are split based on the agricultural value added share in the sub-national region.

2.2 Estimation of trade flows across sub-national regions

The second step is the most challenging because we need to determine the bilateral trade flows across sub-national regions. These data are very often missing. As mentioned before researchers usually use the gravitational approach to estimate the trade flows as in Horridge and Wittwer (2010) and Dixon *et al.* (2012). By this method, the bilateral trade flows across sub-national regions are estimated using the sectoral production in the origin and destination regions and the distance between them, following the gravity equation as in the Newtonian physics. Consequently, it is possible to overcome the problem of the missing data. This comes at cost to introduce some distortions and inconsistencies because other variables are likely to play a role in the determination of the trade across regions (omitted variables).

Some alternative approaches exist. For example, reliable transport data exist for United States of America. Chintrakarn and Millimet (2006) and Canning and Tsigas (2000) make use of them to obtain trade flows across member States. Dubé and Lemelin (2005) also use transport data to estimate the trade flows across the 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 consistent the two types of information.

Given the transport information from ISTAT, 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. Nevertheless, following the approach of Dubé and Lemelin, we decide to integrate the transport data with the economic production information in the computation of trade flows across Italian regions. This is done by adjusting the trade flows across sub-national regions by the RAS statistical method to make these flows consistent with the production data.³ This operation is important for three reasons. First, we have a more detailed sectoral aggregation for the production and this will be useful to derive the full database with 57 GTAP sectors. Second production reports value and not volume data. Finally, we maximise all the information available at the sub-national level in a consistent framework.

Practically, we use the shares obtained from ISTAT transport data to distribute the sectoral GTAP Italian production, which is demanded domestically, between domestic sub-national use and trade flows across Italian regions.

Consider the share matrix Π represented in Table 1. Afterwards, vectors and matrixes are in bold type. In matrix Π the general element is π_{rc} with $0 \leq \pi_{rc} \leq 1$. The row represents the origin sub-national region and the column the destination sub-national region. Basically, 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.

³ The RAS is a 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 (McDougall, 1999).

Table 1

	North	Center	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 GTAP Italian production in a sector which is sold in Italy, D the sub-national demand (excluded demand for foreign goods), EXP the bilateral sub-national exports towards the other sub-national regions, IMP the bilateral 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:

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

We apply the same procedure for the other sub-national regions.

The use of two different sources to obtain the sub-national database (economic data for production and transport data for demand and trade) makes the following equations not verified:

$$\begin{aligned}
Y_{North} &= D_{North} + EXPAG_{North} - IMPAG_{North} \\
Y_{Centre} &= D_{Centre} + EXPAG_{Centre} - IMPAG_{Centre} \\
Y_{South} &= D_{South} + EXPAG_{South} - IMPAG_{South}
\end{aligned}$$

In order to adjust these equations we resort to the bi-proportional method, the so-called RAS method. Consider the bilateral trade matrix $\mathbf{A} = \Pi Y_{ITA}$, size 3×3 , computed starting from transport data, where we put $\pi_{11} = \pi_{22} = \pi_{33} = 0$. In matrix $\mathbf{A}$ the general element is a_{rc} where row r represents the origin sub-national region and column c the destination sub-national region. We also have target vector of row totals $\mathbf{R}$ (aggregate sub-national exports to the rest of Italy, size 3×1) and target vector of column totals $\mathbf{C}$ (aggregate sub-national imports from the rest of Italy, size 3×1). Targets are computed using also the ISTAT information about economic production according to the following equations:

$$\begin{aligned}
R_{North} &= Y_{North} - D_{North} + IMPAG_{North} \\
R_{Centre} &= Y_{Centre} - D_{Centre} + IMPAG_{Centre} \\
R_{South} &= Y_{South} - D_{South} + IMPAG_{South} \\
C_{North} &= D_{North} + EXPAG_{North} - Y_{North} \\
C_{Centre} &= D_{Centre} + EXPAG_{Centre} - Y_{Centre} \\
C_{South} &= D_{South} + EXPAG_{South} - Y_{South}
\end{aligned}$$

The RAS method attempts to find a new similar matrix $\mathbf{B}$ such that:

$$\sum_r b_{rc} = c_c$$

$$\sum_c b_{rc} = r_r$$

where b_{rc} , r_r and c_c are, respectively, the general element of matrix $\mathbf{B}$, vector $\mathbf{R}$ and vector $\mathbf{C}$.

The new matrix $\mathbf{B}$ is related to the original $\mathbf{A}$ via the iterative procedure:

$$b_{rc} = rm_r \cdot cm_c \cdot a_{rc}$$

where rm_r is the multiplier of row r and cm_c is the multiplier of column c .

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

3. Model improvement

So far we have worked only on the database, searching the best rule to obtain consistent SAMs across the sub-national regions. However, it is reasonable to assume that a sub-national region does not behave exactly as a country. This, in turn, implies some changes in the theoretical structure of the model.

For example, in GTAP the factor endowments cannot move outside the country they belong. This makes sense in a national context but it is unlikely to happen at the sub-national level. Workers and capital can easily reallocate in other sub-national regions after an economic shock.

Another issue is the product substitution from the demand side. In the CGE framework, the standard Armington assumption prevents unrealistic specialization phenomenon and trade overflows from warping the results of the model. The values of the Armington elasticity are set by econometric estimations, which are carried out at the national level. Given the empirical evidence about the fact that trade within a country is bigger than trade between countries given the same distance, the so-called border effect (McCallum, 1995), these Armington elasticities should be recalibrated at the sub-national level and the demand tree modified to consider the increased product substitution inside the borders.

We incorporate all these characteristics in our theoretical structure and evaluate different sub-national models in order to verify their consistency with CGE economic theory and with the standard GTAP model. Basically we have two main model improvements. The first one consists in introducing capital and labour mobility within Italy (endogenous factor supply at the sub-country level) through a CET (*constant elasticity of transformation*) function, as a result workers and capital can move outside the Italian sub-national region they belong after a shock in the economic system. In the second improvement we insert a special Armington nest for the sub-national regions to take into account the fact that products are closer substitutes within the country than across countries.

3.1 First model improvement: mobility in factors market

The value added in the standard GTAP model is function of five primary factors: land, natural resources, unskilled labour, skilled labour and capital. All the sectors use labour and capital while

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.

only some sectors use land and natural resources. Land and natural resources supplies are sluggish across sectors while labour and capital are perfectly mobile. However, all the primary factor supplies are geographically immobile. We do the following assumptions:

- 1) The mobility across sectors does not change.
- 2) Land and natural resources continue to be geographically immobile at the sub-national level.
- 3) Sub-national unskilled labour, skilled labour and capital supplies are geographically sluggish within Italy and they continue to be immobile for rest of Europe and rest of the world.

The third assumption is new with respect to the standard GTAP model. We model it through a CET function to represent the imperfect national mobility of the sluggish factor endowments (unskilled labour, skilled labour and capital). 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. We make the hypothesis that $\sigma_L = \sigma_H = \sigma_K$.

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

$$\sum_r QL_r PL_r = QL_{ITA} PL_{ITA} \quad (2)$$

$$QH_r = QH_{ITA} \left(\frac{PH_{ITA}}{PH_r} \right)^{\sigma_H} \quad \text{with } \sigma_H < 1 \quad (3)$$

$$\sum_r QH_r PH_r = QH_{ITA} PH_{ITA} \quad (4)$$

$$QK_r = QK_{ITA} \left(\frac{PK_{ITA}}{PK_r} \right)^{\sigma_K} \quad \text{with } \sigma_K < 1 \quad (5)$$

$$\sum_r QK_r PK_r = QK_{ITA} PK_{ITA} \quad (6)$$

3.2 Second model improvement: the new trade structure across sub-national regions

In the standard GTAP model the demand side is made up of three elements: private consumption, government spending and intermediate goods. The demand tree follows a double nest. The first nest links domestic demand of each three elements and aggregate foreign imports. The second nest differentiates foreign imports according to the geographical origin. Figure 1 describes the traditional GTAP demand scheme.

The second model improvement consists in modifying the tree in order to make sub-national products closer substitutes among them than the national 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.

Figure 1

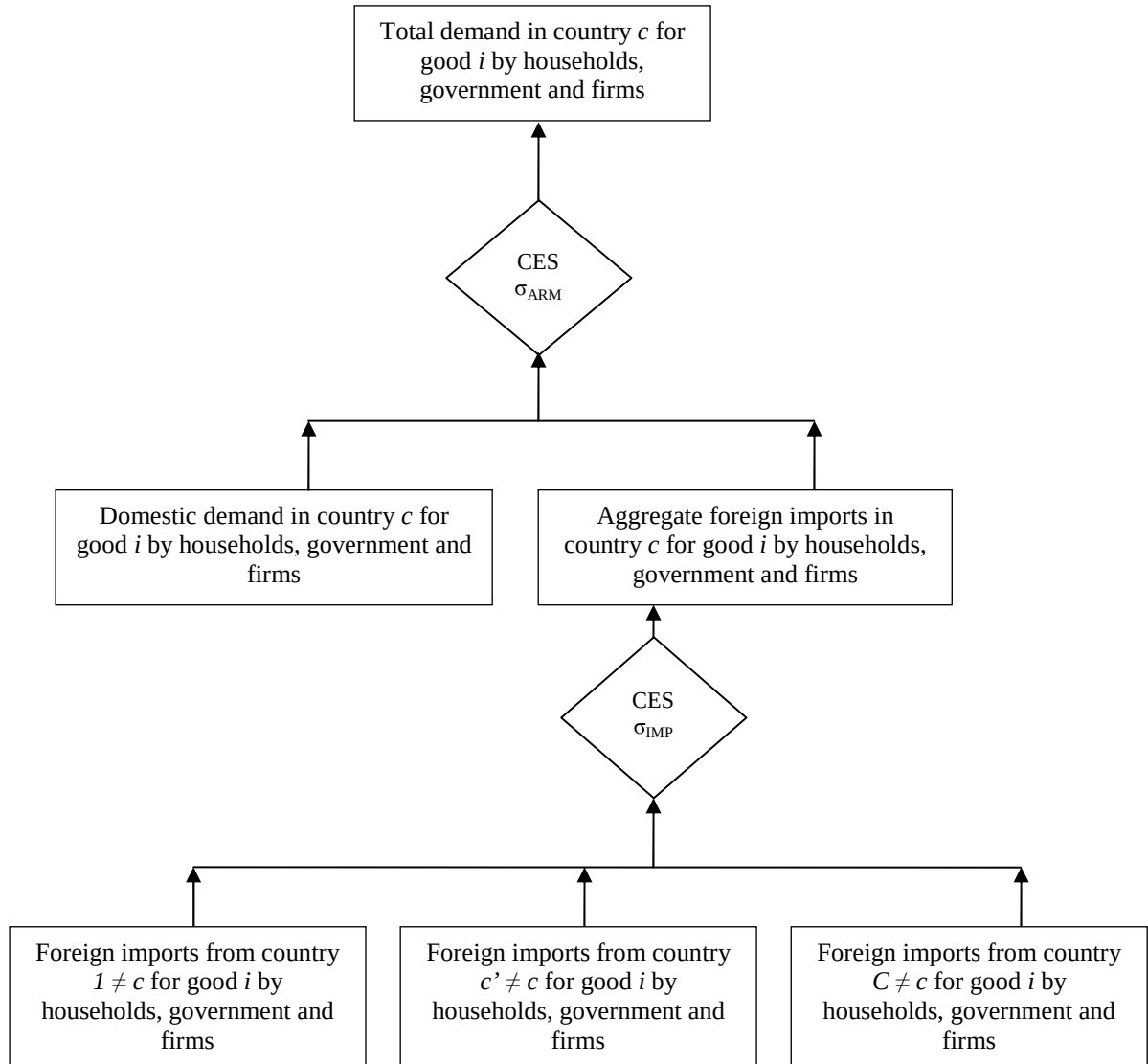
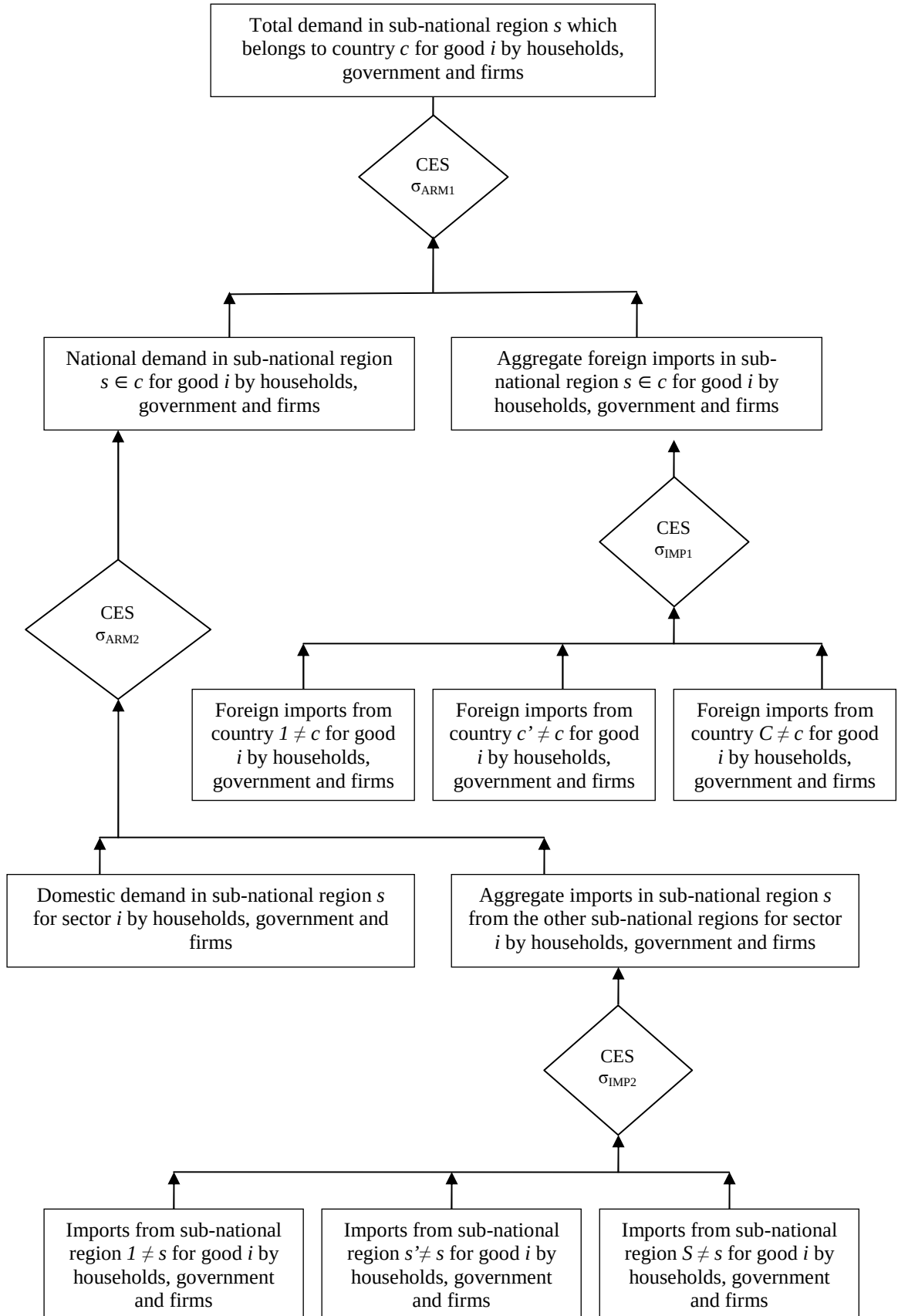


Figure 2



As we can note from Figure 2, each sub-national region has the classical nest for the foreign aggregate imports and the foreign imports according to the geographical origin but now there are two further bundles because the national demand in the sub-national region 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 four additional parameters σ_{ARM1} , σ_{IMP1} , σ_{ARM2} and σ_{IMP2} . Two relations characterises these four parameters:

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

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

where σ_{ARM} and σ_{IMP} are the Armington elasticities in 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). QC DL and QC ML 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, PC DL and PC ML are the associated prices.

The equations 7-12 show the mathematics behind the new trade structure in Figure 2 for private consumption :

$$QCD_c = QC_c \left(\frac{PC_c}{PCD_c} \right)^{\sigma_{ARM}} \quad \text{with } \sigma_{ARM} > -1 \quad (7)$$

$$QCM_c = QC_c \left(\frac{PC_c}{PCM_c} \right)^{\sigma_{ARM}} \quad \text{with } \sigma_{ARM} > -1 \quad (8)$$

$$QCDU_r = QCU_r \left(\frac{PCU_r}{PCDU_r} \right)^{\sigma_{ARM1}} \quad \text{with } \sigma_{ARM1} > -1 \quad (9)$$

$$QCMU_r = QCU_r \left(\frac{PCU_r}{PCMU_r} \right)^{\sigma_{ARM1}} \quad \text{with } \sigma_{ARM1} > -1 \quad (10)$$

$$QC DL_r = QCDU_r \left(\frac{PCDU_r}{PC DL_r} \right)^{\sigma_{ARM2}} \quad \text{with } \sigma_{ARM2} > -1 \quad (11)$$

$$QC ML_r = QCDU_r \left(\frac{PCDU_r}{PC ML_r} \right)^{\sigma_{ARM2}} \quad \text{with } \sigma_{ARM2} > -1 \quad (12)$$

Concerning the government spending 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. QG DL and QG ML represent the domestic and intra-national imported government goods purchased by the government in the sub-national region. PG, PGD, PGM, PGU, PGDU, PGMU, PG DL and PG ML are the associated prices.

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

$$QGD_c = QG_c \left(\frac{PG_c}{PGD_c} \right)^{\sigma_{ARM}} \quad \text{with } \sigma_{ARM} > -1 \quad (13)$$

$$QGM_c = QG_c \left(\frac{PG_c}{PGM_c} \right)^{\sigma_{ARM}} \quad \text{with } \sigma_{ARM} > -1 \quad (14)$$

$$QGDU_r = QGU_r \left(\frac{PGU_r}{PGDU_r} \right)^{\sigma_{ARM1}} \quad \text{with } \sigma_{ARM1} > -1 \quad (15)$$

$$QGMU_r = QGU_r \left(\frac{PGU_r}{PGMU_r} \right)^{\sigma_{ARM1}} \quad \text{with } \sigma_{ARM1} > -1 \quad (16)$$

$$QGDL_r = QGDU_r \left(\frac{PGDU_r}{PGDL_r} \right)^{\sigma_{ARM2}} \quad \text{with } \sigma_{ARM2} > -1 \quad (17)$$

$$QGML_r = QGDU_r \left(\frac{PGDU_r}{PGML_r} \right)^{\sigma_{ARM2}} \quad \text{with } \sigma_{ARM2} > -1 \quad (18)$$

Finally, with regard to the intermediate goods 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:

$$QID_c = QI_c \left(\frac{PI_c}{PID_c} \right)^{\sigma_{ARM1}} \quad \text{with } \sigma_{ARM} > -1 \quad (19)$$

$$QIM_c = QI_c \left(\frac{PI_c}{PIM_c} \right)^{\sigma_{ARM1}} \quad \text{with } \sigma_{ARM} > -1 \quad (20)$$

$$QIDU_r = QIU_r \left(\frac{PIU_r}{PIDU_r} \right)^{\sigma_{ARM1}} \quad \text{with } \sigma_{ARM1} > -1 \quad (21)$$

$$QIMU_r = QIU_r \left(\frac{PIU_r}{PIMU_r} \right)^{\sigma_{ARM1}} \quad \text{with } \sigma_{ARM1} > -1 \quad (22)$$

$$QIDL_r = QIDU_r \left(\frac{PIDU_r}{PIDL_r} \right)^{\sigma_{ARM2}} \quad \text{with } \sigma_{ARM2} > -1 \quad (23)$$

$$QIML_r = QIDU_r \left(\frac{PIDU_r}{PIML_r} \right)^{\sigma_{ARM2}} \quad \text{with } \sigma_{ARM2} > -1 \quad (24)$$

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 reported below:

$$PDS_c QDS_c = PCD_c QCD_c + PGD_c QGD_c + PID_c QID_c \quad (25)$$

$$PDS_r QDS_r = PCDL_r QCDL_r + PGDL_r QGDL_r + PIDL_r QIDL_r \quad (26)$$

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:

$$PAI_c QAI_c = PCM_c QCM_c + PGM_c QGM_c + PIM_c QIM_c \quad (27)$$

$$PAIU_r QAIU_r = PCMU_r QCMU_r + PGMU_r QGMU_r + PIMU_r QIMU_r \quad (28)$$

$$PAIL_r QAIL_r = PCML_r QCML_r + PGML_r QGML_r + PIML_r QIML_r \quad (29)$$

The additional sub-national nest for imports also requires the structure of the bilateral trade flows to be modified. 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. The upper one puts together goods coming from abroad while the lower one goods coming from the other Italian regions. 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:

$$QXS_{dc} = QAI_c \left(\frac{PAI_c}{PXS_{dc}} \right)^{\sigma_{IMP}} \quad \text{with } \sigma_{IMP} > -1 \quad (30)$$

$$\sum_d QXS_{dc} PXS_{dc} = QAI_c PAI_c \quad (31)$$

$$QXSU_{cr} = QAIU_r \left(\frac{PAIU_r}{PXSU_{cr}} \right)^{\sigma_{IMP1}} \quad \text{with } \sigma_{IMP1} > -1 \quad (32)$$

$$\sum_c QXSU_{cr} PXSU_{cr} = QAIU_r PAIU_r \quad (33)$$

$$QXSL_{sr} = QAIL_r \left(\frac{PAIL_r}{PXSL_{sr}} \right)^{\sigma_{IMP2}} \quad \text{with } \sigma_{IMP2} > -1 \quad (34)$$

$$\sum_s QXSL_{sr} PXSL_{sr} = QAIL_r PAIL_r \quad (35)$$

4. Model validation

The main purpose of this paper is to establish and test a good method in order to obtain a consistent sub-national database along with a reasonable theoretical model.

Therefore, this section presents a validation process of four sub-national models applied to the GTAP database integrated with the Italian sub-national data, which has been derived following the procedure illustrated in section 2.

Beyond the four sub-national specifications, we have also the standard GTAP model with Italy considered as a whole. The legend below summarizes the different types of model.

Legend:

AI	Aggregated Italy in the standard GTAP model
RI	Regionalised Italy in the standard GTAP model
RIMFM	Regionalised Italy with geographical M obility in F actor M arkets
RIARM	Regionalised Italy with increased inter regional A rmington elasticities
RIAFM	Regionalised Italy with both increased A rmington and mobility in F actor M arkets

The **AI** 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. The AI model is not a sub-national model. It is only to assess the robustness and economic consistency in the results of the real sub-national models with respect to the standard GTAP model in which Italy is aggregated.

The **RI** model considers North, Centre and South of Italy separately, rest of Europe and rest of the world. It is the first real sub-national model. The theoretical structure and parameter values are the same of the standard GTAP model. For this reason sub-national regions behave exactly as GTAP countries. The RI is the basic model with the lowest degree of market integration and competition at the sub-national level.

The **RIMFM** model considers North, Centre and South of Italy, rest of Europe and rest of the world. We model a different factor market for capital, unskilled and skilled labour as illustrated in sub-section 3.1. Parameter values are the same but we insert an additional one, the elasticity of factor supply $\sigma_{FAC} = \sigma_K = \sigma_L = \sigma_H$ (it is the same for capital and labour). In our reference case this parameter is set equal to -2.

In the **RIARM** specification we have the same regions as before. Nevertheless, we build the new trade structure to make products closer substitutes inside the national borders than outside the national borders, as we have seen in sub-section 3.2. In addition, we put four additional parameters for the sub-national regions, σ_{ARM1} , σ_{ARM2} , σ_{IMP1} , and σ_{IMP2} . We have explained the economic meaning of these parameters in sub-section 3.2. In our reference case their values are set according to the following formulas:

$$\sigma_{ARM2} = 2 \sigma_{ARM1} \quad \sigma_{ARM1} = \sigma_{ARM}$$

$$\sigma_{IMP2} = 2 \sigma_{IMP1} \quad \sigma_{IMP1} = \sigma_{IMP}$$

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

Finally, in the **RIAFM** model both changes in goods and factors market are incorporated. RIAFM is the full model with the highest degree of market integration and competition at the sub-national level.

We compare the results of the different sub-national models among them and with the standard GTAP model where Italy is aggregated as a single country. We also carry out a sensitivity analysis on the parameters adopted at the sub-national level to model factors mobility and the new trade structure.

The aim of this validation process is threefold:

- Testing if our results are robust enough with respect to the standard GTAP model but at the same time verifying if welfare outcomes improve both at the Italian and world level when moving towards more competitive and integrated markets.
- Analysing the distributional effects at the sub-national level.
- Carrying out a sensitivity analysis to test the economic consistency of our results on the following parameters:

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

4.1 The experiment

We implement a simple experiment (a 20% uniform decrease in land productivity in North, Centre and South of Italy, rest of Europe and rest of the world). The simulation results are not intended to be realistic but they allow us to assess how the model works from an economic point of view and to verify its consistency with respect to classical CGE assumptions. For example, we expect that the loss in welfare for Italy and the world as a whole, following the negative shock, decreases starting from the RI (the basic sub-national model) to the RIAFM (modifications both in the factors and goods market) because we are moving towards more competitive and flexible markets in the Italian sub-national regions.

For this initial application, we group the economic system in 10 GTAP sectors. Table 2 reports them. We have two agricultural sectors, five manufactures and three service sectors. The sectoral aggregation is the same in all the models considered in this work.

The geographical aggregation is displayed in Table 3. It is the same for all the sub-national model. As mentioned before, in the AI we have the aggregated Italy.

Table 2: sectors

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

Table 3: regions

North	North of Italy
Centre	Centre of Italy
South	South of Italy
EU	Rest of European Union (27 countries except Italy)
ROW	All remaining countries in the world

4.2 Results and sensitivity analysis

For our results we look at the EV (Equivalent Variation), expressed in 2004 million \$. This is a standard measure used in the CGE models to assess the welfare gain or loss after a shock in the economic system. Basically it is the income that you need to take away from an individual to make her/him equivalently worse off or better off following a price change.

Tables 4 shows the outcomes for all the regions and all the types of model. As expected, the numbers are negative but the magnitudes are different. To appreciate the underlying dynamic it is more useful to represent the results in a graphical way. If we look at the Figures 3 and 4 we can observe that the outcomes are robust with respect to the standard GTAP model in which Italy is aggregated (**AI** model) and are similar in all the sub-national specifications. This is true for the World and Italy. On the other hand, looking in a restricted scale on the vertical axis (Figures 5 and 6) we can appreciate as moving towards more competitive and integrated markets at the sub-national level, that is moving from the RI to RIAFM, the welfare outcomes improve. This is the case for both World and Italy.

To summarize, the Figures above confirm the robustness of our sub-national models with respect to the standard GTAP model and their economic consistency with the neoclassical CGE framework.

Nevertheless, Figure 6 shows a surprising result, the reduction in welfare is lower in RIARM and RIMFM models than in the AI model. This sounds strange if we think at the AI model as the one in which factors and goods market are perfectly integrated and competitive within Italy. A possible explanation could be that the geographical aggregation is not neutral in GTAP. In fact in the AI we have three regions while in the other sub-national models we have five regions. The other possible explanation could refer to the introduction of the new trade structure across sub-national regions. However this result should be further investigated.

Table 4

EV (2004 milion \$)	AI	RI	RIMFM	RIARM	RIAFM
North		-679.13	-265.67	-676.54	-275.83
Center		-235.32	-152.31	-201.78	-22.24
South		-1137.30	-1626.91	-1102.77	-1670.14
Italy	-1996.62	-2051.75	-2044.89	-1981.09	-1968.21
EU	-16150.98	-16085.24	-16074.82	-16125.42	-16119.20
ROW	-67655.07	-67624.08	-67619.89	-67638.67	-67636.64
World	-85802.67	-85761.07	-85739.60	-85745.18	-85724.05

Turning to the distributional effects, we can observe in Figures 7, 8, 9 and 10 that in all the sub-national specifications the first outcome we get is in favour of having sub-national detail within a country. In fact, even when using an undifferentiated impact through the Italian territory, we can note that South is the most affected sub-national region because its economy is agricultural intensive while North and Centre are less impacted.

From the modelling perspective, it is also interesting to look at the different roles played by the factors and goods market. In fact with respect to RI model the new Armington trade structure basically does not change the pattern of the distributional effects in the RIARM model. On the other hand the new factors market exacerbates the difference between South and Centre/North regions because South is more and more affected while Centre and North mitigate their losses. The reason for such result is that workers and capital can now move from South to North and Centre.

Finally, Figures 11 and 12 display the results of the sensitivity analysis on sub-national Armington elasticity and CET elasticity in the sub-national endogenous supply of mobile primary factors. The sensitivity analysis is carried out in the last specification (RIAFM) because it is comprehensive of all modifications. The Figures show the welfare outcomes in terms of EV for the World and Italy, respectively.

The blue line takes a picture of the economy in three different instants. Keeping the Armington structure fixed at our reference case, we progressively increase the factor mobility in three steps according to the following formulas:

- 1) $\sigma_{FAC} = 0$
- 2) $\sigma_{FAC} = -2$
- 3) $\sigma_{FAC} = -5$

The absolute values, $|\sigma_{FAC}|$, represent, respectively low, medium and high level of factor mobility. They are depicted on the horizontal axis.

The red line does the same thing for the goods market. Keeping the factors market structure fixed at our reference case ($\sigma_{FAC} = -2$), we progressively increase the substitution across products coming from different sub-national regions using the formulas reported below:

- 1) $\sigma_{ARM2} = \sigma_{ARM1}$, $\sigma_{IMP2} = \sigma_{IMP1}$
- 2) $\sigma_{ARM2} = 2 \sigma_{ARM1}$, $\sigma_{IMP2} = 2 \sigma_{IMP1}$
- 3) $\sigma_{ARM2} = 5 \sigma_{ARM1}$, $\sigma_{IMP2} = 5 \sigma_{IMP1}$

Case 1, 2 and 3 above represent, respectively low, medium and high mobility in the goods market.

Finally, the green line merges these different pictures in the following way:

- 1) $\sigma_{ARM2} = \sigma_{ARM1}$, $\sigma_{IMP2} = \sigma_{IMP1}$, $\sigma_{FAC} = 0$
- 2) $\sigma_{ARM2} = 2 \sigma_{ARM1}$, $\sigma_{IMP2} = 2 \sigma_{IMP1}$, $\sigma_{FAC} = -2$
- 3) $\sigma_{ARM2} = 5 \sigma_{ARM1}$, $\sigma_{IMP2} = 5 \sigma_{IMP1}$, $\sigma_{FAC} = -5$

Case 1, 2 and 3 above represent, respectively low, medium and high mobility in the goods and factors market.

The aim is to disentangle the mobility factor effect (blue line), the increasing sub-national Armington effect (red line) and finally to analyse them simultaneously (green line). The three lines cross in the reference case of the RIAFM model.

At first glance, we can immediately see that all the lines are monotonically increasing. This is a good new because it is a further proof about the fact that our theoretical changes are consistent with the standard CGE framework of competitive markets.

It is also interesting to note that red line is steeper than blue line. This implies that the model is more sensitive to the Armington assumptions than to factor market assumptions.

As expected, green line represents the lowest and highest point on the vertical axis. Its slope is very high suggesting goods and factors market interact in a multiplicative way rather than additive.

In Table 5 we report the results of the sensitivity analysis for each region. Rest of the world and rest of Europe show similar results in all the considered scenarios. It is worthwhile to notice that in the case $\sigma_{FAC} = 0$, $\sigma_{ARM2} = 2 \sigma_{ARM1}$ and $\sigma_{IMP2} = 2 \sigma_{IMP1}$ the RIAFM model collapses exactly in the RIARM specification.

Concerning the sub-national patterns, it is important to stress that moving towards the south-east scenarios (increasing overall mobility), North and Centre experience a change in the sign of EV. On the contrary South absorbs all the negative impact. This dynamic is similar to that observed moving from RI to RIAFM model but now it is much stronger because North and Centre even gain from the negative land productivity shock. This outcome is not very surprising. As production reallocates from agriculture to manufactures and services and being North and Centre intensive in these two sectors, factors and goods also reallocate in this new sectoral/geographical space.

Figure 3: equivalent variation in the World (2004 \$ million)

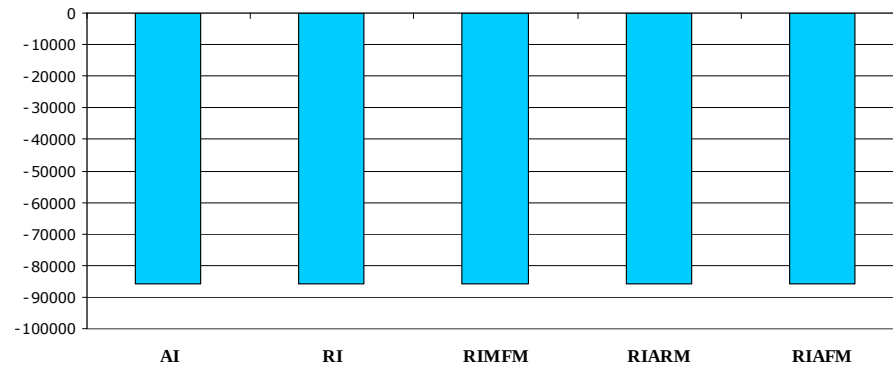


Figure 4: equivalent variation in Italy (2004 \$ million)

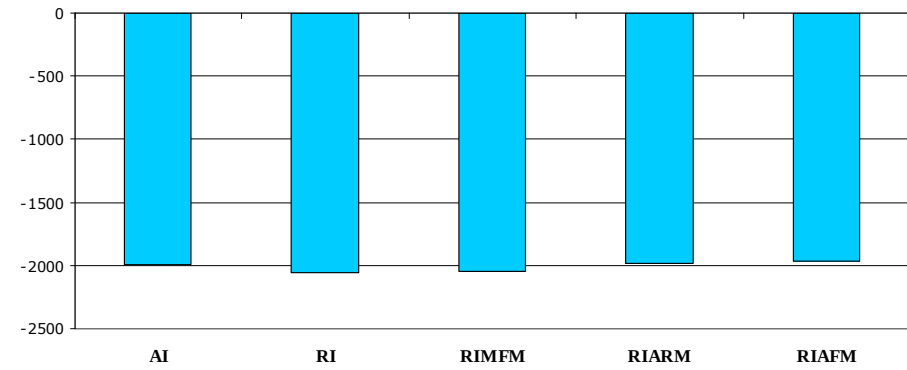


Figure 5: equivalent variation in the World (2004 \$ million, restricted scale)

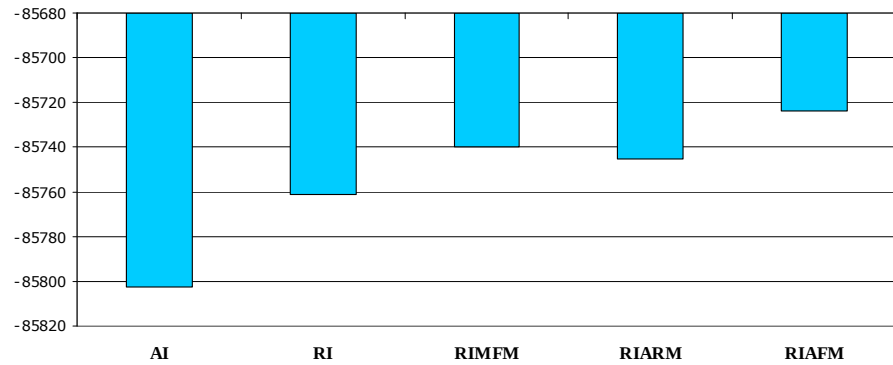


Figure 6: equivalent variation in Italy (2004 \$ million, restricted scale)

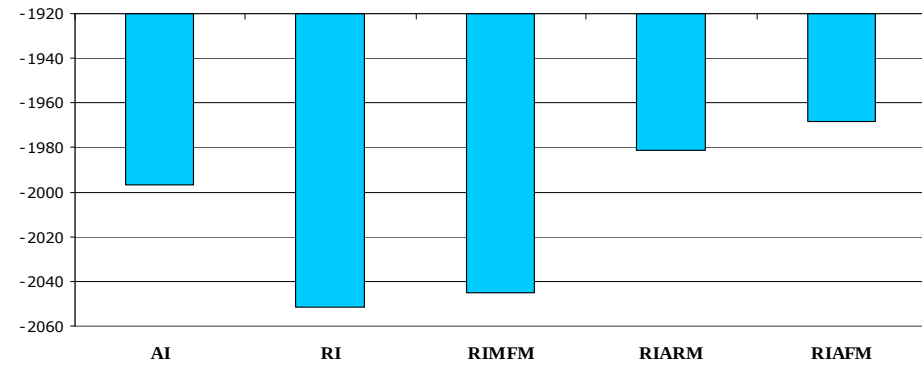


Figure 7: equivalent variation RI model (2004 \$ million)

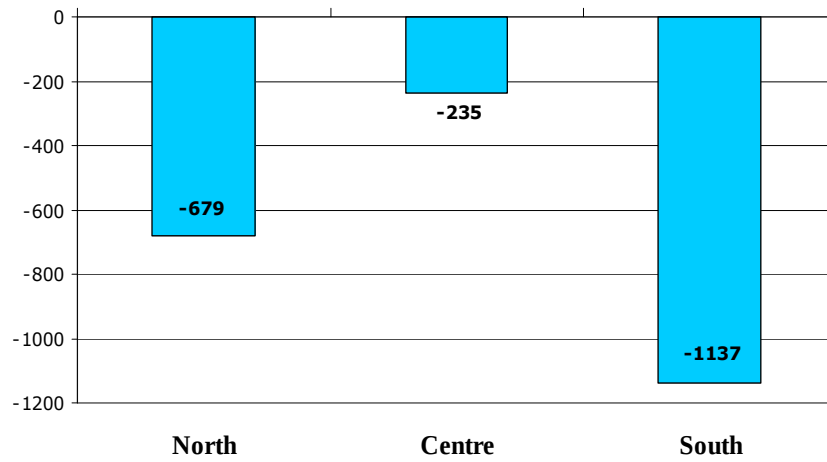


Figure 8: equivalent variation RIMFM model (2004 \$ million)

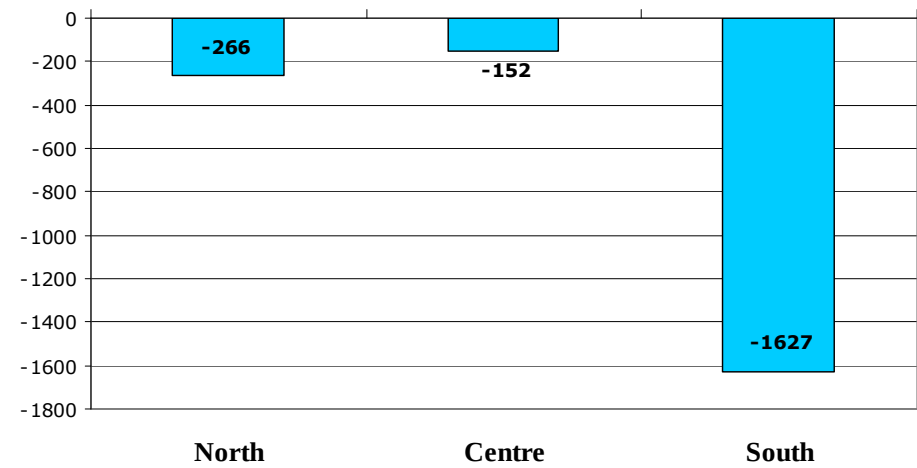


Figure 9: equivalent variation RIARM model (2004 \$ million)

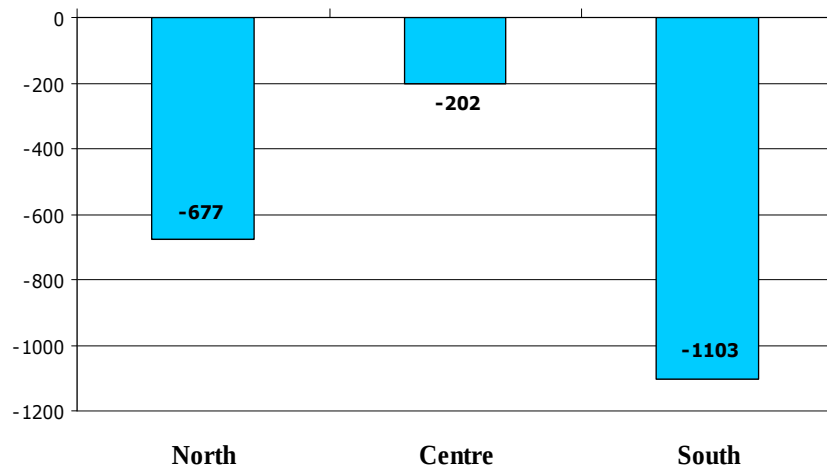


Figure 10: equivalent variation RIAFM model (2004 \$ million)

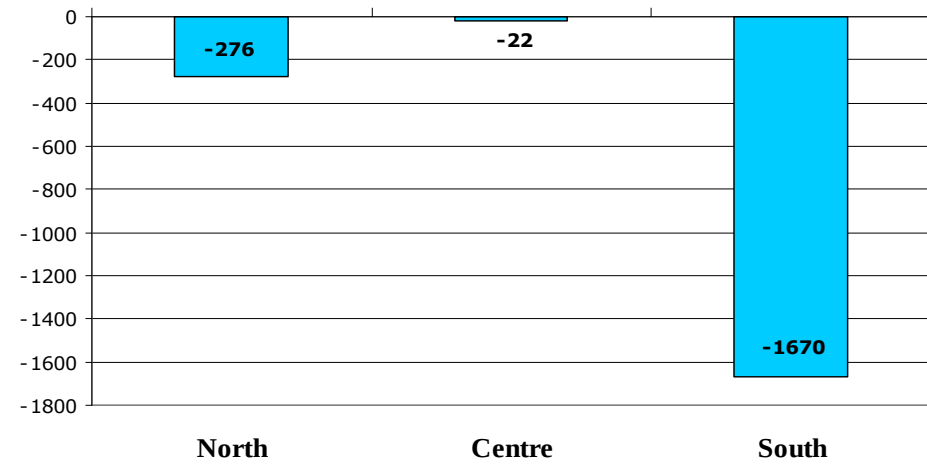


Figure 11: equivalent variation in the World (2004 \$ million)

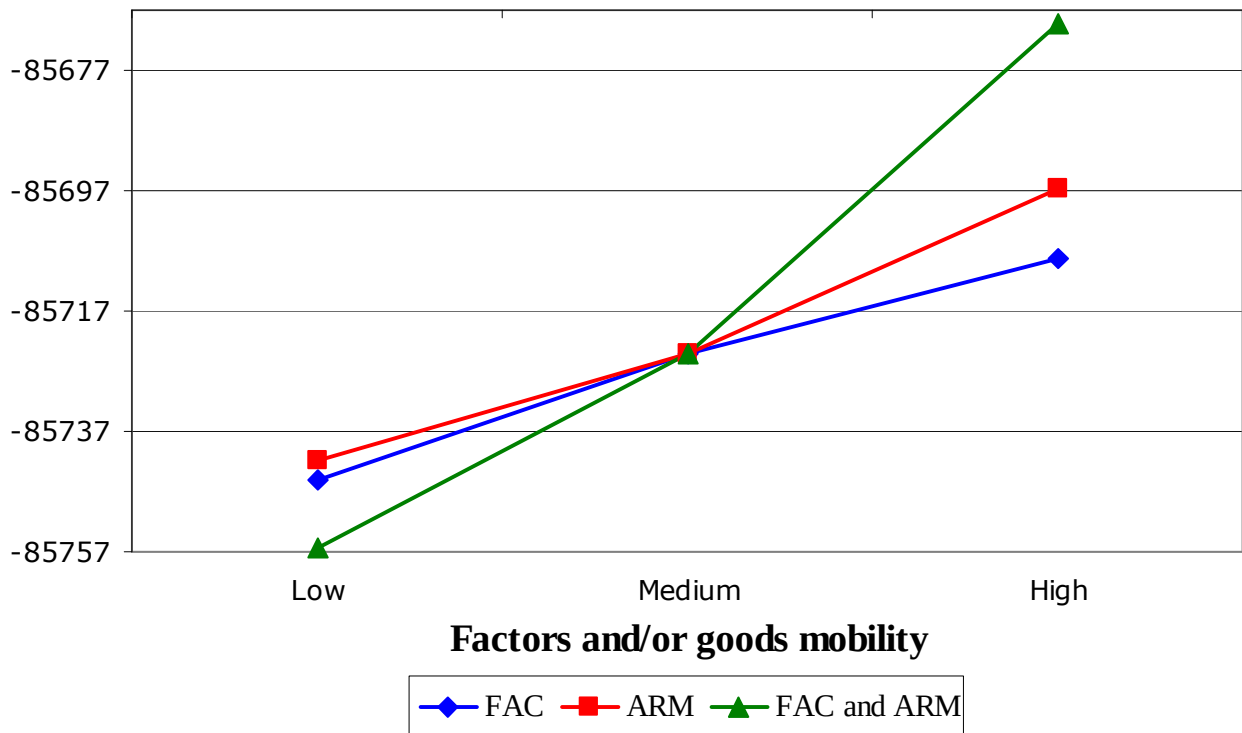


Figure 12: equivalent variation in Italy (2004 \$ million)

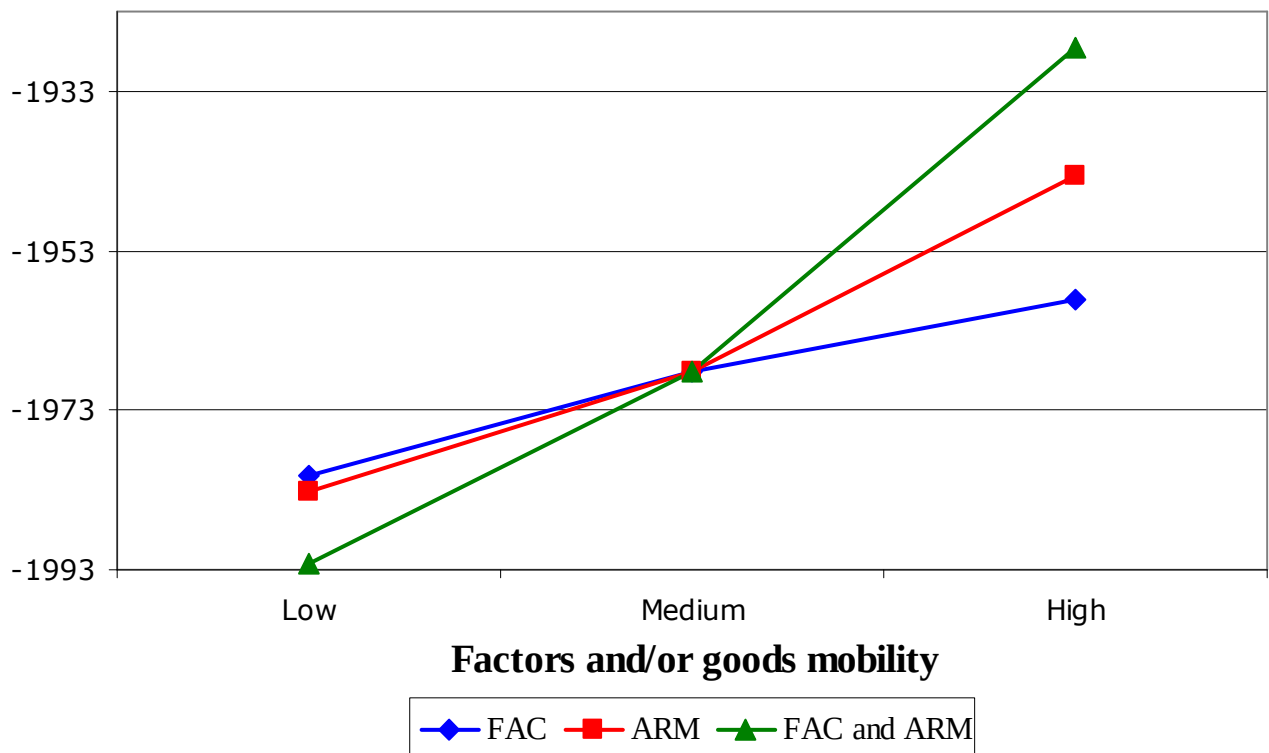


Table 5: sensitivity analysis (EV, 2004 million \$)

	$\sigma_{\text{ARM2}} = \sigma_{\text{ARM1}}$ $\sigma_{\text{IMP2}} = \sigma_{\text{IMP1}}$	$\sigma_{\text{ARM2}} = 2 \sigma_{\text{ARM1}}$ $\sigma_{\text{IMP2}} = 2 \sigma_{\text{IMP1}}$	$\sigma_{\text{ARM2}} = 5 \sigma_{\text{ARM1}}$ $\sigma_{\text{IMP2}} = 5 \sigma_{\text{IMP1}}$
North			
$\sigma_{\text{FAC}} = 0$	-719.20	-676.54	-610.43
$\sigma_{\text{FAC}} = -2$	-452.90	-275.83	-88.47
$\sigma_{\text{FAC}} = -5$	-299.97	31.65	453.91
Centre			
$\sigma_{\text{FAC}} = 0$	-214.79	-201.78	-173.75
$\sigma_{\text{FAC}} = -2$	-103.74	-22.24	63.72
$\sigma_{\text{FAC}} = -5$	-52.25	110.34	318.95
South			
$\sigma_{\text{FAC}} = 0$	-1058.30	-1102.77	-1175.69
$\sigma_{\text{FAC}} = -2$	-1426.65	-1670.14	-1918.82
$\sigma_{\text{FAC}} = -5$	-1626.61	-2101.19	-2700.40
EU			
$\sigma_{\text{FAC}} = 0$	-16125.73	-16125.42	-16124.89
$\sigma_{\text{FAC}} = -2$	-16121.66	-16119.20	-16116.65
$\sigma_{\text{FAC}} = -5$	-16119.21	-16114.28	-16108.03
ROW			
$\sigma_{\text{FAC}} = 0$	-67638.41	-67638.67	-67639.09
$\sigma_{\text{FAC}} = -2$	-67636.91	-67636.64	-67636.55
$\sigma_{\text{FAC}} = -5$	-67635.93	-67634.91	-67633.80

5. Conclusions and further research

Our approach uses both transport information and economic data in a consistent statistical framework via the RAS method to obtain a sub-national database for Italy.

Results are robust enough with respect to the standard GTAP model and welfare outcomes improve when moving toward more competitive 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).

Distributional economic effects are strongly uneven across sub-national regions even in the case of a uniform shock. Increasing mobility of factors (labour and capital) within Italy amplifies the uneven patterns across sub-national regions. Sensitivity analysis on Armington and CET elasticity shows consistent economic results.

Further research involves two main field: the database and the model. Concerning the database we have to extend this first version to the 20 Italian regions. Actually, this goal has been achieved, we just need to do some additional refinement and check. It will be important to find a better estimation method to determine trade flows in the service sector because so far we have used the overall amount of shipped goods as proxy. It would be also interesting to cooperate with other countries inside and outside EU for collecting sub-national information and extending the database beyond Italy, especially in the Mediterranean area. In fact, our methodology can be applied to other countries according to the data availability, in particular for transport bilateral flows of carried goods.

With regard to the modelling part, we should test the model with real shocks (e.g. extreme natural events as floods) to check which model parameterization produces more reasonable results. Finally, the major effort in the next months will be to combine the ICES, the energy-oriented CGE model developed in CMCC and FEEM, and the sub-national model to analyse deeper the linkages in the energy sector (RES included) and assess better CO2 emission patterns.

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References

Canning, P. & Tsigas, M. (2000). Regionalism, Federalism, and Taxation: A Food and Farm Perspective. Technical Bulletin No. 1882, Economic Research Services, U.S. Department of agriculture.

Chintrakarn, P. & Millimet, D.L. (2006). The environmental consequences of trade: Evidence from subnational trade flows. *Journal of Environmental Economics and Management*, Elsevier, 52(1), 430-453.

Dixon, P., Rimmer, M. & Wittwer, G. (2012). USAGE-R51, a state-level multi-regional CGE model of the US economy: <https://www.gtap.agecon.purdue.edu/resources/download/5933.pdf>.

Dubé, J. & Lemelin, A. (2005). Estimation expérimentale des flux d'échanges interrégionaux par la méthode de minimisation de l'entropie croisée. *Revue canadienne des sciences régionales/Canadian Journal of Regional Science*, 28(3), 513-534.

Horridge, M. & Wittwer, G. (2010). Bringing regional detail to a CGE model using CENSUS data. *Spatial Economic Analysis*, 5(2), 229-255.

McCallum, J. (1995). National Borders Matter: Canada-U.S. Regional Trade Patterns. *American Economic Review*, 85(3), 615-23.

McDougall, R. (1999). Entropy Theory and RAS are Friends. GTAP Working Papers 300, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.

Narayanan, B. & Walmsley, T. (2008). *Global Trade, Assistance, and Production: The GTAP 7 Data Base*. Center for Global Trade Analysis, Purdue University.

Perali, F., Pieroni, L. & Standardi, G. (2012). World tariff liberalization in agriculture: An assessment using a global CGE trade model for EU15 regions. *Journal of Policy Modeling*, 34(2), 155-180.

Rodriguez, U-P. E. (2007). State-of-the-Art in Regional Computable General Equilibrium Modelling with a Case Study of the Philippines, *Agricultural Economics Research Review*, Agricultural Economics Research Association (India), 20(1), 1-28.