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Modelling Inter-Regional Trade Flows

Data and Methodological Issues in RHOMOLO[1]

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Abstract: Being a dynamic spatial general equilibrium model, for the base year calibration RHOMOLO requires a full set of inter-regional trade flow matrices. Given that there is no readily available dataset covering all 267 NUTS2 regions of the EU, we developed a methodology to regionalise the trade flows using freight data. Our approach follows the parameter free estimation of Simini et al. (2012). Data on trade in goods and services have been derived from freight transport data. The trade flows were estimated by distributing the trade over the regions, given the amount produced and consumed in every region.

Keywords: Spatial dynamic general equilibrium model; inter-regional trade flows; Social Accounting Matrix; data estimation; input-output.

JEL: C68, C82, E16.

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1 Introduction

RHOMOLO is a dynamic spatial general equilibrium model used for ex-ante impact assessment of policy instruments such as the EU Cohesion Policy. It has been developed within the European Commission by DG JRC and DG REGIO. The regional structure of the model covers 267[2] EU NUTS2 regions under the European Nomenclature of Territorial Units for Statistics (NUTS[3]). In the tradition of dynamic spatial general equilibrium models, RHOMOLO's database is organised in form of a Social Accounting Matrix (SAM). Given that there is no readily available dataset covering all 267 NUTS2 regions of the EU, we developed a methodology to regionalise the trade flows using freight data.

This paper describes in detail the method applied in the regionalisation process, which can be summarised as follows. Our approach follows the methodology proposed by Thissen et al. (2013), and the parameter free estimation approach proposed by Simini et al. (2012). Data on trade in goods and services have been derived from freight transport data. The trade flows were determined by distributing the trade over the regions, given the amount produced and consumed in every region.

Given the amount of goods consumed per region that are also produced in that region (the diagonal of the trade matrix), the total production in every region, the total consumption in a region and the total international exports and imports on the country level, we can determine all regional trade between the regions. To determine export destinations, we use a parameter free transport model, based on the probabilities of trade flows between different regions. These probabilities are derived from micro data on freight transport.

In particular, the underlying regionalisation methodology requires the following data (which were collected and harmonised before the regionalisation):

1. Production and consumption at the sector detail used in the RHOMOLO model for the complete coverage of all NUTS2 regions and for the base year (2010). The regional production satisfies the conditions that it adds up to national production and that national production exceeds national exports. These data were extracted from the Eurostat.

[2] The EU27 has 271 NUTS2 regions, but the four French overseas regions of Guadeloupe, Reúnion, French Guyana and Martinique are not covered by RHOMOLO. We are currently working on a new database for the EU28, including Croatia that joined the EU in on 1 July 2013. For this version, with base year 2010, Croatia was not a Member State and thus not covered by the model.

[3] See for more information http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction

2. The amount of consumption of goods in a region that are produced in the own region. These data were derived from the PBL trade data and separate gravity estimations for Bulgaria and Romania.

3. A consistent set of bilateral trade data at the national level conform the specification used in RHOMOLO from the World Input Output Database (WIOD[4]).

4. Freight transport data describing the amount of goods transported between regions. These data are being collected from Eurostat micro data (the micro- data reported by Member States in the frame work of their survey for carriage of goods by road is now available (under conditions) for research purposes).[5]

The paper is organised as follows. Section 2 provides a non-technical overview of RHOMOLO. Section 3 describes in detail the data that are used for the construction of the national tables and the sources for regionalisation. Section 4 describes the approaches that are taken for regionalising each entry in the national tables (Sections 4.1 - 4.5). Finally, Section 5 concludes and provides an overview of future steps foreseen to improve the regionalisation methodology in RHOMOLO.

2 Description of the RHOMOLO model

2.1 Overview

This section provides a non-technical overview of the RHOMOLO model.[6] RHOMOLO is a dynamic spatial general equilibrium model designed to work at the regional level. The model currently consists of 267 NUTS2 regions of the EU27 and covers 6 sectors (agriculture, manufacturing, construction, transport, financial services and public services). Each region is inhabited by households that receive income from labour, capital and transfers (from national and regional governments). The income is split between savings, consumption and taxes. In addition, there is also a national R&D sector, which produces research services, and sells these innovations to firms (see Figure 1).

Each region contains 6 sectors that produce goods that are consumed by households and the government or used as an input by firms (in the same sector or in the others). Transport costs

[4] See World Input-Output Database, http://www.wiod.org/
[5] http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/introduction.
[6] For a more detailed and technical description of RHOMOLO 2, we refer to Brandsma et al. (2014).

for trade between and within regions are assumed to be of the iceberg type. Within each region they vary by sector, between regions they vary by sector and region pair. This implies a 267×267 asymmetric trade cost matrix derived from the transport model of European Commission – TRANSTOOLS.[7]

Varieties produced in different regions are combined via a CES function. Trade and transport margins are applied to imports from all NUTS2 regions, including the domestic sales. A CET function defines the sectors' choice between sales on the domestic market and exports to other regions as function of relative prices on these markets. A fixed-proportion device is employed to allocate consumer income between savings and consumption. The lower level of the sector's production function features the possibility of trade-offs between labour and capital services specified with a CES function.

The national government levies taxes on the income of households, firms and production factors and pays social contributions to the households. Disposable income of regional governments is fully spent on their consumption of final goods and savings.

In RHOMOLO, the world consists of R regions and S sectors. Each region is inhabited by H_r households. Each household supplies a specific variety of low, medium and high skilled labour services to firms, which are considered as imperfect substitutes to the ones offered by other households.

There are two types of producers in the model: the national R&D sector and final output firms producing final demand and intermediate goods. The final output sector is disaggregated into 6 economic sectors in which firms provide final goods to consumers and intermediate goods to other firms by operating under monopolistic competition à la Dixit-Stiglitz (1977). Each firm produces a differentiated variety, which is considered as an imperfect substitute to other households and firms. Goods are either consumed by households or used by other firms as intermediate inputs or as investment goods.

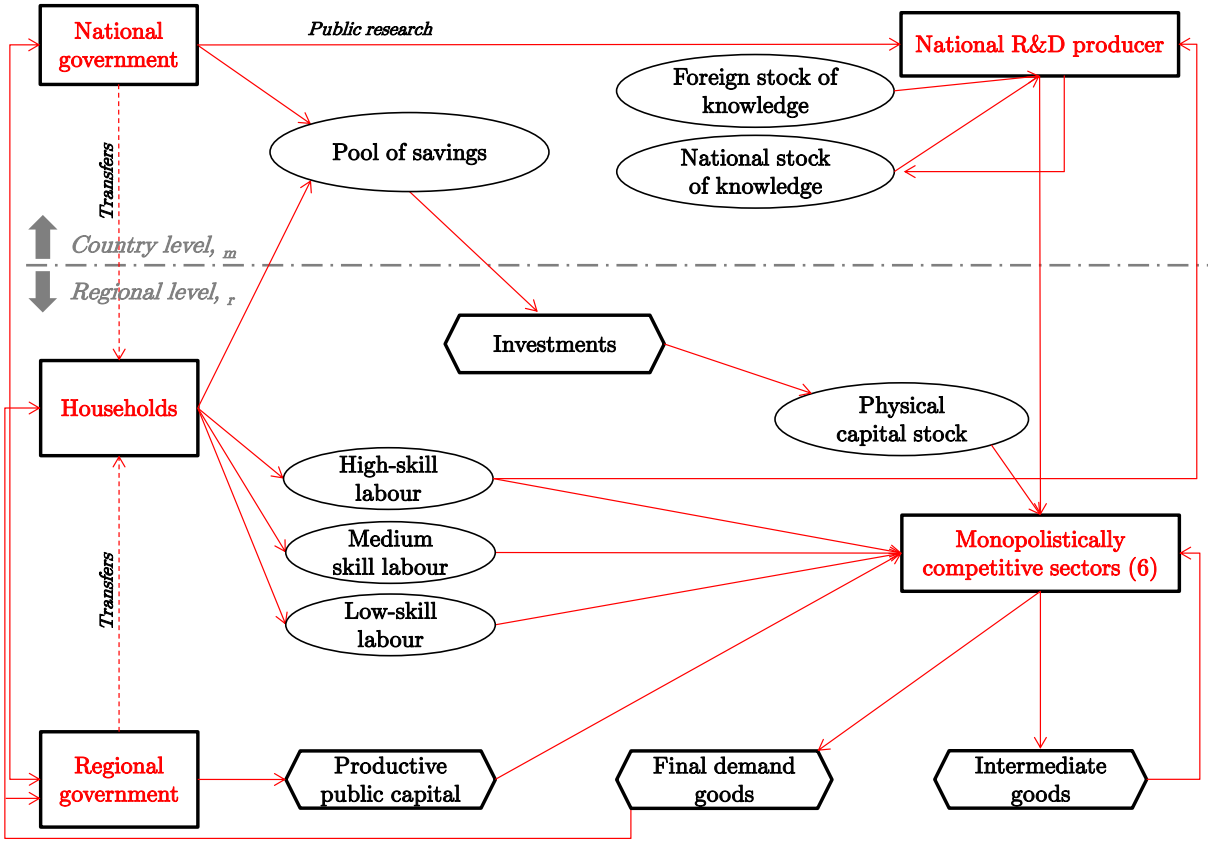
Goods have to incur iceberg transport costs to reach their customers, which amounts to assuming that $\tau > 1$ units of good have to be shipped for one unit to reach its final destination (see, for instance, Krugman, 1991). Transport costs are identical across varieties within region-sectors, but specific to sectors and trading partners (region pairs). Information

[7] TOOLS for TRansport Forecasting ANd Scenario testing (TRANSTOOLS) http://www.transportmodel.eu/

on transport costs is borrowed from the model TRANSTOOLS and are related to distance and other factors, such as transport infrastructure and national borders.

Public research augments the stock of knowledge, which in turn increases the productivity and hence output of the national R&D sector. For calibration purposes, the size of public research is determined by the level of public expenditure in R&D. The production of ideas in both the public and private domain is approximated by knowledge production. The stock of knowledge depends on the production of new designs, which also replace previous designs becoming obsolete. The absorption of ideas from other regions is discounted by a measure of spatial weight matrix.

Figure 1 Structure of the RHOMOLO model



There are two levels of government: national and regional. Taxes are levied on consumption and on the income of regional households to provide public goods in the form of public capital, which is used by firms. It also subsidises the private sector, including the production of R&D and innovation.

The detailed regional and sectoral dimensions of RHOMOLO imply that the number of (non-linear) equations to be solved simultaneously is extremely high (ca. 1.5 million). Therefore,

in order to keep the model manageable from a computational point of view, its dynamics is kept relatively simple. Agents are assumed to save a constant fraction of their income in each period and form their expectations based only on the current and past states of the economy. The dynamics of the model is then described as in a standard Solow model, with a sequence of short-run equilibria related to each other through the build-up of physical and human capital stocks, in addition to knowledge and assets.

3 Data description

RHOMOLO is calibrated to the regionalised Social Accounting Matrices (SAMs) of the EU Member States (these SAMs were constructed with the World Input-Output Database project[8]). The Social Accounting Matrix (SAM) represents the basic structure of the model. It is a matrix-based representation of the National Accounts where the cells are the flows of economic transactions within an economy: payment flows from column accounts to row accounts. A SAM represents a macro-economic equilibrium where aggregate demand equals aggregate supply.

For the construction of all EU27 countries' SAMs, the recently published data of the EU funded World Input Output Database (WIOD) project have been used. This database provides World Input-Output tables, International and National Supply and Use tables, National Input-Output tables, and Socio-Economic and Environmental Accounts covering all EU27 countries and 13 other major countries in the world for the period from 1995 to 2009 (RHOMOLO takes 2010 as the base year). The availability of WIOD data allows verifying the consistency between different data sources and facilitated the construction of reliable and consistent SAMs. For instance, interregional trade data are now also based on WIOD data (in turn, consistent with Eurostat), just like the SAMs. The database ensures now a higher level of consistency compared to previous attempts where interregional trade data were estimated by using other external trade data. Moreover, an additional advantage of WIOD data is that re-exports are subtracted from normal exports to arrive at the final value of exports. This is necessary because re-exports do not undergo any value-added processes, so cannot be counted towards a nation's or region's exports. Data are available for 59 NACE Rev. 1.1 sectors, but are aggregated in an early stage into the six macro-sectors used in RHOMOLO.

[8] World Input-Output Database, http://www.wiod.org/

SAMs are first constructed at the national level – based on the SUTs and expanded with Eurostat data – and afterwards regionalised in the model code. The structure of a Social Accounting Matrix used in RHOMOLO is shown in Figure 2, which provides an overview of the flows in the typical format of a SAM.

Figure 2 A simplified version of RHOMOLO's SAMs

<table>
<tr><th></th><th>Commodities</th><th>Industries</th><th>Value Added</th><th colspan="2">Final Demand</th></tr>
<tr><td>Commo-dities</td><td></td><td>Intermediate Use</td><td rowspan="2"></td><td>Final Use</td><td>Exports</td></tr>
<tr><td>Indus-tries</td><td>Supply</td><td rowspan="2"></td></tr>
<tr><td rowspan="2">Value Added</td><td></td><td rowspan="2">Value Added and Taxes</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td>Taxes less Subsidies on Products</td></tr>
<tr><td rowspan="3">Final Demand</td><td rowspan="2"></td><td rowspan="2">Sources of Value Added</td><td rowspan="2"></td><td>Incoming Transfers</td></tr>
<tr><td rowspan="2">Imports</td><td rowspan="2">Outgoing Transfers</td><td rowspan="2"></td></tr>
<tr><td></td><td>Trade & Transport Margins</td><td></td><td></td><td></td></tr>
</table>

The task of balancing SAMs - where columns equal rows - is particularly challenging. WIOD facilitates the balancing process due to the fact that both Supply and Use Tables (SUTs) and Input-Output Tables (I/O) are consistent and based on Eurostat National Accounts. In turn, this makes both the international comparison and the completion of the SAMs with other Eurostat data more reliable than other CGE modelling databases.

The use row of the Commodities corresponds to the WIOD Use Table and contains the activities' Intermediate Use of each commodity. The Commodities column is the inverted WIOD Supply table and represents Domestic Supply, Taxes less Subsidies on Products, total Imports, and the total Trade and Transport margins (of the tradable commodities and services paid to Transport). The Domestic supply matrix in RHOMOLO has been diagonalised, which means that activities only produce one commodity in the same category – so Manufacturing activities only produces manufacturing commodities. For each activity, the intermediate use comes, as mentioned above, from the WIOD Use table. Value added consists of employees' compensation (wages + employees social security contribution) and the net operating surplus (a residual variable for the difference between value added and labour compensation). The assumption that net operating surplus is paid from activities to the production factors means

that firms are considered as a production factor. Capital consumption was not available in the WIOD SUT framework and was therefore obtained from Eurostat (consumption of fixed capital). For the factor column, the wages and salaries as paid to Households, Employer's Social Contributions (SC) and Taxes paid to the Government, the Operating Surplus flow to the Households are simply the sum of the corresponding row in the Activities column. Employees' SC, Personal Income Tax and Corporate Income Tax are obtained from Eurostat.

In the Household column, Household Savings is represented by a residual cell that balances the column and row and can be calculated after income and consumption (and tax payments) are known Expenditures Abroad are represented by Resident's purchases abroad from the WIOD Input-Output tables.

Data on bilateral transport costs per sector are provided externally by TRANSTOOLS, a model covering freight and passenger movements around Europe. The costs of different shipments are calculated in terms of share of the value shipped, based on the time needed to reach the destination using alternative modes of transport. Transport costs thus differ by type of good and depend on the distance between the regions and the variety and characteristics of modes of transport connecting them, which also means that they can be asymmetric. The transport costs are measured in Euros and cover the agriculture and manufacturing and energy sectors. In order to calculate regional transport margins, transport costs were divided by the value of bilateral regional trade flows.

For the industry detail, data has been collected for 6 industries using the NACE Rev. 1.1 classification,[9] as shown in Table 1. RHOMOLO sector A covers the exploitation of vegetable and animal natural resources. The section comprises the activities of growing crops, raising animals, harvesting timber, and harvesting other plants and animals from a farm or their natural habitats. RHOMOLO sector B is defined as the use of fishery resources from marine or freshwater environments, with the goal of capturing or gathering fish, crustaceans, molluscs and other marine products (e.g. pearls, sponges, etc). RHOMOLO sector C includes the extraction of minerals occurring naturally as solids (coal and ores), liquids (petroleum) or gases (natural gas). Extraction can be by underground or surface mining or well operation. RHOMOLO sector D contains the mechanical, physical or

[9] Statistical Classification of Economic Activities in the European Community, Rev. 1.1 (2002) (NACE Rev. 1.1). Commission Regulation (EEC) No 761/93 of 24 March 1993 amending Council Regulation (EEC) No 3037/90 on the statistical classification of economic activities in the European Community (OJ No L 83, 3.4.1993, p. 1, and corrigendum, OJ No L 159, 11.7.1995, p. 31).

chemical transformation of materials, substances or components into new products. The materials, substances or components transformed are raw materials that are products of agriculture, forestry, fishing, mining or quarrying as well as products of other manufacturing activities. RHOMOLO sector E covers the activity of providing electric power, natural gas, steam supply, and water supply through a permanent infrastructure (network) of lines, mains, and pipes. The size of the network is not decisive; also included is electricity, gas, steam and water supply and the like in industrial parks or blocks of flats. RHOMOLO sector F includes general construction and special trade construction for buildings and civil engineering, building installation and building completion. It includes new work, repair, additions and alterations, the erection of pre-fabricated buildings or structures on the site and also constructions of a temporary nature.

Table 1: Six NACE Rev. 1.1 industries

CODE	SECTOR
AB	Agriculture, hunting and forestry
CDE	Mining and quarrying + Manufacturing + Electricity and Gas
F	Construction
GHI	Wholesale and retail trade; repair of motor vehicles, motorcycles, personal, household goods
JK	Financial intermediation, real estate and business services
LMNOP	Non-Market Services

RHOMOLO sector G includes wholesale and retail sale (sale without transformation) of any type of goods, and rendering services incidental to the sale of merchandise. Wholesale and retailing are the final steps in the distribution of merchandise. Also included in this section is the repair of motor vehicles and installation and repair of personal and household goods. RHOMOLO sector H comprises the provision to customers of lodging and/or prepared meals, snacks, and beverages for immediate consumption. The section includes both accommodation and food services because the two activities are often combined at the same unit. RHOMOLO sector I includes activities related to providing passenger or freight transport, whether scheduled or not, by rail, pipeline, road, water or air; supporting activities such as terminal and parking facilities, cargo handling, storage, etc.; postal activities and telecommunication; and renting of transport equipment with driver or operator. RHOMOLO sector J covers financial intermediation, except insurance and pension funding, it includes the activity of obtaining and redistributing funds other than for the purpose of insurance or pension funding

or compulsory social security. RHOMOLO sector K includes activities which mainly focus on the business sector. But more or less all activities covered by this section can be provided to private households, too, e.g. renting of personal and household goods, database activities, legal activities, investigation and security services, interior decoration or photographic activities. RHOMOLO sector L includes activities normally carried out by the public administration. The legal or institutional status is not, in itself, the determining factor. This division includes units which are part of local or central public bodies which enable the administration of the community to function properly. RHOMOLO sector M includes public as well as private education at any level or for any profession, oral or written as well as by radio and television. It includes both education by the different institutions in the regular school system at its different levels as well as adult education, literacy programmes, etc. RHOMOLO sector N includes hospitalisation activities such as: medical and surgical technical care activities such as diagnosis, treatment, operations, analyses, emergency activities, etc; and accommodation activities such as boarding, meals, etc. RHOMOLO sector O includes collection and treatment of household and industrial waste, not for a further use in an industrial manufacturing process, but with the aim of disposal and resulting a product of little or no value. It also includes other activities such as street cleaning and snow removal, etc. RHOMOLO sector P is strictly limited to the activities of households as employers of domestic personnel such as maids, cooks, waiters, valets, butlers, laundresses, gardeners, gatekeepers, stable-lads, chauffeurs, caretakers, governesses, babysitters, tutors, secretaries, etc. It allows the domestic personnel employed to state the activity of their employer in censuses or studies, even though the employer is an individual.

Goods produced by all six RHOMOLO sectors can be traded between all regions, implying that we need to estimate a 267x267x6 matrix of bilateral trade flows.

4 Regionalisation

Due to the high number of regions in RHOMOLO and limited availability of reliable regional data for all 267 regions, the regionalisation procedure is highly complex. The main requirement for the first version of the regionalised SAMs is the consistency of the data amongst all regions. Therefore we started with the variable for which most regional details were available: interregional trade.

4.1 Interregional Trade Flows (imports, exports and domestic supply)

For the regionalised SAMs, data on interregional imports and exports is required, but are not readily available for all 267 regions and for the 6 industries. WIOD provides us with data on the national level that serve as macro-constraints for constructing these interregional trade flows. These macro-constraints are combined with prior data on trade flows developed by Thissen et al (2013). For this exercise, Thissen et al (2013) use data from Eurostat for the year 2000 that are then adjusted to the base year of RHOMOLO (2010) by imposing the national macro-constraints. Data are available on (a) locally produced consumption per region, (b) total production in every region, (c) the total consumption in a region, and (d) the total international exports and imports on the country level. As such, all regional trade between the regions can be determined. A non-parametric transport model was used to determine export destinations, based on the probabilities of trade flows between different regions. These probabilities are derived from data on freight transport, collected from Eurostat micro data of their survey on carriage of goods by road.[10]

Before estimating inter-regional trade flows that are consistent with other parts of the RHOMOLO database, a preceding step is necessary for estimating the inter-regional trade flows for the missing countries in the Thissen et al (2013) dataset – Bulgaria and Romania – by using a gravity model of trade and the available macro-constraints. This is described in Section 4.1.1. These trade flows for all 27 EU countries are then used as priors to estimate the trade flows updating the macro constraints from the Thissen et al (2013) database to the RHOMOLO database by solving an optimisation problem minimising the error of estimated and actual trade given the available macro-constraints (Section 4.1.2).

4.1.1 Estimation of inter-regional trade priors for Bulgaria and Romania

4.1.1.1 Available macro constraints

The estimation of inter-regional trade priors for Bulgaria and Romania will be illustrated by a simple 2×3 example (for a formal discussion see Ivanova, Kancs and Stelder, 2009). The example consists of two countries, c1 and c2, each containing 3 regions, *i1*, *i2*, and *i3* (*c1*)

[10] See http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/eu_road_freight_trans_survey

and *i4*, *i5* and *i6* (*c2*), and the rest of the word (*RoW*). The following data are available in the statistics that can serve as macro constraints:

- SAMs (country-level data, as available from the WIOD)
    - The value of goods produced and consumed in each country. In our example *c1* produces and consumes domestically 35 units, *c2* produces 25 units, and *RoW* produces 94 units.
    - The SAMs contain information also about transport and trade margins, trade and transport margin. In our example 6 units for *c1*, 7 units for *c2*, and 0 units for *RoW*.
- International trade data (country-level data, as available from the WIOD)
    - The bilateral trade flows between countries. In our example, *c1* exports 4 units to *c2*, and 11 units to RoW; *c2* exports 10 units to *c1*, and 5 units to *RoW*; *RoW* exports 5 units to *c1*, and 11 units to *c2*.
    - The value of goods imported into each country. In our example, 56 units in *c1*, 47 units in c2, and 110 units in *RoW*.
- Regional production (regional data, as available from the Eurostat)
    - The regional production (value added). In our example, 12 units in i1, 15 units in i2, 23 units in i3, 8 units in i4, 11 units in i5, 21 units in i6.

Table 2: Available macro-constraints

	j1	j2	j3	**c1**	j4	j5	j6	**c2**	**RoW**	**Tot FOB**
i1										12.0
i2										15.0
i3										23.0
c1				**35.0**				**4.0**	**11.0**	**50.0**
i4										8.0
i5										11.0
i6										21.0
c2				**10.0**				**25.0**	**5.0**	**40.0**
RoW				**5.0**				**11.0**	**94.0**	**110.0**
Tot FOB				**50.0**				**40.0**	**110.0**	**200.0**
TT marg				**6.0**				**7.0**	**0.0**	**13.0**
Tot CIF				**56.0**				**47.0**	**110.0**	**213.0**

Notes: Regional data Country data

4.1.1.2 Estimation of domestic exports (from region to country)

For each region, we assume that the share of regional production that is sold within the country and that is exported is the same as at the national level. This implies that *i1* is exporting the same share of its output to *c2* as regions *i2* and *i3* (and thus the same share as *c1* exports to *c2*). Multiplying these shares by the domestic production sold domestically and international trade flows yields domestic sales and exports from each region to each country. In our example, *i1* sells 8.4 units in *c1*, exports 1.0 units to *c2*, and 2.6 units to *RoW*.

Note that imposing this assumption amounts to imposing some structure to the data. However, this is necessary when little data is available and/or quality of the data is questionable, as in our case.

Generally, it is possible to skip this step and proceed directly with the estimation of gravity model of trade (Section 4.1.1.3). In such an unconstrained gravity model, all inter-regional trade flows would solely depend on regional characteristics. Yet, such an unconstrained gravity model may yield results which are inconsistent with empirical observations in the data, because many unobservable regional characteristics, such as differences in consumer preferences, language, culture, geo-political history, etc., are omitted from the simple gravity model (1). For example, according to the unconstrained gravity model, in relative terms a

region in South UK would trade with Germany many times more than a region in North UK, because the South UK region has considerably lower trade costs to all German regions than North UK. Given that such results are not supported by the trade data, in RHOMOLO we impose a structure on the shares of regional production, which are sold in the country of production and which are exported to each trading partner.

Table 3: Domestic sales/exports from region to country

	j1	j2	j3	**c1**	j4	j5	j6	**c2**	**RoW**	**Tot FOB**
i1				8.4				1.0	2.6	12.0
i2				10.5				1.2	3.3	15.0
i3				16.1				1.8	5.1	23.0
c1				**35.0**				**4.0**	**11.0**	**50.0**
i4				2.0				5.0	1.0	8.0
i5				2.8				6.9	1.4	11.0
i6				5.3				13.1	2.6	21.0
c2				**10.0**				**25.0**	**5.0**	**40.0**
RoW				**5.0**				**11.0**	**94.0**	**110.0**
Tot FOB				**50.0**				**40.0**	**110.0**	**200.0**
TT marg				**6.0**				**7.0**	**0.0**	**13.0**
Tot CIF				**56.0**				**47.0**	**110.0**	**213.0**

4.1.1.3 Estimation of a gravity model of inter-regional trade

The third step consists of estimating a gravity model of inter-regional trade. According to Anderson and Van Wincoop (2003), if consumers have CES preferences with common elasticity of substitution σ among all goods, the gravity equation can be expressed as:

$$P_{ij} = \frac{X_i C_j}{Y_w}\left(\frac{t_{ij}}{\prod_i \prod_j}\right)^{1-\sigma}$$

$$\prod_j^{1-\sigma} = \sum_i \prod_i^{1-\sigma} y_i t_{ij}^{1-\sigma} \qquad (1)$$

$$\prod_i^{1-\sigma} = \sum_j \prod_j^{1-\sigma} y_j t_{ji}^{1-\sigma}$$

where P_{ij} are the inter-regional trade priors we are interested in, X_i and C_j are production and consumption in origin region i and destination region j, respectively, y is the corresponding

share, Y_w is total production of all trading partners, t_{ij} are trade costs between i and j, and $\prod_i$ and $\prod_j$ are price indices, which often are referred to as multilateral trade resistance.

Table 4: The estimates of inter-regional trade priors

	j1	j2	j3	**c1**	j4	j5	j6	**c2**	**RoW**	**Tot FOB**
i1	2.8	2.9	2.7	8.4	0.3	0.3	0.3	1.0	2.6	12.0
i2	2.8	3.6	4.2	10.5	0.4	0.4	0.4	1.2	3.3	15.0
i3	5.9	6.3	3.9	16.1	0.7	0.6	0.5	1.8	5.1	23.0
c1	**11.5**	**12.8**	**10.7**	**35.0**	**1.5**	**1.3**	**1.2**	**4.0**	**11.0**	**50.0**
i4	0.7	0.7	0.5	2.0	2.2	1.5	1.3	5.0	1.0	8.0
i5	0.8	1.1	0.8	2.8	2.1	1.9	2.9	6.9	1.4	11.0
i6	1.8	1.8	1.7	5.3	3.5	5.8	3.9	13.1	2.6	21.0
c2	**3.3**	**3.6**	**3.0**	**10.0**	**7.8**	**9.2**	**8.1**	**25.0**	**5.0**	**40.0**
RoW				**5.0**				**11.0**	**94.0**	**110.0**
Tot FOB				**50.0**				**40.0**	**110.0**	**200.0**
TT marg				**6.0**				**7.0**	**0.0**	**13.0**
Tot CIF				**56.0**				**47.0**	**110.0**	**213.0**

Data on regional production and consumption, X_i and C_j, are available from the regional SAMs, inter-regional trade costs, and t_{ij}, are readily available from the TRANSTOOLS data base. Values for the elasticity of substitution, σ, are taken from the literature (Okagawa and Ban 2008)).

According to the gravity model estimates, in our example *i1* sells 2.8 units locally, exports 2.9 units to *j2*, 2.7 units to *j3*, 0.3 units to *j4*, 0.3 units to *j5*, and 0.3 units to *j6* (see Table 4).[11]

The above gravity model is only one among many potential gravity models that can be used to estimate inter-regional trade flows. This particular gravity model, however, is well founded theoretically and is widely used in the literature, which explains our choice.

4.1.1.4 Regionalising the trade margins and imports from RoW

The next step concerns the regionalisation of imports from *RoW* and splitting the international trade and transport margins (available from the national SAMs) by importing region.

[11] Note that in our one sector example expenditure is equal to output.

In absence of regional specific data on trade margins, the most natural way to disaggregate imports from *RoW* is to assume the same regional import shares as of regional imports from other EU countries. According to Table 5, in our example *j1* imports $(3.3/10 \times 5.0 =)$ 1.7 units, *j2* imports $(3.6/10 \times 5.0 =)$ 1.8 units, and *j3* imports $(3.0/10 \times 5.0 =)$ 1.5 units from the *RoW*.

Table 5: Regionalising trade margins and imports from RoW

	j1	j2	j3	**c1**	j4	j5	j6	**c2**	**RoW**	**Tot FOB**
i1	2.8	2.9	2.7	8.4	0.3	0.3	0.3	1.0	2.6	12.0
i2	2.8	3.6	4.2	10.5	0.4	0.4	0.4	1.2	3.3	15.0
i3	5.9	6.3	3.9	16.1	0.7	0.6	0.5	1.8	5.1	23.0
c1	**11.5**	**12.8**	**10.7**	**35.0**	**1.5**	**1.3**	**1.2**	**4.0**	**11.0**	**50.0**
i4	0.7	0.7	0.5	2.0	2.2	1.5	1.3	5.0	1.0	8.0
i5	0.8	1.1	0.8	2.8	2.1	1.9	2.9	6.9	1.4	11.0
i6	1.8	1.8	1.7	5.3	3.5	5.8	3.9	13.1	2.6	21.0
c2	**3.3**	**3.6**	**3.0**	**10.0**	**7.8**	**9.2**	**8.1**	**25.0**	**5.0**	**40.0**
RoW	1.7	1.8	1.5	**5.0**	3.5	4.0	3.5	**11.0**	**94.0**	**110.0**
Tot FOB	**16.5**	**18.3**	**15.3**	**50.0**	**12.8**	**14.4**	**12.8**	**40.0**	**110.0**	**200.0**
TT marg	2.0	2.2	1.8	**6.0**	2.2	2.5	2.2	**7.0**	**0.0**	**13.0**
Tot CIF	**18.4**	**20.5**	**17.1**	**56.0**	**15.0**	**17.0**	**15.1**	**47.0**	**110.0**	**213.0**

Analogously, the most natural way to disaggregate the international trade and transport margins (from SAMs) by importing region is to attribute these proportionately to the total import shares. According to Table 5, in our example *j1* pays 2.0 units, *j2* pays 2.2 units, and *j3* pays 1.8 units for the transportation services of importing goods.

Regional trade and transport margins and regional imports from the *RoW* were the last missing entries for completing the full inter-regional trade matrix. Having this information, one can estimate the total consumption and imports for each region in CIF prices. According to Table 5, in our example the total consumption of *j1* is 18.4 units, 20.5 units of *j2*, and 17.1 units of *j3*.

4.1.2 The estimation of inter-regional trade flows

4.1.2.1 The estimation problem

The prior information on inter-regional trade, P_{ij}, which is equal to the trade from region i to region j, is used for estimating the bilateral trade flows between the EU regions. First, we introduce the following two new priors that give the *relative* trade information such that the procedure takes possible differences in the overall totals of regional production and consumption into account. These relative priors Px_{ij} and Pc_{ij} are taken relative to the production and demand, respectively:

$$Px_{ij} = \frac{P_{ij}}{\sum_j P_{ij}}$$
$$Pc_{ij} = \frac{P_{ij}}{\sum_i P_{ij}} \qquad (2)$$

The objective function used to estimate the trade flows T_{ij} is given by the following equation:

$$minZ = \sum_{ij}\left[\left(Px_{ij} - \frac{T_{ij}}{X_i}\right)^2 + \left(Pc_{ij} - \frac{T_{ij}}{C_j}\right)^2\right] + \frac{1}{\left(\frac{\sum_i X_i}{\#i}\right)^2}\sum_{ij}\left(X_i Px_{ij} - T_{ij}\right)^2 + \frac{1}{\left(\frac{\sum_j C_i}{\#j}\right)^2}\sum_{ij}\left(C_j Pc_{ij} - T_{ij}\right)^2 \qquad (3)$$

where $\#i$ is the number of origin (exporting) regions and $\#j$ is the number of destination (importing) regions. This objective function consists of three parts. The first part describes the quadratic relative error of the final trade matrix in relation to the prior information. The second and third parts describe the absolute errors which are rescaled such that they have the same weight in the objective function as the relative errors. Note that these trade data include the diagonal and therefore take the cross-hauling of trade into account as well.

We have chosen a quadratic objective function, because it is convenient in solving very large optimisation problems. The quadratic function can be solved as either a conic or a quadratic program which are much faster to solve than the nonlinear logarithmic objective function. An entropy-based optimisation problem would involve changing the objective function into a

logarithmic function. This is easy to change from a programming perspective, but cumbersome from a computational perspective.

In order to obtain the trade matrix consistent with the regional consumption and production figures, we add the following two constraints to the minimisation problem:

$$X_i = \sum_j T_{ij} \tag{4}$$

$$C_j = \sum_i T_{ij} \tag{5}$$

Note that one of these constraints can be omitted for one region because the system would otherwise be over-determined.

4.1.2.2 Additional constraints

Given the national SAMs, next we add additional constraints where data are available. For instance, we add the country constraints such that the regional trade adds up to the country trade T^c_{od} between origin country o and destination country d:

$$T^c_{od} = \sum_{i \in o} \sum_{j \in d} T_{ij} \tag{6}$$

Note, however, that this also adds information on the national flows, which if not properly taken into account would result in a bias in the estimate. The estimate should also be on the national level if the international trade is taken as given. The complete optimisation problem together with constraint (6) changes to:

$$\begin{aligned} minZ = \sum_{ij} \left[\left(PxN_{ijn} - \frac{T_{ij,j \in n}}{X_{i,n}} \right)^2 + \left(PcN_{ijn} - \frac{T_{iji \in n}}{C_{n,j}} \right)^2 \right] \\ + \frac{1}{\left(\frac{\sum_i X_{i,n}}{\#i} \right)^2} \sum_{ij} \left(X_{i,n} PxN_{ijn} - T_{ij} \right)^2 \\ + \frac{1}{\left(\frac{\sum_j C_{j,n}}{\#j} \right)^2} \sum_{ij} \left(C_j PcN_{ijn} - T_{ij} \right)^2 \end{aligned} \tag{7}$$

where subscript n refers to the set of nations. Together with (7) we have the following set of additional constraints:

$$X_i = \sum_j T_{ij} \quad \textbf{(8)}$$

$$C_j = \sum_j T_{ij} \quad \textbf{(9)}$$

$$X_{i,n} = \sum_{j \in n} T_{ij} \quad \textbf{(10)}$$

$$C_{n,j} = \sum_{i \in n} T_{ij} \quad \textbf{(11)}$$

The relative probability priors Px_{ij} and Pc_{ij} are:

$$PxN_{ijn} = \frac{P_{ij}}{\sum_{j \in n} P_{ij}} \quad \textbf{(12)}$$

$$PcN_{ijn} = \frac{P_{ij}}{\sum_{i \in n} P_{ij}} \quad \textbf{(13)}$$

As a result, a fully completed, consistent and balanced inter-regional trade matrix is obtained, which can be readily used as data input in RHOMOLO. Note that this estimation procedure needs to be performed only once (not for each model run).

4.2 Supply and Use

We start by estimating the Supply columns of the regional SAMs with the regional output by industry and the regional intra- and extra-EU imports, all available from the interregional trade flows and consistent with our national SAMs, as described in Section 4.1. For the Taxes less Subsidies on Products, we apply the share of regional production over national production per industry.

4.3 IOZ+VA+Taxes

For regionalising the cells of Intermediate Use, first the ratio of national Intermediate Demand (by industry and commodity) over the total national Supply is calculated. This share is then applied to the regional total Supply.

For Value Added and Taxes, the share of each industry's regional supply over total regional supply has been applied to the regional total of the Value Added and Taxes (assuming national technology). For balancing regional [IOZ+VA] and regional Supply, entropy has been applied where industry imbalances in Intermediate Demand are redistributed.

4.4 Sources of Value Added and Transfers

The sources of Value Added (wages, taxes and operating surplus and depreciation) also follow the national technology assumption and are thus multiplied by the regional share in national output. Outgoing Transfers, such as Employees' Social Contributions for Households, Social Transfers for the Government are proportional to regional Supply of national Supply.

4.5 Final Demand

Intra-EU and extra-EU exports come from the consistent interregional trade flows. Final Demand (consumption of government, households, investments and inventories) is assumed to be in the same proportion per commodity as on the national level and is balanced with total income for each of the agents.

5 Conclusions and further steps

This paper describes in detail the method applied in the regionalisation process, which can be summarised as follows. Our approach follows the methodology proposed by Thissen et al. (2013), and the parameter free estimation approach proposed by Simini et al. (2012). Data on trade in goods and services have been derived from freight transport data. The trade flows were determined by distributing the trade over the regions, given the amount produced and consumed in every region.

Given the amount of goods consumed per region that are also produced in that region (the diagonal of the trade matrix), the total production in every region, the total consumption in a

region and the total international exports and imports on the country level, we can determine all regional trade between the regions. To determine export destinations, we use a parameter free transport model, based on the probabilities of trade flows between different regions. These probabilities are derived from micro data on freight transport.

In particular, the underlying regionalisation methodology requires the following data (which were collected and harmonised before the regionalisation):

1. Production and consumption at the sector detail used in the RHOMOLO model for the complete coverage of all NUTS2 regions and for the base year (2010). The regional production satisfies the conditions that it adds up to national production and that national production exceeds national exports. These data were extracted from the Eurostat.

2. The amount of consumption of goods in a region that are produced in the own region. These data were derived from the PBL trade data and separate gravity estimations for Bulgaria and Romania.

3. A consistent set of bilateral trade data at the national level conform the specification used in RHOMOLO from the World Input Output Database (WIOD).

4. Freight transport data describing the amount of goods transported between regions. These data are being collected from Eurostat micro data (the micro- data reported by Member States in the frame work of their survey for carriage of goods by road is now available (under conditions) for research purposes).

Currently, more regional detail is being introduced gradually in the present consistently regionalised SAMs, as regional data on employment and government consumption are becoming increasingly available.[12] A challenging task in the future will be to link the inter-regional trade cost matrices to trade and transport margins in the SAMs. Whereas bilateral trade costs from the TRANSTOOLS data are expressed as a share of transported goods value, the trade and transport margins in the SAMs use an inter-sectoral flow approach linking those sectors that produce transport services (GHI) to those sectors that purchase transport services (AB, CDE, F, JK, LMNOP). Note that in the SAMs, the transport services sales enter with negative sign, whereas the purchases enter with positive sign. A further complication arises from the fact that for many countries the trade and transport margins in the SAMs are zero,

[12] The newly regionalised SAMs will be described in separate Working Papers forthcoming in 2015.

suggesting that trade costs are zero (or the respective goods are non-tradable). These issues need to be addressed conceptually, before the inter-regional trade cost data can be linked to trade and transport margins in the SAMs.

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Annex I: Detailed SAM of RHOMOLO

		p1	p2	p3	p4	p5	p6	a1	a2	a3	a4	a5	a6	Wages and salaries	Employers' social contribution	Employees' social contribution	Personal income tax	Corporate income tax	Operating surplus, net	Other net taxes on production	Taxes-subsidies on products	Households and NPISH	Government	SavingsInvestments	Changes in inventories	Other regions in EU	Outside EU
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
p1	1							IOZ(reg,sec,secc)														CZ	CGZ	SIZ	SVZ	EEU27Zreg	EROWZ
p2	2																					CZ	CGZ	SIZ	SVZ	EEU27Zreg	EROWZ
p3	3																					CZ	CGZ	SIZ	SVZ	EEU27Zreg	EROWZ
p4	4																					CZ	CGZ	SIZ	SVZ	EEU27Zreg	EROWZ
p5	5																					CZ	CGZ	SIZ	SVZ	EEU27Zreg	EROWZ
p6	6																					CZ	CGZ	SIZ	SVZ	EEU27Zreg	EROWZ
a1	7	≈XDZ																									
a2	8		≈XDZ																								
a3	9			≈XDZ																							
a4	10				≈XDZ																						
a5	11					≈XDZ																					
a6	12						≈XDZ																				
Wages and salaries	13							LZ	LZ	LZ	LZ	LZ	LZ														
Employers' social contribution	14							EMPSCZ	EMPSCZ	EMPSCZ	EMPSCZ	EMPSCZ	EMPSCZ														
Employees' social contribution	15																					EMPLSCZ					
Personal income tax	16																					TRYZ					
Corporate income tax	17							TYKZ	TYKZ	TYKZ	TYKZ	TYKZ	TYKZ														
Operating surplus, net	18							OSurpl	OSurpl	OSurpl	OSurpl	OSurpl	OSurpl														
Other net taxes on production	19							TAXPZ	TAXPZ	TAXPZ	TAXPZ	TAXPZ	TAXPZ														
Taxes-subsidies on products	20	TAXCZ	TAXCZ	TAXCZ	TAXCZ	TAXCZ	TAXCZ																TaxGov	TaxInv	TaxChInv		
Households and NPISH	21													LTZ					TOsurpl				Gov2HH			EU2HH	ROW2HH
Government	22														22;14	EMPLSCZ		22;17			22;20	TRFZ				EU2Gov	ROW2Gov
SavingsInvestments	23							DEPRZ	DEPRZ	DEPRZ	DEPRZ	DEPRZ	DEPRZ									SHZ	SGZ	TDEPRZ		EU2InvZ	ROW2InvZ
Changes in inventories	24																							ColumnSVZ			ROW2SVZ
Other regions in EU	25	MEU27Zreg	MEU27Zreg	MEU27Zreg	MEU27Zreg	MEU27Zreg	MEU27Zreg															HH2EU	Gov2EU	Inv2EUZ			
Outside EU	26	MROWZ	MROWZ	MROWZ	MROWZ	MROWZ	MROWZ															HH2ROW	Gov2ROW	Inv2ROWZ	SVZ2ROW		
	27	TMTZ	TMTZ	TMTZ	TMTZ	TMTZ	TMTZ																				

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