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European NUTS 2 regions: construction of interregional trade-linked Supply and Use tables with consistent transport flows

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Abstract

Economic development is interregional in nature, with economic growth being determined by physical and technological proximity identified by interregional and national cross-border interactions in trade, investments, and knowledge. This report explains the construction of a system of multiregional input-output tables for the EU28 interlinked with trade in goods and services within the same country as well as with regions in other Member States. Taking transhipment locations into account, trade in goods and services is derived from freight transport data, airline data on flights, and business travel data. The methodology is centred on the probability of trade flows and was developed to fit the information available without pre-imposing any geographical structure on the data.

European NUTS 2 regions: construction of interregional trade-linked Supply and Use tables with consistent transport flows

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1 Introduction

The regional dimension of economic development is more and more at the centre of both policy and academic debates, with inter-regional and national cross-border interactions in trade, investments, and knowledge being considered as important determinants of economic growth. However, quantitative research analysing regional development in Europe as well as policy-supporting activities (such as those of the regional smart specialization strategy) have been hampered by data deficiencies, in particular regarding interregional trade relations (McCann and Ortega-Argilés, 2012). Due to the lack of data, interregional trade flows data need to be estimated based on the state of the art methodology and developed in such a way that they can be subsequently used in transport, economic, econometric, and spatial CGE analyses.

This study focuses on the derivation of the data on trade in goods and services for 2013 from freight transport data and data on flights and business travels, taking into account transhipment locations (logistic hubs). The main purpose of the resulting dataset is the use for the spatial CGE model called RHOMOLO routinely utilised by the Regional Economic Modelling group of JRC Seville (the latest description of the model is contained in Lecca et al., 2018).[1]

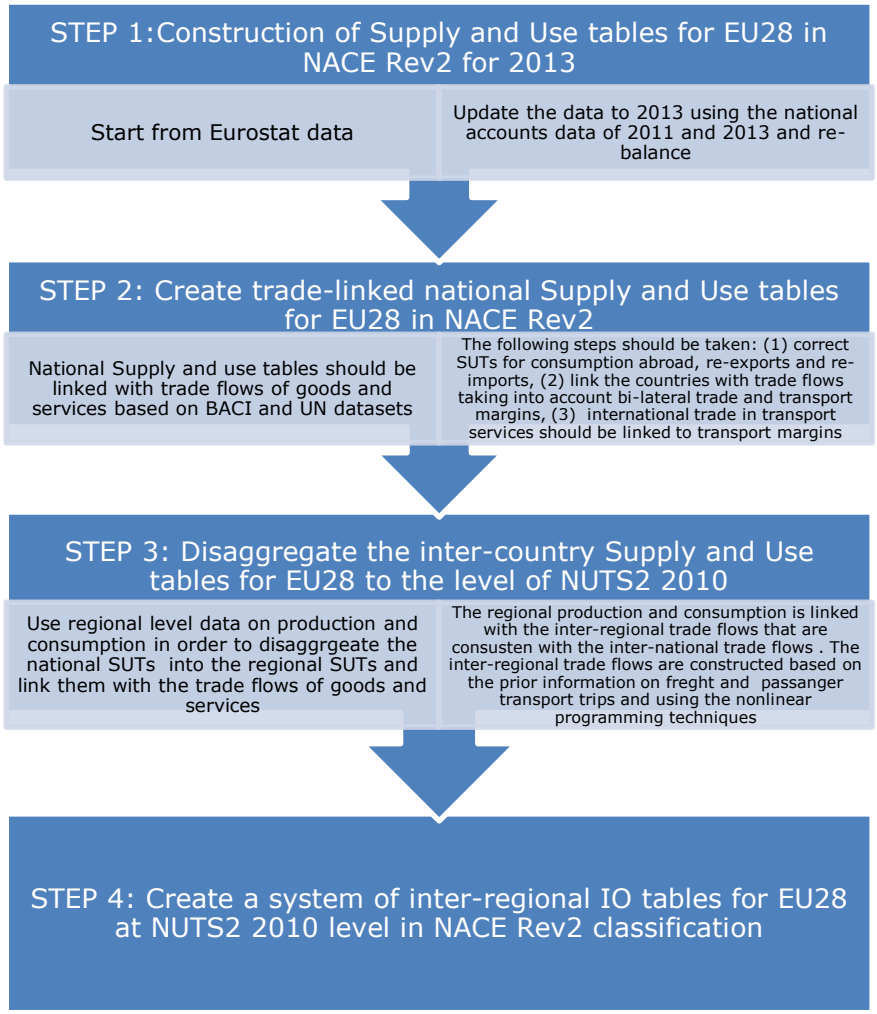
The method described in this paper extends the approach proposed in Thissen et al. (2013) and it is in line with the 'parameter-free' methodology proposed by Simini et al. (2012). This makes it possible to analyse the importance of transhipment locations (hubs) for regional trade and to link transport costs to inter-regional trade flows. An additional key advantage of this methodology is that it does not pre-impose any geographical structure on the data as a traditional gravity model would do. We find that some type of goods hardly use any logistic hub, while others pass through a substantial number of hubs before reaching their final destination. Our results suggest that only goods like agricultural products, mining, food and oil directly normally reach their final destination without going through intermediate locations. This implies that using a

[1] The dataset has been prepared by JRC Seville in collaboration with the PBL Institute in the Netherlands.

gravity model to estimate trade based on transport data should only be recommended for these types of goods. Such a method should not be used for all the other goods which are traded making use of intermediate locations.

This finding strengthens the motivation behind the construction of this inter-regional dataset and extends its use beyond the field of economics, with important implications for studies on transportation and logistics. In this report, we illustrate the steps needed for the construction of the Multi-Regional Input-Output (MRIO) table for the EU28 at the NUTS 2 level (see Figure 1).[2]

Figure 1: Steps required for the construction of the inter-regional trade data



First, we use the regional trade data to regionalize the Supply and Use Tables (SUTs) for the EU28 and subsequently construct a multiregional product by product Input-Output (IO) table. The latter is organised according to the two-digit based classification of

[2] All the NUTS 2 regions included in this study are listed in the Appendix.

industries (NACE 2) used in the national accounts of Eurostat. In a first step, the national SUTs are disaggregated into regional ones based on Eurostat regional statistics. These "regionalized" SUTs, however, are not disaggregated with respect to interregional and international trade. The interregional and international trade in goods is determined in a second step based on regional flows of goods and services as briefly anticipated above.

The remainder of the report is organised as follows. The second section describes the first two steps towards the construction of the consistent inter-regional EU28 MRIO table, including the update of the existing Eurostat SUTs in NACE Rev2 classification to the year 2013 and the creation of the trade-linked country-level SUTs for the EU28 and the rest of the world. The third section describes the regionalisation of the inter-country SUTs and the creation of the system of inter-regional IO tables. The fourth section discusses the results and concludes.

2 National trade-linked SUTs

In this section we explain the construction of a set of national SUTs which are internally consistent and linked with each other through import and export trade flows between countries. We start with an overview of the available sources of SUTs and IO tables for the EU. Then, we turn to the adjustments needed to create an internally consistent international system of SUTs.

2.1 Overview of available data sources

The main data sources for the construction of trade-linked SUTs covering all the individual EU28 countries as well as the rest of the world include:

1. SUTs and/or IO tables of the individual countries;
2. national accounts data needed to update the SUTs and the IO tables to the year 2013;
3. International trade data for both goods and services.

Table 1 gives an overview of the available data sources used for the construction of the national trade-linked SUTs. The SUTs and national accounts data come from the publicly accessible databases published by Eurostat and the OECD. The SUTs for the EU28 countries in NACE 2 are available for different years (see Table 2) and are all updated to 2013 using time-series data from national accounts. The SUTs are linked with the international trade flows based on the international trade data taken from the BACI database managed by CEPII as well as from the UN trade in services database.[3]

[3] Access to BACI database requires subscription to UN COMTRADE as it is based on this dataset.

Table 1: Overview of the data sources and short description

Data source	Availability	Sectoral/commodity details	Geographical details	Notes
Eurostat National SUTs	2008-2012	NACE Rev2	EU27	2013 data is only available for 3 countries
Eurostat national accounts, annual data (main GDP categories)	2000-2015	SNA categories	EU28	
Eurostat national accounts, annual data (detailed sectoral split)	2000-2013	90 NACE 2 economic sectors	EU28	Some of the sectors are the aggregates of the sub-sectors
BACI international reconciled bi-lateral commodity trade dataset	2008-2014	HS07	232 countries	Represents the reconciled version of the UN COMTRADE dataset prepared by CEPII for DG Trade - Trade flows are reported both in volumes and in values
STAN database national IO tables	1995-2011	34 sectors/commodities	Croatia and other 63 countries including the rest of the world	There are also inter-country IO tables available from OECD linking all countries with trade of goods and services
UN trade in services database	2000-2014	184 types of EBOPS items (types of services)	260 countries	This database is not reconciled and has a lot missing values

Eurostat provides SUTs for all the EU28 member states. These tables are produced using NACE 2 sectoral and commodity classification and are available for various years, but not for 2013 (the latest year of availability for each of the EU28 countries is presented in table 2). Thus, an updating procedure is needed, as explained below. The Eurostat SUTs are unbalanced for many countries after the updating, as they include re-exports and re-imports. Also, in some cases, the fixed capital formation column contains negative elements. We need a consistent set of trade-linked SUTs before we can start the regionalisation. Thus, we make the SUTs consistent before linking them by using the international trade flows data. The fact that the SUTs from Eurostat are not available for the year 2013 means that we need to use growth rates based on national accounts data in order to project the tables to 2013.

Table 2: SUTs' availability in NACE Rev2 at Eurostat

Country	Data type	Latest available year
AT Austria	Supply and Use tables in NACE Rev2	2010
BE Belgium	Supply and Use tables in NACE Rev2	2010
BG Bulgaria	Supply and Use tables in NACE Rev2	2010
CY Cyprus	Supply and Use tables in NACE Rev2	2009
CZ Czech Republic	Supply and Use tables in NACE Rev2	2011
DE Germany	Supply and Use tables in NACE Rev2	2010
DK Denmark	Supply and Use tables in NACE Rev2	2009
EE Estonia	Supply and Use tables in NACE Rev2	2009
ES Spain	Supply and Use tables in NACE Rev2	2010
FI Finland	Supply and Use tables in NACE Rev2	2011
FR France	Supply and Use tables in NACE Rev2	2010
GR Greece	Supply and Use tables in NACE Rev2	2010
HU Hungary	Supply and Use tables in NACE Rev2	2010
IE Ireland	Supply and Use tables in NACE Rev2	2010
IT Italy	Supply and Use tables in NACE Rev2	2010
LT Lithuania	Supply and Use tables in NACE Rev2	2010
LU Luxembourg	Supply and Use tables in NACE Rev2	2012
LV Latvia	Supply and Use tables in NACE Rev2	2010
MT Malta	Supply and Use tables in NACE Rev2	2010
NL Netherlands	Supply and Use tables in NACE Rev2	2010
PL Poland	Supply and Use tables in NACE Rev2	2009
PT Portugal	Supply and Use tables in NACE Rev2	2008
RO Romania	Supply and Use tables in NACE Rev2	2010
SE Sweden	Supply and Use tables in NACE Rev2	2010
SI Slovenia	Supply and Use tables in NACE Rev2	2010
SK Slovakia	Supply and Use tables in NACE Rev2	2010
UK United Kingdom	Supply and Use tables in NACE Rev2	2011

For the 2005 -2014 period, Eurostat provides national accounts of all the EU28 countries covering many of the same elements as the national SUTs. This includes all the elements of the final consumption block (final consumption of households, final consumption of

NPISH, final consumption of government, fixed capital formation, and changes in inventories), exports, and imports. The data are not sector-specific, thus the growth rates extracted from the national accounts are used for the relevant elements of the SUTs without differentiating across sectors. Table 3 presents the full list of national accounts data elements provided by Eurostat and used to project the SUTs to the year 2013.

Table 3: National accounts elements

Code	Description
B1GQ	Gross domestic product at market prices
B1G	Value added, gross
P3	Final consumption expenditure
P3_S13	Final consumption expenditure of general government
P31_S13	Individual consumption expenditure of general government
P32_S13	Collective consumption expenditure of general government
P31_S14_S15	Household and NPISH final consumption expenditure
P31_S14	Final consumption expenditure of households
P31_S15	Final consumption expenditure of NPISH
P41	Actual individual consumption
P5G	Gross capital formation
P51G	Gross fixed capital formation
P52_P53	Changes in inventories and acquisitions less disposals of valuables
P52	Changes in inventories
P53	Acquisitions less disposals of valuables
P6	Exports of goods and services
P61	Exports of goods
P62	Exports of services
P7	Imports of goods and services
P71	Imports of goods
P72	Imports of services
B11	External balance of goods and services
B111	External balance - Goods
B112	External balance - Services

D1	Compensation of employees
D11	Wages and salaries
D12	Employers' social contributions
B2A3G	Operating surplus and mixed income, gross
D2X3	Taxes on production and imports less subsidies
D2	Taxes on production and imports
D3	Subsidies
D21X31	Taxes less subsidies on products
D21	Taxes on products
D31	Subsidies on products
YA1	Statistical discrepancy (production approach)
YA0	Statistical discrepancy (expenditure approach)
YA2	Statistical discrepancy (income approach)
P3_P5	Final consumption expenditure and gross capital formation
P3_P6	Final consumption expenditure, gross capital formation and exports of goods and services

Besides the aggregated national accounts data, Eurostat also provides some detailed sectoral data for the period 20005-2014 in NACE 2 classification (the same 64 sectors as used in SUTs). This data includes:

- Gross value added
- Wages
- Output
- Net operating surplus
- Net taxes minus subsidies on production

These data were also used in order to extract growth rates capturing changes in the economic structure of the EU28 countries and to update the SUTs to the year 2013 with some sectoral differentiation.

The SUTs for the non-European countries come from the OECD world-wide IO database published for 2011. The sectoral classification chosen by OECD for its IO database is slightly different from NACE 2 and includes the 34 economic sectors presented in table 4.

Table 4: Sectors/commodities used in OECD IO database

Code	Description
1	TTL_C01T05: Agriculture, hunting, forestry and fishing
2	TTL_C10T14: Mining and quarrying
3	TTL_C15T16: Food products, beverages and tobacco
4	TTL_C17T19: Textiles, textile products, leather and footwear
5	TTL_C20: Wood and products of wood and cork
6	TTL_C21T22: Pulp, paper, paper products, printing and publishing
7	TTL_C23: Coke, refined petroleum products and nuclear fuel
8	TTL_C24: Chemicals and chemical products
9	TTL_C25: Rubber and plastics products
10	TTL_C26: Other non-metallic mineral products
11	TTL_C27: Basic metals
12	TTL_C28: Fabricated metal products
13	TTL_C29: Machinery and equipment, nec
14	TTL_C30T33X: Computer, Electronic and optical equipment
15	TTL_C31: Electrical machinery and apparatus, nec
16	TTL_C34: Motor vehicles, trailers and semi-trailers
17	TTL_C35: Other transport equipment
18	TTL_C36T37: Manufacturing nec; recycling
19	TTL_C40T41: Electricity, gas and water supply
20	TTL_C45: Construction
21	TTL_C50T52: Wholesale and retail trade; repairs
22	TTL_C55: Hotels and restaurants
23	TTL_C60T63: Transport and storage
24	TTL_C64: Post and telecommunications
25	TTL_C65T67: Financial intermediation
26	TTL_C70: Real estate activities
27	TTL_C71: Renting of machinery and equipment
28	TTL_C72: Computer and related activities
29	TTL_C73T74: R&D and other business activities
30	TTL_C75: Public administration and defence; compulsory social security

31	TTL_C80: Education
32	TTL_C85: Health and social work
33	TTL_C90T93: Other community, social and personal services
34	TTL_C95: Private households with employed persons

The OECD IO database covers the whole world and includes data for 62 separate countries, with the rest of the world aggregated in one residual region. Besides these data, the OECD also provides time-series data for the aggregated elements of the national accounts of 42 of the countries included in the IO database, thus making it possible to project the IO tables to 2013 as needed for our purposes.

2.2 International trade data sources

BACI is a detailed international trade database for the 1994-2014 period covering more than 200 countries and 5,000 products. New approaches have been developed to reconcile the data reported by over 150 countries to the UN Statistics Division which publishes them via their COMTRADE database. One issue in dealing with these data is the following: when both exporting and importing countries report their trade flows, typically there are two different values for the same flow. In order to have a single consistent figure of a bilateral flow, we reconcile them using the procedure explained below.

Firstly, transport costs must be removed from the reported imports values (expressed in CIF: cost, insurance and freight) in order to enable comparisons between the latter and the export values (expressed in FOB: free on board). Since detailed information on the product and transport components of the CIF rates is not available, the CIF rates are estimated using a gravity-type equation taking into account bilateral distance (in a non-linear manner), contiguity and land-locked dummies, year fixed-effects, and the world median unit-value for each product category. Secondly, we need some criteria to average the FOB-FOB mirror numbers, as even after taking out the transport costs there remain some differences between the reported import and export values of the same trade flows. We evaluate the reliability of each country's reporting by computing an indicator of the reporting distance among partners (the absolute value of the natural log of the ratio of the mirror flows) and decompose it using a (weighted) variance analysis. The relative reliability of country reporting is then cleaned from the effects of its geographical and sectoral specialization. These adjusted qualities of reporting are finally used as weights in the averaging of the mirror flows.

The three main advantages of BACI data, in comparison to other similar databases, are the following: the inclusion of many products (more than 5,000), its geographical coverage (more than 200 countries), and its unit values which are more reliable than the raw data thanks to the reconciliation of mirror figures which tends to correct any discrepancies. Since the methodology is purely statistical and does not require extensive additional data, the procedure can be applied exhaustively, even to cases in which knowledge on each country and product is very limited. Thus, the BACI data allow us to obtain an international trade dataset covering the largest number of countries at the highest degree of product-detail for the longest period possible.

The UN Trade in Services database provides information on annual bilateral services trade flows in mode 1 (cross-border trade) and mode 2 (consumption abroad) for 199 countries across a multitude of sectors and for the 1985-2011 periods. The collection of data on cross-border trade in services is notoriously difficult, mostly due to the intangible nature of services and to the high ability needed to record such data. This is particularly true for developing countries. This database tries to fill this gap by consolidating multiple sources of bilateral trade data in services using the mirror technique (permitting to retrieve export trade flows of a reporter by using information on imports of the partner country), including data published by OECD, Eurostat, UN, and IMF, in order to provide a broad coverage of both developed and developing countries over time.

As a word of caution, it should be added that the quality of these trade data in services is still far from being comparable to that of the trade data for manufactured goods. Due to the long-standing issue of tariff revenues, trade data for goods have been collected with quite high quality and accuracy. On the other hand, the intangibility and non-storability of services make it hard/impossible to apply at-the-border-duties to services, thus resulting in much weaker compilation practices and less accuracy. Thus, services' statistics have ample space for improvement in terms of measurement, particularly with respect to modes 3 and 4. Ongoing revisions and refinements of the balance of payments classification aim at solving these issues. As such, the Trade in Services Database should be seen as the best currently available approximation of the global trade flows in services.

Trade in services is provided for 90 various categories of services that are traded between 199 countries of the world. Table 5 presents the sectoral coverage of the UN trade in services database.

Table 5: Types of services in UN trade in services database

1 Transportation	5 Insurance services
1.1 Sea transport	5.1 Life insurance and pension funding
1.1.1 Passenger	5.2 Freight insurance
1.1.2 Freight	5.3 Other direct insurance
1.1.3 Other	5.4 Reinsurance
1.2 Air transport	5.5 Auxiliary services
1.2.1 Passenger	6 Financial services
1.2.2 Freight	7 Computer and information services
1.2.3 Other	7.1 Computer services
1.3 Other transport	7.2 Information services
1.3.1 Passenger	7.2.1 News agency services
1.3.2 Freight	7.2.2 Other information provision services
1.3.3 Other	8 Royalties and license fees
1.4 Other transport of which: Space transport	8.1 Franchises and similar rights
1.5 Other transport of which: Rail transport	8.2 Other royalties and license fees
1.5.1 Passenger	9 Other business services
1.5.2 Freight	9.1 Merchanting and other trade-related services
1.5.3 Other	9.1.1 Merchanting
1.6 Other transport of which: Road transport	9.1.2 Other trade-related services
1.6.1 Passenger	9.2 Operational leasing services
1.6.2 Freight	9.3 Miscellaneous business, professional, and technical services
1.6.3 Other	9.3.1 Legal, accounting, management consulting, and public relations
1.7 Other transport of which: Inland waterway transport	9.3.1.1 Legal services
1.7.1 Passenger	9.3.1.2 Accounting, auditing, bookkeeping, and tax consulting services
1.7.2 Freight	9.3.1.3 Business and management consulting and public relations services
1.7.3 Other	9.3.2 Advertising, market research, and public opinion polling
1.8 Other transport of which: Pipeline transport and electricity transmission	9.3.3 Research and development
1.9 Other transport of which: Other supporting and	9.3.4 Architectural, engineering, and other

auxiliary transport services	technical services
2 Travel	9.3.5 Agricultural, mining, and on-site processing services
2.1 Business travel	9.3.5.1 Waste treatment and depollution
2.1.1 Expenditure by seasonal and border workers	9.3.5.2 Agricultural, mining, and other on-site processing services
2.1.2 Other	9.3.6 Other business services
2.2 Personal travel	9.3.7 Services between related enterprises, n.i.e.
2.2.1 Health-related expenditure	10 Personal, cultural, and recreational services
2.2.2 Education-related expenditure	10.1 Audio-visual and related services
2.2.3 Other	10.2 Other personal, cultural, and recreational services
3 Communications services	10.2.1 Education services
3.1 Postal and courier services	10.2.2 Health services
3.1.1 Postal services	10.2.3 Other
3.1.2 Courier services	11 Government services, n.i.e.
3.2 Telecommunications services	11.1 Embassies and consulates
4 Construction services	11.2 Military units and agencies
4.1 Construction abroad	11.3 Other government services
4.2 Construction in the compiling economy	

2.3 Updating and balancing the Eurostat SUTs for the EU28 to 2013

Before updating the Eurostat SUTs to the year 2013, it is necessary to check the data for outliers and inconsistencies. Only with consistent and correct tables we can link together the trade flows between the Eurostat table for Europe and the OECD tables for the Non-EU countries. The following checks have been performed:

1. Check that for each EU28 country there is data available from SUTs on wages, fixed capital formation and net operating surplus. For some EU counties this type of data is missing and we fill the missing data using sector-specific EU average values.
2. Check for the mismatch between supply and use from SUTs for a specific product group. In case there is such a mismatch, the corresponding rows and columns of SUTs have been removed.
3. Check for the negative values in the fixed capital formation column of the use table and replace the negative values with positive ones based on the average EU ratios of fixed capital formation to total supply.

In order to simplify the trade linking of the SUTs of the EU28 countries, we moved the data for 'Direct purchases abroad by residents' to the household consumption column of the use table and the data for 'Purchases on the domestic territory by non-residents' to the exports column of the use table. We use the structure of household consumption and exports, respectively, in order to split the values among the various commodity groups. Table 6 presents the correspondence between the elements of the SUTs and those of the national accounts whose growth rates have been used for the update to the year 2013.

Table 6: Correspondence between the SUTs and the national accounts elements

Element of SUTs	Element of national accounts data
Sectoral outputs and inputs	Sectoral outputs
Sectoral wages	Sectoral wages
Sectoral net operative surplus	Sectoral net operative surplus
Consumption of fixed capital by sector	Sectoral outputs
Sectoral net taxes on production	Sectoral net taxes on production
Households consumption by type of commodity	Households consumption total
NIPSH consumption by type of commodity	NIPSH consumption total
Governmental consumption by type of commodity	Governmental consumption total
Fixed capital formation by type of commodity	Fixed capital formation total
Exports by type of commodity	Exports total
Imports by type of commodity	Imports total
All remaining elements	GDP

Both the initial SUTs from Eurostat and the SUTs updated to 2013 are unbalanced. This means that supply and demand for particular commodities are not equal to each other and that the zero profit condition does not hold for those economic sectors. In order for the tables to be used in the RHOMOLO model, they should be consistent and balanced. For the balancing of SUTs we use the nonlinear programming method minimizing the measure of distance between the initial updated SUTs and the resulting balanced SUTs under a set of constraints. The set of constraints includes the following:

1. supply equals demand for all commodities;
2. the zero profit condition holds for all economic sectors;
3. GDP calculated from the SUTs is consistent with that of the Eurostat data for 2013;

4. the transport and trade margins are balanced (the sum of positive elements of the column is equal to the sum of the negative elements of the column);
5. there are no re-exports (output multiplied by the EU-average export rate is not lower than the exports);
6. there are no re-imports (total consumption is lower than the imports);
7. net taxes on consumption commodities cannot be higher than 90% of the value of total consumption;
8. the zero elements of the SUTs should remain equal to zero;
9. the variation of the results coming out of the nonlinear programming problem should not exceed 25% of the initial value of the SUTs. This restriction is implemented via introduction of lower and upper boundaries for the outputs of the nonlinear programming problem.

The full formulation of the nonlinear programming problem, solved separately for each country of EU28, is presented below.

Indices are defined as:

- *cnt* countries
- s economic sectors
- *p* commodities
- *c* columns of SUTs
- *r* rows of SUTs
- *'P7'* Imports CIF
- *'P118'* Trade and transport margins
- *'D21_M_D31'* Taxes less subsidies on products
- *'P6'* Exports FOB
- *fdem* Subset of final demand categories
- *vadded_f* Subset of value added categories

Variables are defined as:

- *SUP_vcnt,r,c* supply table
- *USE_vcnt,r,c* use table

Parameters are defined as:

- *SUPcnt,r,c* initial data for supply table
- *USEcnt,r,c* initial data for use table

Finally, *equations* are defined as:

- Supply equals demand for all commodities:

$$\sum_{c} SUP\_v_{cnt,p,c} = \sum_{c} USE\_v_{cnt,p,c} \quad (1)$$

- The zero profit condition holds for all the economic sectors:

$$\sum_{r} SUP\_v_{cnt,r,s} = \sum_{r} USE\_v_{cnt,r,s} \quad (2)$$

- GDP calculated from SUTs should be consistent with the 2013 GDP reported by Eurostat:

$$GDP_{2013} = \sum_{p,s} SUP\_v_{cnt,p,s} - \sum_{p,s} USE\_v_{cnt,p,p} + \sum_{p} USE\_v_{cnt,p,'D21\_M\_D31'} \quad (3)$$

- The domestic output multiplied by the EU28 average share that goes to exports should not be lower than exports of the country (no re-exports):

$$\sum_{s} SUP\_v_{cnt,p,s} \cdot (1 - Dom\_cons_{p}) \geq SUP\_v_{cnt,p,'P7'} \quad (4)$$

- The value of net total consumption in the country is not lower than the imports of the country (no re-imports):

$$\sum_{s} USE\_v_{cnt,p,s} + \sum_{c \in fdem} USE\_v_{cnt,p,c} - SUP\_v_{cnt,p,'P118'} \geq SUP\_v_{cnt,p,'P7'} \quad (5)$$

- 90% of the value of total consumption per type of commodity is not lower than the value of the transport and trade margins plus the net taxes on consumption:

$$\left(\sum_{s} USE\_v_{\partial cnt,p,s} + \sum_{c \in fdem} USE\_v_{cnt,p,c} - \left(SUP\_v_{cnt,p,'P118'} \right)_{SUP\_v_{cnt,p,'P118'} \leq 0} \right) \cdot 0.9 \geq \left(SUP\_v_{cnt,p,'P118'} \right)_{SUP\_v_{cnt,p,'P118'} \geq 0} + SUP\_v_{cnt,p,'D21\_M\_D31'} \quad (6)$$

- The optimization function is the entropy function that measures the distance between the initial called SUTs and the outcome of the nonlinear programming program:

$$\sum_{p,s} abs(USE\_v_{cnt,p,s}) \cdot \log(abs(USE\_v_{cnt,p,s}) / abs(USE_{cnt,p,s}))$$
$$+\sum_{p,c} abs(USE\_v_{cnt,p,c}) \cdot \log(abs(USE\_v_{cnt,p,c}) / abs(USE_{cnt,p,c}))$$
$$+ \sum_{r \in vadded\_f,s} abs(SUP\_v_{cnt,r,s}) \cdot \log(abs(SUP\_v_{cnt,r,s}) / abs(SUP_{cnt,r,s})) \rightarrow \min \quad (7)$$

2.4 Preparing the data of the rest of the world

The OECD IO tables cover 62 separate countries (including all the EU28 member states) and one residual rest of the world region. The latest data refer to the year 2011 and must be updated to the year 2013 for the use in this project. National accounts data published from the OECD are not as detailed as those of Eurostat and we can only use the growth rates for the GDP as a whole in order to update the data to 2013. The OECD data contain some strange values that need to be removed and modified, and there are many missing values in the value-added part of the IO table. The strange values include for example negative numbers for fixed capital formation, exports, and imports. The missing parts of the value-added include consumption of fixed capital and net operating surplus by economic sector. As in the case of the Eurostat tables, we move the data for 'Direct purchases abroad by residents' to the household consumption column of the use table and the data for 'Purchases on the domestic territory by non-residents' to the exports column of the use table. We use the structure of consumption of the final consumer (there is only one category in the OECD IO tables) and exports, respectively, in order to split the values across the various commodities.

The initial OECD IO tables are unbalanced and include re-exports and re-imports for some countries. These re-exports and re-imports must be removed and the IO tables should be balanced before we can proceed with the trade linking procedure. In order to balance the OECD IO tables we make use of nonlinear programming techniques and formulate the following system of equations:

1. supply equals demand for each commodity;
2. no re-exports: total domestic output times 0.9 should be not lower than the total exports per type of commodity;
3. no re-imports: the total consumption in basic prices should be not lower than the total imports per type of commodity;
4. The elements of the IO tables (with the exception of changes in inventories, exports, and imports) should not deviate by more than 5% from the initially updated to 2013 version of the tables.

The distance from the initial update to 2013 version of IO tables and the outcomes of the nonlinear programming problem measured as the entropy function is minimized under the system of equations presented in section 2.3.

In order to be able to use the OECD data in the trade linking procedure we need to disaggregate the OECD IO tables to the level of detail of the Eurostat SUTs, that is to the NACE 2 sectoral and commodity classification. This is done using the mapping that we have prepared between the OECD and Eurostat classifications. The OECD classification is quite similar to the NACE 1 classification and we have made use of the mappings between NACE 1 and 2 that are available from Eurostat-RAMON.[4]

In order to disaggregate the OECD IO tables to the format and sectoral/commodity classification of the Eurostat SUTs we have followed the following steps:

1. for each OECD country, identify a 'similar' EU28 country whose economic sectoral and technological (sectoral inputs) structure can be used for disaggregation;
2. construct the SUTs on the basis of OECD IO tables where the supply is diagonal. For the construction of the use tables, we use the transport and trade margins and net taxes ratios from the 'similar' EU28 country in order to go from producer/basic to consumer prices (IO tables are given in producer/basic prices and need to be translated into consumer prices using information on transport and trade margins and net taxes);
3. disaggregate the different parts of the constructed OECD SUTs using the data from the Eurostat SUTs taking into account the inconsistencies. In case there is no data from Eurostat SUTs, the disaggregation is done proportionally between the number of sectors and commodities that are mapped to the OECD aggregated commodity/sector groups;
4. solve the nonlinear programming problem including the equations and the optimization function described in section 2.2 in combination with the restrictions that ensure that the disaggregated OECD SUTs sum up to the initial balanced OECD IO tables (with the exception of changes in inventories element of the IO tables). Since the use table is in consumer prices and the IO table is in basic prices, trade and transport margins and net taxes on consumption should be used in the equations in order to ensure the consistency.

The outcome of this procedure is the set of SUTs for all the countries and the rest of the countries of the OECD dataset (listed in Table 7).

[4] See: http://ec.europa.eu/eurostat/ramon.

Table 7: Countries in the global OECD IO database

Australia	AUS	**Japan**	JPN	**Argentina**	ARG	**Philippines**	PHL
Austria	AUT	**Korea**	KOR	**Brazil**	BRA	**Romania**	ROU
Belgium	BEL	**Luxembourg**	LUX	**Brunei Darussalam**	BRN	**Russia**	RUS
Canada	CAN	**Mexico**	MEX	**Bulgaria**	BGR	**Saudi Arabia**	SAU
Chile	CHL	**Netherlands**	NLD	**Cambodia**	KHM	**Singapore**	SGP
Czech Republic	CZE	**New Zealand**	NZL	**China (Peoples Republic of)**	CHN	**South Africa**	ZAF
Denmark	DNK	**Norway**	NOR	**Colombia**	COL	**Chinese Taipei**	TWN
Estonia	EST	**Poland**	POL	**Costa Rica**	CRI	**Thailand**	THA
Finland	FIN	**Portugal**	PRT	**Croatia**	HRV	**Tunisia**	TUN
France	FRA	**Slovak Republic**	SVK	**Cyprus**	CYP	**Viet Nam**	VNM
Germany	DEU	**Slovenia**	SVN	**Hong Kong, China**	HKG	**Rest of the world**	ROW
Greece	GRC	**Spain**	ESP	**India**	IND		
Hungary	HUN	**Sweden**	SWE	**Indonesia**	IDN		
Iceland	ISL	**Switzerland**	CHE	**Latvia**	LVA		
Ireland	IRL	**Turkey**	TUR	**Lithuania**	LTU		
Israel	ISR	**United Kingdom**	GBR	**Malaysia**	MYS		
Italy	ITA	**United States**	USA	**Malta**	MLT		

2.5 Linking the SUTs with the international trade flows

The BACI and the UN trade in services datasets provide us with the necessary data on international trade flows in both goods and services in 2013. One of the difficulties of using the BACI dataset is its treatment of re-exports and re-imports. For the construction of BACI, CEPII has used all the available data on re-exports and re-imports from UN COMTRADE. Unfortunately, such data were available for many non-European countries but not for the EU28 countries, meaning that the BACI trade flows should be adjusted for the EU28 re-exports and re-imports. The initial steps of the analysis include the adjustment of the SUTs and IO tables for re-exports and re-imports, resulting in the values of re-exports and re-imports being calculated per country and per type of good

and service. The adjustment procedure that has been implemented can be described as follows:

1. Calculate the trade flows corresponding to the re-exports of the country *cntt* by allocating them to the correct origin and destination countries *cnt* and *cntt*, respectively, following the patterns of incoming and outgoing trade flows of the country *cntt*. The following formula calculates the re-exports of country *cntt* that actually represent the trade between the countries *cnt* and *cnttt*:

$$\mathrm{Re}\_\ flows_{cnt,cntt,cnttt,p} = -\mathrm{Re}\exp orts_{cntt,p} \cdot \frac{Trade_{cnt,cntt,p}}{\sum_{cntttt} Trade_{cntttt,cntt,p}} \cdot \frac{Trade_{cntt,cnttt,p}}{\sum_{cntttt} Trade_{cntt,cntttt,p}} \quad (8)$$

2. The initial value of trade between the countries is increased with the value of the additional trade flows representing the re-exports of the EU28 countries:

$$Trade_{cnt,cntt,p} = Trade_{cnt,cntt,p} + \sum_{cnttt} \mathrm{Re}\_\ flows_{cnt,cnttt,cntt,p} \quad (9)$$

This adjusted value of trade flows is used for the calculation of the trade shares and trade flows consistent with the values in the SUTs.

Before starting the trade-linking procedure, we should make sure that the global values of exports and imports are consistent with each other, that is if there are exports of a particular good or service from one of the countries of the world, there should also exist imports of that same good or service by one other country. The checks show that this is not the case for some types of services, which means that their values of exports/imports in the SUTs should be put to zero in order to avoid inconsistencies in the trade linking procedure. We have also found the following inconsistencies between the international trade data, data on bi-lateral trade and transport margins (based on BACI), and the data on exports and imports from the SUTs:

1. There are data on exports and/or imports in the SUTs but there are no corresponding trade flows data: in this case we have used the data on exports or imports of other countries in order to split the SUTs data between possible origins and destinations, thus creating the missing trade flows.
2. There are data on trade flows but there are no corresponding data on exports or imports in the SUTs: in this case, we have removed the data on trade flows as for us the SUTs remain the main data source.
3. There are data on trade flows for goods but there are no corresponding bilateral trade and transport margins: in this case we have created the trade

and transport margins between these origin and destination countries as the average of the existing trade and transport margin data for other types of goods traded between these two countries.

The following nonlinear programming problem has been solved in order to create the trade flows between the EU28 and other non-European countries. The trade system is a closed one and covers the whole world.

Variables are defined as:

- *Trade_v* $_{cnt,cntt,p}$ inter-national trade
- *TT_margin_v* $_{cnt,\ cntt,p}$ inter-national trade and transport margins
- *Exports_v* $_{cnt,p}$ total country exports
- *Imports_v* $_{cnt,p}$ total country imports
- *Inventories_v* $_{cnt,p}$ changes in inventories

Equations are defined as:

- Country exports are equal to the sum of outgoing trade flows in FOB prices:

$$Exports\_v_{cnt,p} = \sum_{cntt} Trade\_v_{cnt,cntt,p} \tag{10}$$

- Country imports are equal to the sum of incoming trade flows in CIF prices (that is including trade and transport margins):

$$\mathrm{Im}\,ports\_v_{cnt,p} = \sum_{cntt} Trade_{cntt,cnt,p} \cdot \left(1 + TT\_margin\_v_{cntt,cnt,p}\right) \tag{11}$$

- The total international trade in transport and trade related services is equal to the total value of the inter-national trade and transport margins:

$$\sum_{cnt,cntt,p \in TTmargin} Trade_{cnt,cntt,p} = \sum_{cnt,cntt,p} Trade_{cnt,cntt,p} \cdot TT\_marign\_v_{cnt,cntt,p} \tag{12}$$

- Minimize the distance (measured as entropy) between the initial estimates of the trade flows based on international trade data (BACI and UN trade in services) and the outcomes of the nonlinear programming problem:

$$\sum_{cnt,cntt,p} Trade\_v_{cnt,cntt,p} \cdot \log\left(Trade\_v_{cnt,cntt,p} / Trade_{cnt,cntt,p}\right) \to \min \tag{13}$$

3 Regionalization of country level SUTs

The regionalization of the national SUTs makes use of several statistics available from Eurostat and other publicly available data sources (listed in Table 8).

Table 8: Overview of the available data sources at NUTS 2 level for EU28

Data source	Availability	Sectoral/commodity details	Geographical details	Notes
Eurostat regional accounts – GDP, households' incomes, employment and wages	2000-2013	14 NACE 2 sectors (cover the whole economy)	NUTS 1 2010 and NUTS 2 2010 regions of EU28 + NO + CH + IS + MK + TR	Some of the sectors are the aggregates of the sub-sectors
Eurostat SBS – employment and wages	2000-2011	100 NACE 2 sectors (cover industry and private services)	NUTS 1 2010 and NUTS 2 2010 regions of EU27 (no HR) + NO	Some of the sectors are the aggregates of the sub-sectors
ETIS-Plus database (freight and passenger transport flows by mode; survey based source data)	2000 and 2010	Freight flows in NST2 classification (52 types of goods) Passenger trips by 7 transport modes, 4 trips lengths, differentiated between business, private, vacation and commuting International trade in values and in volumes	NUTS 1 2006, NUTS 2 2006 and NUTS 3 2006 regions of EU28 (in total for 235 countries of the world by sub-national regions of these countries)	This database has been constructed for DG MOVE and is used as the baseline database of the TRANSTOOLS model Freight flows between the regions are represented in volumes

Regional accounts data contain information on wages and employment by NACE Rev2 sectors according to the classification presented in Table 9. This sectoral level of detail, although not particularly deep, covers the whole economy. Also, there are no missing values.

Table 9: Sectoral classification of the regional accounts data at NUTS 2 level

Code	Nace Rev.2
A	Agriculture, forestry and fishing
B-E	**Industry (except construction)**
C	Manufacturing
F	Construction
G-J	**Wholesale and retail trade; transport; accommodation and food service activities; information and communication**
G-I	Wholesale and retail trade, transport, accommodation and food service activities
J	Information and communication
K-N	**Financial and insurance activities; real estate activities; professional, scientific and technical activities; administrative and support service a...**
K	Financial and insurance activities
L	Real estate activities
M_N	Professional, scientific and technical activities; administrative and support service activities
O-U	**Public administration and defence; compulsory social security; education; human health and social work activities; arts, entertainment and recreation**
O-Q	Public administration, defence, education, human health and social work activities
R-U	Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organizations and bodies

Another set of sectoral data at the NUTS 2 regional level provided by Eurostat is the Structural Business Statistics (SBS) dataset. This dataset contains a higher level of sectoral detail than that of the NACE 2 classification for the private part of the economic sectors and includes information on both wages and employment. The level of sectoral details is presented in Table 10. The SBS dataset has some missing values for some regions and sectors that we have imputed using the data on regions with similar levels of GDP per capita. In several cases, we used SBS data from earlier years to fill in gaps. The share of missing values in the SBS dataset is less than 1% of all observations.

We have chosen to combine the data from SBS and the regional accounts in order to be able to regionalize the 65 NACE Rev2 sectors of the SUTs. SBS data are used for the regionalization of private economic sectors, and the regional accounts are used for the regionalization of agriculture, forestry and fishery as well as the public economic sectors.

Table 10: Sectoral details of the Structural Business Statistics data from Eurostat

B	**Mining and quarrying**	C23	Manufacture of other non-metallic mineral products	F42	Civil engineering	G473	Retail sale of automotive fuel in specialised stores	J61	Telecommunications
B05	Mining of coal and lignite	C24	Manufacture of basic metals	F43	Specialised construction activities	G474	Retail sale of information and communication equipment in specialised stores	J62	Computer programming, consultancy and related activities
B06	Extraction of crude petroleum and natural gas	C25	Manufacture of fabricated metal products, except machinery and equipment	**G**	**Wholesale and retail trade; repair of motor vehicles and motorcycles**	G475	Retail sale of other household equipment in specialised stores	J63	Information service activities
B07	Mining of metal ores	C26	Manufacture of computer, electronic and optical products	**G45**	**Wholesale and retail trade and repair of motor vehicles and motorcycles**	G476	Retail sale of cultural and recreation goods in specialised stores	**L**	**Real estate activities**
B08	Other mining and quarrying	C27	Manufacture of electrical equipment	G451	Sale of motor vehicles	G477	Retail sale of other goods in specialised stores	L68	Real estate activities
B09	Mining support service activities	C28	Manufacture of machinery and equipment n.e.c.	G452	Maintenance and repair of motor vehicles	G478	Retail sale via stalls and markets	**M**	**Professional, scientific and technical activities**
C	**Manufacturing**	C29	Manufacture of motor vehicles, trailers and semi-trailers	G453	Sale of motor vehicle parts and accessories	G479	Retail trade not in stores, stalls or markets	M69	Legal and accounting activities
C10	Manufacture of food	C30	Manufacture of other	G454	Sale, maintenance and repair of	**H**	**Transportation and**	M70	Activities of head offices; management

	products		transport equipment		motorcycles and related parts and accessories		**storage**		consultancy activities
C11	Manufacture of beverages	C31	Manufacture of furniture	**G46**	**Wholesale trade, except of motor vehicles and motorcycles**	H49	Land transport and transport via pipelines	M71	Architectural and engineering activities; technical testing and analysis
C12	Manufacture of tobacco products	C32	Other manufacturing	G461	Wholesale on a fee or contract basis	H50	Water transport	M72	Scientific research and development
C13	Manufacture of textiles	C33	Repair and installation of machinery and equipment	G462	Wholesale of agricultural raw materials and live animals	H51	Air transport	M73	Advertising and market research
C14	Manufacture of wearing apparel	**D**	**Electricity, gas, steam and air conditioning supply**	G463	Wholesale of food, beverages and tobacco	H52	Warehousing and support activities for transportation	M74	Other professional, scientific and technical activities
C15	Manufacture of leather and related products	D35	Electricity, gas, steam and air conditioning supply	G464	Wholesale of household goods	H53	Postal and courier activities	M75	Veterinary activities
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	**E**	**Water supply; sewerage, waste management and remediation activities**	G465	Wholesale of information and communication equipment	**I**	**Accommodation and food service activities**	**N**	**Administrative and support service activities**
C17	Manufacture of paper and paper products	E36	Water collection, treatment and supply	G466	Wholesale of other machinery, equipment and supplies	I55	Accommodation	N77	Rental and leasing activities
C18	Printing and reproduction of recorded media	E37	Sewerage	G467	Other specialised wholesale	I56	Food and beverage service activities	N78	Employment activities

C19	Manufacture of coke and refined petroleum products	E38	Waste collection, treatment and disposal activities; materials recovery	G469	Non-specialised wholesale trade	**J**	**Information and communication**	N79	Travel agency, tour operator reservation service and related activities
C20	Manufacture of chemicals and chemical products	E39	Remediation activities and other waste management services	**G47**	**Retail trade, except of motor vehicles and motorcycles**	J58	Publishing activities	N80	Security and investigation activities
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	**F**	**Construction**	G471	Retail sale in non-specialised stores	J59	Motion picture, video and television programme production, sound recording and music publishing activities	N81	Services to buildings and landscape activities
C22	Manufacture of rubber and plastic products	F41	Construction of buildings	G472	Retail sale of food, beverages and tobacco in specialised stores	J60	Programming and broadcasting activities	N82	Office administrative, office support and other business support activities

We used the regional-level indicators specific for each element of the tables in order to regionalize the EU28 national SUTs. In some cases, these indicators are published by Eurostat, such as the regional sectoral wages and regional GDP. In other cases, the indicators are derived on the basis of other regionalized elements of the SUTs. Table 11 presents the mapping between the indicators used for regionalization and the elements of the national SUTs. Unfortunately, there is not always a close correspondence for the regionalization of the different SUTs columns/rows, so in some cases we have used a proxy that seems economic logical derived from the available data. Some proxies like "Total regional intermediate inputs by type of good/service" can only be determined after the regionalisation of the sector columns.

Table 11: Mapping between the national SUTs and the regional data at NUTS 2 level from Eurostat

Element of the national –level Supply and Use tables	**Data at the regional NUTS 2 level from Eurostat used for regionalization/disaggregation**	**Derived indicator used for regionalization/disaggregation**
Intermediate demand/sectoral inputs	Wage sum by region and sector	GDP based on national capital share and total regional GDP data
Sectoral outputs	Wage sum by region and sector	GDP based on national capital share and total regional GDP data
Final consumption expenditure of households and NPISH	Households' income	Not applicable
Final consumption expenditure of government	Households' income	Not applicable
Gross fixed capital formation	Not available	Total regional intermediate inputs by type of good/service
Taxes less subsidies on products	Not available	Total regional production for region use by type of good/service
Trade and transport margins	Not available	Total regional consumption by type of good/service
Compensation of employees	Wage sum by region and sector	GDP based on national capital share and total regional GDP data
Other net taxes on production	Wage sum by region and sector	GDP based on national capital share and total regional GDP data
Consumption of fixed capital	Wage sum by region and sector	GDP based on national capital share and total regional GDP data
Operating surplus net	Wage sum by region and sector	GDP based on national capital share and total regional GDP data
Changes in inventories and valuables	Not available	Total regional consumption by type of good/service

The formula used for the regionalization of the national SUTs elements is the following:

$$X_r = Y_l \cdot \frac{I_r}{\sum_{k \in S_l} I_k} \tag{14}$$

where X_r is the element of the regional SUTs of region r, Y_l is the corresponding element of the national SUTs of country l, I_r is the used indicator, S_l is the set of NUTS 2 regions of country l, indices r,k are used for regions, and index l is used for countries. The disaggregation formulas are used for all elements of the SUTs except for the changes in inventories and acquisitions less disposals of valuables. Table 12 below presents the various categories of the Eurostat SUTs and their corresponding codes that are used for the regionalization step. These codes are used in the formula for the derivation of regional changes in inventories and acquisitions less disposals of valuables.

Table 12: Sub-Categories of the SUTs with Eurostat codes

Name of the SUTs category	**Code**
Final consumption expenditure by households	P3_S14
Final consumption expenditure by non-profit organisations serving households (NPISH)	P3_S15
Final consumption expenditure by government	P3_S13
Gross fixed capital formation	P51
Changes in inventories and valuables	P52_P53
Gross capital formation	P5
Exports FOB	P6
Compensation of employees	D1
Other net taxes on production	D29_M_D39
Consumption of fixed capital	K1
Operating surplus, net	B2N_B3N
Imports CIF	P7
Trade and transport margins	P118
Taxes less subsidies on products	D21_M_D31
Net trade of a region with the rest of the country	T1

At the regional level, we introduced one extra column in the use table for the region- and product- specific net trade of the region with the rest of the country. This regional-level net trade at product level p is calculated as follows:

$$USE_{p,T1} = \sum_{c} SUP_{p,c} - \sum_{s} USE_{p,s} - USE_{p,P3\_S13} - USE_{p,P3\_S14} - USE_{p,P3\_S15} - USE_{p,P51} - USE_{p,P6} - USE_{p,P52\_P53} \quad (15)$$

where c is the index for the columns, and s is the index for the economic sectors.

3.1 Deriving inter-regional trade flows

We use a newly developed estimation technique in order to determine the interregional trade among all the European NUTS 2 regions and between those regions and the rest of the world using data on freight transport. The methodology is based on both linear and non-linear optimization techniques and consists of two independent steps. First, we determine the probability matrices of trade between regions using 0, 1, 2, 3 or 4 hubs. Second, these probability matrices are used to estimate the trade between the regions where we minimize the estimate for value per ton shipped in a country and the data on tons of goods leaving a region. The end result is a regional trade matrix that is not only consistent with the regional SUTs, but also as close as possible to the main European transport data. The associated transport matrix estimated simultaneously with the trade flows represents the complete chain of multimodal transport (air, road and sea) with endogenously determined transhipment locations from a region where the product/service is produced to a region where the product/service is consumed.

3.1.1 Distribution probabilities

In order to calculate all possible trade destinations accounting for different numbers of transhipment locations τ, we need different probability matrices for each good. We consider up to five transhipment locations. The basis is the probability matrix $\chi_{\tau,p,r,s}$ without transhipment that is derived from the freight matrix $F_{p,r,s}$ as follows:

$$\chi_{0,p,r,s} = \frac{F_{p,r,s}}{\sum_{s'} F_{p,r,s'}}, \quad (16)$$

where r and s are origin and destination NUTS 2 regions. Using the $\xi_{r,s}$ distance matrix in km from region r to region s we can also determine the following associated distance $\zeta_{0,p,r,r}$ for non-transhipment trade.

$$\begin{aligned}\zeta_{0,p,r,r} &= \sum\nolimits_s \chi_{0,p,r,s}\xi_{r,s} \\ \psi_{0,p,r,r} &= 1\end{aligned}, \tag{17}$$

where $\psi_{\tau,p,r,s}$ is the probability matrix of trade of product p from region r that will be shipped to region s using τ transhipment locations. Using this information, we can determine the probability of trade using one or multiple transhipment locations. The following set of equations determines the needed probabilities and distances.

$$\begin{aligned}\chi_{1,p,r,s} &= \sum\nolimits_{r'|r'\neq r,r'\neq s} \chi_{0,p,r,r'}\chi_{0,p,r',s} \\ \zeta_{1,p,r,r'} &= \sum\nolimits_{s|r'\neq r,r'\neq s} \chi_{0,p,r,r'}\chi_{0,p,r',s}\xi_{r,s} \\ \psi_{1,p,r,r'} &= \sum\nolimits_{s|r'\neq r,r'\neq s} \chi_{0,p,r,r'}\chi_{0,p,r',s} = \chi_{0,p,r,r'}\end{aligned} \tag{18}$$

We also need the probabilities of a good leaving a region for every possible transhipment route, as well as the kilometres associated with the trade of that good. These probabilities can be easily calculated from the probabilities of transhipment summing up in different points of the transport chain.

3.1.2 Trade assignment model

We used quadratic and nonlinear programming (NLP) to minimize the distance of the predicted trade flows based on the calculated probabilities and the trade flows determined in the trade assignment. Moreover, we minimize the distance to the observed information on value per ton for every good, goods loaded in every region, the goods unloaded in every region, and the ton kilometres of goods leaving a region.

In mathematical terms we have the following model. Let us have regions r and s, countries l and k, and products p. Production and trade are classified according to the number of $\tau[0,\ldots,4]$ transhipment locations used. The NLP model is the following:

$$Minimize \quad Z = \sum\nolimits_{l,k}\left(\sum\nolimits_{\tau,p,r\in l,s\in k}\left(\nu_{\tau,p,r,s} - \nu_{p,l,k}\right)^2\right) + \frac{1}{\bar{G}_{p,s}}\sum\nolimits_{p,s}\left(\bar{G}_{p,s} - G_{p,s}\right)^2 \tag{19}$$

Subject to:

$$X_{p,r} = \sum\nolimits_{\tau,s} \nu_{\tau,p,r,s} Q_{\tau,p,r}\chi_{\tau,p,r,s} \tag{20}$$

$$C_{p,s} = \sum\nolimits_{\tau,r} \nu_{\tau,p,r,s} Q_{\tau,p,r}\chi_{\tau,p,r,s} \tag{21}$$

$$T_{p,l,k} = \sum\nolimits_{\tau,r\in l,s\in k} \nu_{\tau,p,r,s} Q_{\tau,p,r}\chi_{\tau,p,r,s} \tag{22}$$

$$\bar{U}_{p,s} = \sum_{\tau,r} Q_{\tau,p,r} \chi_{\tau,p,r,s} + \sum_{\tau,r \neq s} Q_{\tau,p,r} \psi_{\tau,p,r,s} \quad (23)$$

$$\bar{N}_{p,r} = \sum_{\tau,s} Q_{\tau,p,r} \psi_{\tau,p,r,s} \quad (24)$$

$$G_{p,s} = \sum_{\tau,r} Q_{\tau,p,r} \psi_{\tau,p,r,s} \zeta_{\tau,p,r,s} \quad (25)$$

$$Q_{0,p,r} \geq Q_{1,p,r} \geq Q_{2,p,r} \geq Q_{3,p,r} \geq Q_{4,p,r} \quad (26)$$

The exogenous variables and parameters needed for probabilities is listed below:

- $F_{p,r,s}$ Freight of product *p* from region *r* to region *s* in tons
- $\xi_{r,s}$ Distance matrix in km from region *r* to region *s*
- $X_{p,r}$ Total production of product *p* in region *r* in values
- $C_{p,r}$ Consumption of product *p* in region *r* in values
- $\chi_{\tau,p,r,s}$ Probability matrix of trade of product *p* from region *r* to region *s* that is going to be traded using τ transhipment locations
- $\psi_{\tau,p,r,s}$ Probability matrix of trade of product *p* from region *r* that will be transhipped in region *s* and that is using τ transhipment locations
- $\zeta_{\tau,p,r,s}$ Distance matrix in km of trade of product *p* from region *r* that is using τ transhipment locations and is leaving transhipment region *s*
- $T_{p,l,k}$ Country trade of product *p* from country *l* to country *k*
- $\bar{U}_{p,r}$ Data on goods unloaded in region *r* (tons)
- $\bar{N}_{p,r}$ Data on goods loaded in region *r* (tons)
- $\bar{G}_{p,r}$ Data on ton kilometres of goods leaving region *r*

The endogenous positive variables are the following:

- $Q_{\tau,p,r}$ Production of product *p* in region *r* in tons that is going to be traded using τ transhipment locations
- $v_{p,r}$ Value per ton
- $G_{p,r}$ Ton kilometres of goods leaving region *r* (tons)

Finally, the trade assignment model used to estimate the trade in services is the same as the model used for the trade in goods where the only difference is that the probability matrices are based on business traveller trips, and that these business travellers are supposed to have no more than two stopovers. The transport services are estimated using only the objective function of the quadratic distance between the estimated and the predicted trade in transport services (which serves as a prior). This predicted trade is assumed to be proportional to the export of goods leaving the region. It is therefore implicitly assumed that the exporting region will pay for the transport services needed to export the goods.

4 Results and conclusions

The methodology presented in this report produces a set of SUTs for all the NUTS 2 regions of the EU28. The detailed SUTs can serve as the basis for the modelling exercises carried out with the RHOMOLO model (see, for instance, Christensen et al., 2018, and Sakkas, 2018). The regional trade matrices accompanying these tables are not only consistent with the national SUTs, but also with the main European transport data taking into account multimodal transport with endogenously determined transhipment locations. This makes it possible to analyse the importance of transhipment locations in regional trade and link up actual transport costs to multiregional trade flows.

A thorough presentation of the results is difficult due to the size of the final dataset, its region and sector specific economic structure and trade patterns. We provide an overview of the EU28 NUTS 2 regions trade links distinguishing over inter-regional exports and imports (as a share of GDP) to other EU regions belonging to a different country and those inside the same country (within country trade).

Looking at trade to other EU countries (Figures 2 and 3), on average, the regions with the highest Export/GDP ratio were found to be predominantly in Central and Eastern Europe. This would suggest a link between the importance of exports and the relatively high growth rates of these regions, highlighting the importance of geographical patterns in trade development. Our estimation confirms the existence of a notable difference between the peripheral regions of the South and West of Europe (such as Southern Italy, Greece, and the UK) and those of the East, which appear to be more integrated in terms of trade with the core of the European Union.

Moreover, in most Eastern European regions the share of exports is well above 100% meaning that these regions are export-oriented economies, while local consumption and investments in locally produced final goods and services are smaller than total imports of intermediate goods. As confirmed by Figure 3, where imports are reported, Eastern regions import a lot of non-final goods to turn them into final product which are generally exported and not consumed locally.

Conversely, the Western regions, on average, show lower Export/GDP ratios due to lower intermediate inputs trade, reflecting a lower degree of economic integration along the production processes within the EU. Notice that gross trade should be used only as a first intuition on the economic integration of an economy, being the value added content in export a better indicator to analyse value chains.

Figure 2: Exports to other countries as a share of GDP (%)

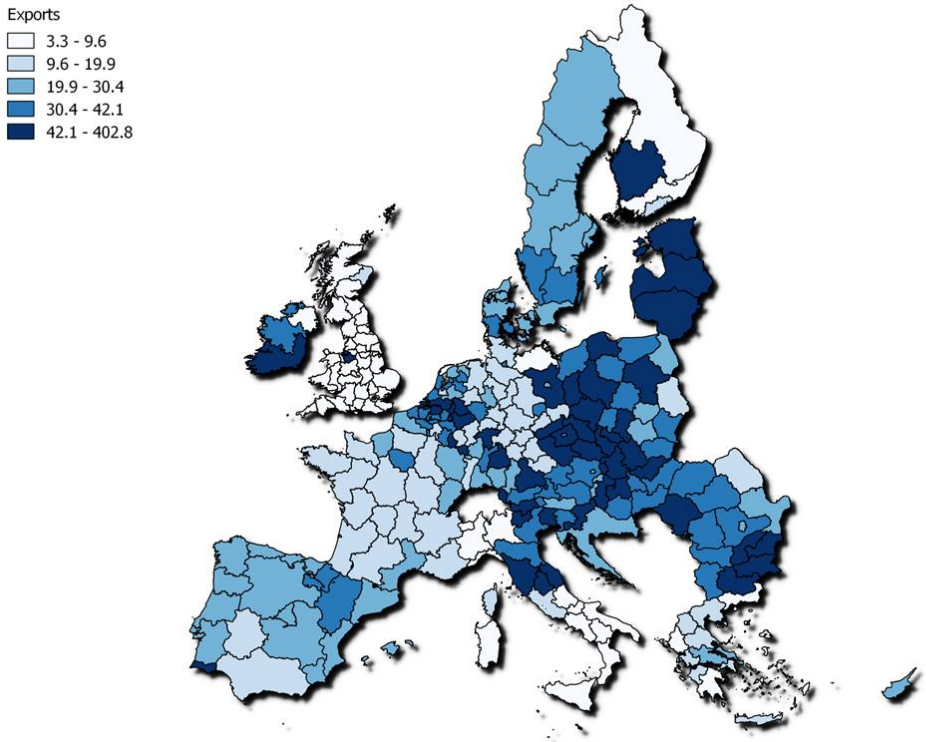
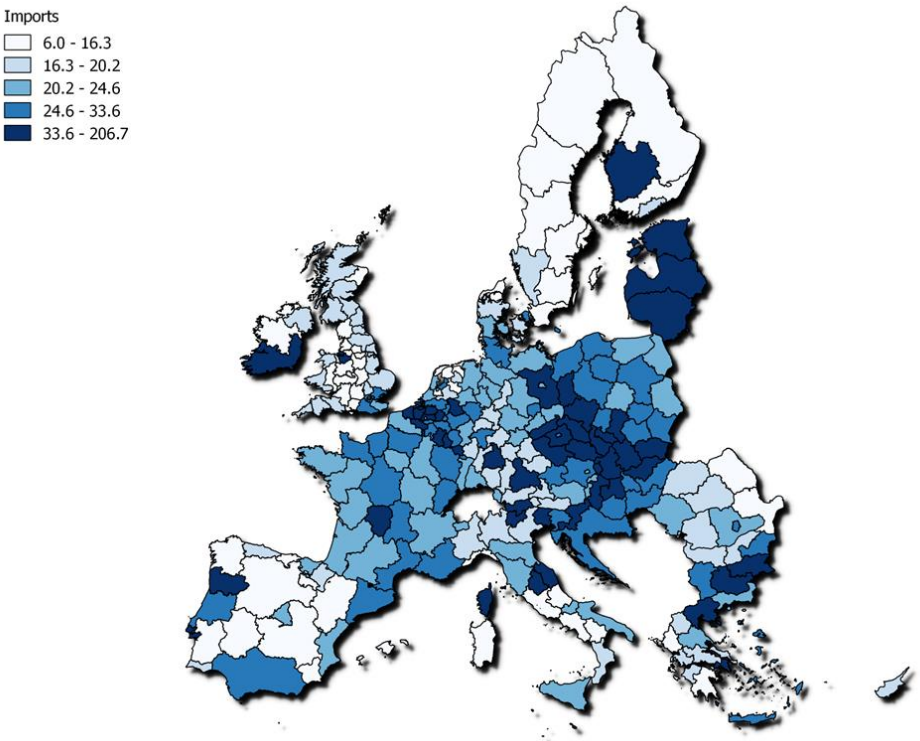


Figure 3: Import from other countries as a share of GDP (%)



As for within-country regional trade (Figures 4 and 5), it seems that the patterns emerging from the previous figures are confirmed, with large trade links, in particular for intermediate inputs, in Eastern EU regions. The cases of the UK and Greek regions are particularly interesting with regards to within-country trade, showing very big differences in Import/GDP (and Export/GDP) ratios compared to those of the other EU countries imports reported in Figure 3. Furthermore, looking at the case of Italy, our estimations confirm that the Southern regions import more than they export from the Northern regions.

Figure 4: Internal exports (within country) as a share of GDP (%)

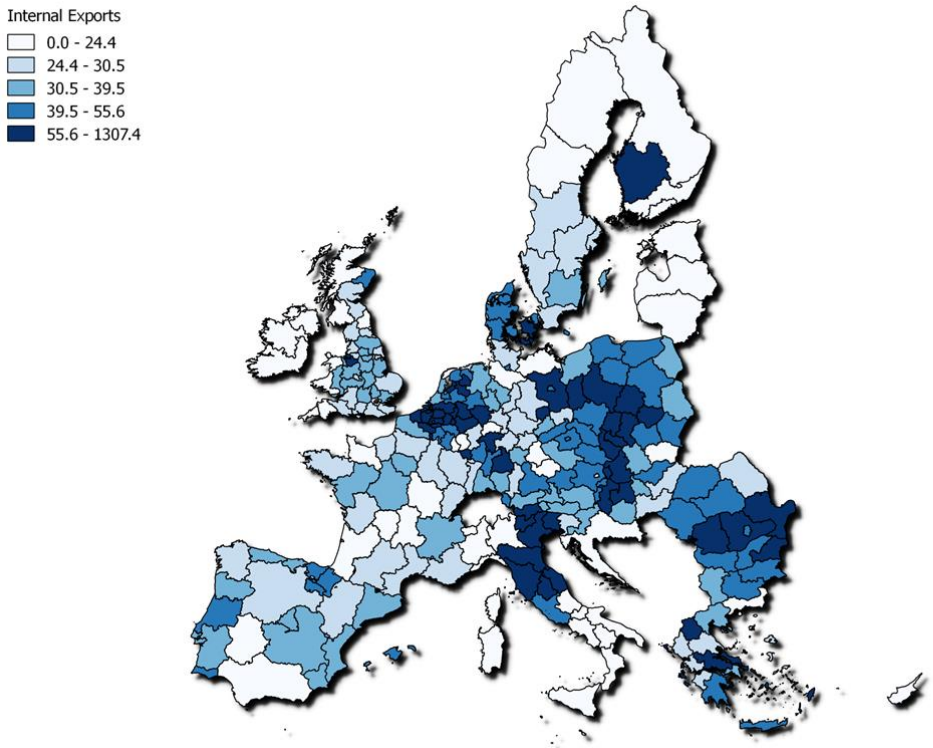
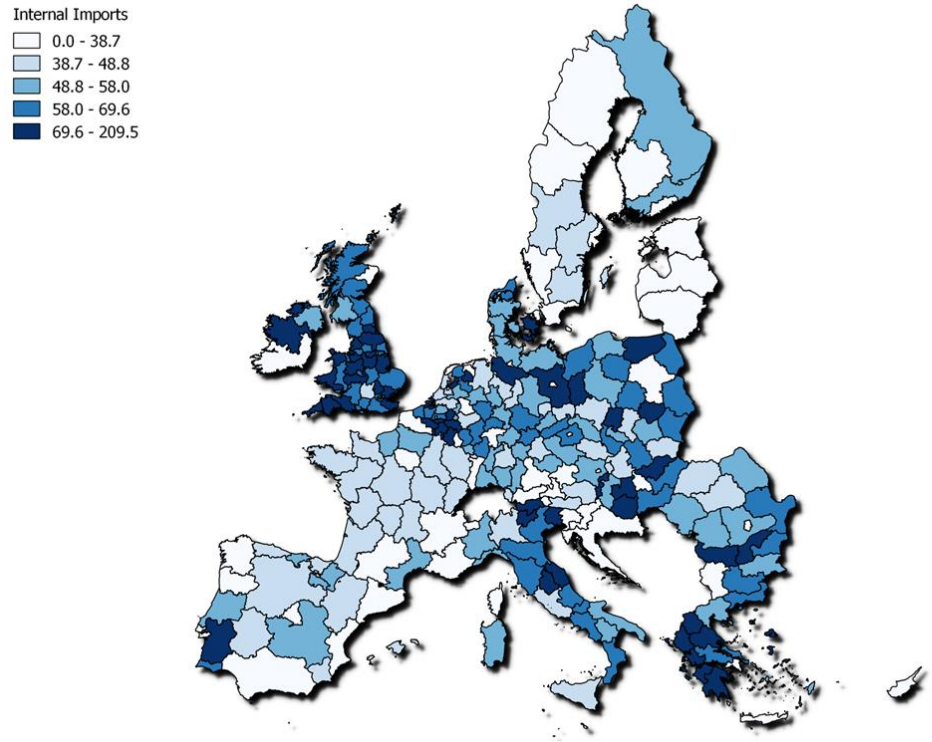


Figure 5: Internal imports (within country) as a share of GDP (%)



Below, we focus on one of the key variables in the estimation: the average amount of times a good stops in intermediate regions before reaching its final consumption destination. This is a good indication of the importance of the used methodology and of its validity versus other alternative methods based on gravity equation estimations. In the case of many hubs used to ship goods to their final destinations, such gravity estimations are based on the "wrong" trade links and will therefore give erroneous trade estimates.

We present the average number of transhipment locations per type of good in Table 13 with *t*-values in brackets. The estimates are very stable across regions and present high *t*-values. In other words, the variation in the number of transhipment locations depends on the type of good and not on the region of origin. We find that some type of goods hardly use any hub, while others pass through a substantial number of hubs before reaching their final destination.

This dichotomy becomes more visible when we present the same results in Figure 6, where we can see that only goods like agricultural products, mining, food, and oil directly reach their final destination without going through intermediate locations. This implies that using a gravity model to estimate trade based on transport data should only

be recommended for these types of goods. Such a method should not be used for all the other goods which are traded making use of intermediate locations.

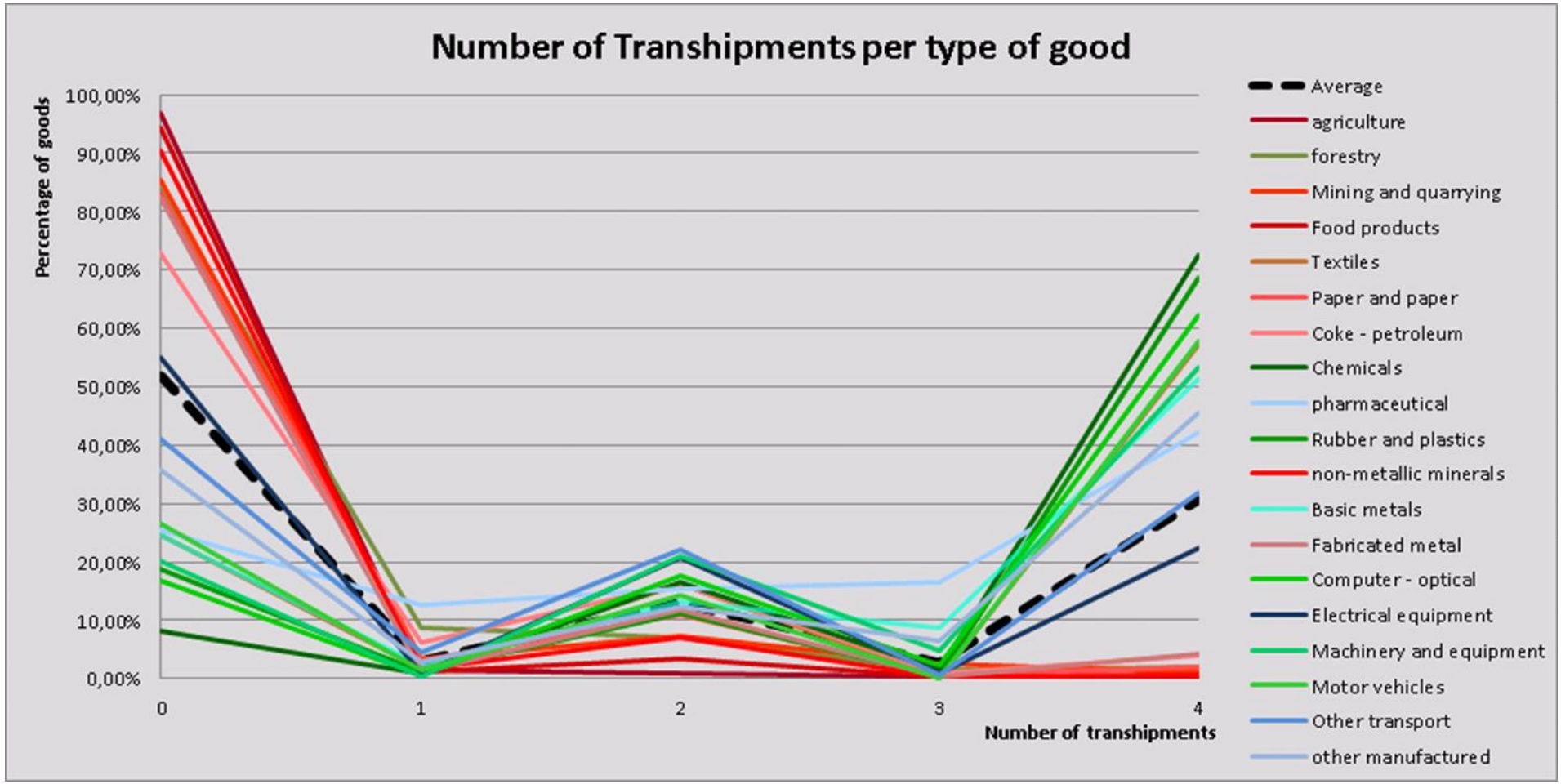
This suggests that this new methodology employed in this paper outperforms gravity equation-based estimations based on transport data. The quality of the trade estimates improves with more detailed information on transported goods. This strengthens the validity of the trade dataset and extends the use of the data beyond the field of economics, with important implications for studies on transportation and logistics. The goods' trade estimates are more detailed than those of services due to the high quality of the micro data on freight transport, while improved data on regional business travels would result in better services' trade estimates.

The data whose construction is described in this report are available upon request (see contact information in the second cover page) and are currently used to run the RHOMOLO model by the Regional Economic Modelling group of JRC Seville.

Table 13: The average number of transhipments per goods exported from European NUTS 2 regions

Transhipments	0	(t)	1	(t)	2	(t)	3	(t)	4	(t)
Average	0,52		0,03		0,13		0,03		0,31	
Agriculture	0,97	(187)	0,02	(6)	0,01	(5)	0,00	(3)	0,00	(2)
Forestry	0,84	(408)	0,09	(17)	0,07	(14)	0,01	(3)	0,02	(4)
Mining and quarrying	0,85	(104)	0,03	(11)	0,07	(13)	0,03	(10)	0,01	(6)
Food products	0,94	(239)	0,01	(11)	0,04	(12)	0,00	(5)	0,01	(5)
Textiles	0,25	(155)	0,02	(36)	0,16	(86)	0,00	(6)	0,57	(405)
Paper and paper	0,83	(324)	0,03	(42)	0,11	(51)	0,01	(8)	0,02	(15)
Coke - petroleum	0,73	(159)	0,06	(31)	0,16	(46)	0,01	(8)	0,04	(18)
Chemicals	0,08	(55)	0,01	(18)	0,16	(74)	0,02	(22)	0,73	(372)
pharmaceutical	0,25	(31)	0,13	(13)	0,15	(17)	0,17	(18)	0,42	(66)
Rubber and plastics	0,19	(119)	0,01	(31)	0,11	(82)	0,00	(6)	0,69	(497)
non-metallic minerals	0,90	(164)	0,02	(12)	0,07	(15)	0,00	(4)	0,01	(5)
Basic metals	0,25	(157)	0,02	(32)	0,13	(58)	0,09	(80)	0,51	(191)
Fabricated metal	0,82	(338)	0,01	(23)	0,12	(64)	0,00	(5)	0,04	(23)
Computer - optical	0,17	(134)	0,01	(19)	0,18	(156)	0,02	(45)	0,62	(455)
Electrical equipment	0,55	(398)	0,01	(23)	0,21	(130)	0,01	(22)	0,23	(156)
Machinery and equipment	0,20	(166)	0,00	(9)	0,21	(113)	0,05	(54)	0,53	(364)
Motor vehicles	0,26	(178)	0,01	(34)	0,14	(120)	0,00	(8)	0,58	(402)
Other transport	0,41	(144)	0,05	(47)	0,22	(105)	0,01	(14)	0,32	(108)
other manufactured	0,36	(95)	0,03	(6)	0,12	(25)	0,07	(13)	0,45	(143)

Figure 6: Average number of transhipment locations per goods exported from European NUTS 2 regions



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Appendix

NUTS2 regions in the dataset (NUTS 2010 Classification)

EU 268 regions	Region Name
AT11	Burgenland (AT)
AT12	Niederösterreich
AT13	Wien
AT21	Kärnten
AT22	Steiermark
AT31	Oberösterreich
AT32	Salzburg
AT33	Tirol
AT34	Vorarlberg
BE10	Région de Bruxelles-Capitale / Brussels Hoofdstedelijk Gewest
BE21	Prov. Antwerpen
BE22	Prov. Limburg (BE)
BE23	Prov. Oost-Vlaanderen
BE24	Prov. Vlaams-Brabant
BE25	Prov. West-Vlaanderen
BE31	Prov. Brabant Wallon
BE32	Prov. Hainaut
BE33	Prov. Liège
BE34	Prov. Luxembourg (BE)
BE35	Prov. Namur
BG31	Severozapaden
BG32	Severen tsentralen
BG33	Severoiztochen
BG34	Yugoiztochen
BG41	Yugozapaden
BG42	Yuzhen tsentralen
CY00	Kypros
CZ01	Praha
CZ02	Střední Cechy
CZ03	Jihozápad
CZ04	Severozápad
CZ05	Severovýchod
CZ06	Jihovýchod
CZ07	Střední Morava
CZ08	Moravskoslezsko
DE11	Stuttgart
DE12	Karlsruhe
DE13	Freiburg
DE14	Tübingen
DE21	Oberbayern
DE22	Niederbayern
DE23	Oberpfalz
DE24	Oberfranken
DE25	Mittelfranken
DE26	Unterfranken
DE27	Schwaben
DE30	Berlin
DE40	Brandenburg
DE50	Bremen
DE60	Hamburg
DE71	Darmstadt
DE72	Gießen
DE73	Kassel
DE80	Mecklenburg-Vorpommern
DE91	Braunschweig
DE92	Hannover
DE93	Lüneburg
DE94	Weser-Ems
DEA1	Düsseldorf
DEA2	Köln
DEA3	Münster
DEA4	Detmold
DEA5	Arnsberg
DEB1	Koblenz
DEB2	Trier
DEB3	Rheinhessen-Pfalz
DEC0	Saarland
DED2	Dresden
DED4	Chemnitz
DED5	Leipzig
DEE0	Sachsen-Anhalt
DEF0	Schleswig-Holstein
DEG0	Thüringen
DK01	Hovedstaden
DK02	Sjælland
DK03	Syddanmark
DK04	Midtjylland
DK05	Nordjylland
EE00	Eesti
ES11	Galicia
ES12	Principado de Asturias
ES13	Cantabria
ES21	País Vasco
ES22	Comunidad Foral de Navarra
ES23	La Rioja
ES24	Aragón
ES30	Comunidad de Madrid
ES41	Castilla y León
ES42	Castilla-la Mancha
ES43	Extremadura

ES51	Cataluña
ES52	Comunidad Valenciana
ES53	Illes Balears
ES61	Andalucía
ES62	Región de Murcia
ES63	Ciudad Autónoma de Ceuta (ES)
ES64	Ciudad Autónoma de Melilla (ES)
ES70	Canarias (ES)
FI19	Länsi-Suomi
FI1B	Helsinki-Uusimaa
FI1C	Etelä-Suomi
FI1D	Pohjois- ja Itä-Suomi
FI20	Åland
FR10	Île de France
FR21	Champagne-Ardenne
FR22	Picardie
FR23	Haute-Normandie
FR24	Centre (FR)
FR25	Basse-Normandie
FR26	Bourgogne
FR30	Nord - Pas-de-Calais
FR41	Lorraine
FR42	Alsace
FR43	Franche-Comté
FR51	Pays de la Loire
FR52	Bretagne
FR53	Poitou-Charentes
FR61	Aquitaine
FR62	Midi-Pyrénées
FR63	Limousin
FR71	Rhône-Alpes
FR72	Auvergne
FR81	Languedoc-Roussillon
FR82	Provence-Alpes-Côte d'Azur
FR83	Corse
GR11	Anatoliki Makedonia, Thraki
GR12	Kentriki Makedonia
GR13	Dytiki Makedonia
GR14	Thessalia
GR21	Ipeiros
GR22	Ionia Nisia
GR23	Dytiki Ellada
GR24	Sterea Ellada
GR25	Peloponnisos
GR30	Attiki
GR41	Voreio Aigaio
GR42	Notio Aigaio
GR43	Kriti
HR03	Jadranska Hrvatska
HR04	Kontinentalna Hrvatska

HU10	Közép-Magyarország
HU21	Közép-Dunántúl
HU22	Nyugat-Dunántúl
HU23	Dél-Dunántúl
HU31	Észak-Magyarország
HU32	Észak-Alföld
HU33	Dél-Alföld
IE01	Border, Midland and Western
IE02	Southern and Eastern
ITC1	Piemonte
ITC2	Valle d'Aosta/Vallée d'Aoste
ITC3	Liguria
ITC4	Lombardia
ITF1	Abruzzo
ITF2	Molise
ITF3	Campania
ITF4	Puglia
ITF5	Basilicata
ITF6	Calabria
ITG1	Sicilia
ITG2	Sardegna
ITH1	Provincia Autonoma di Bolzano/Bozen
ITH2	Provincia Autonoma di Trento
ITH3	Veneto
ITH4	Friuli-Venezia Giulia
ITH5	Emilia-Romagna
ITI1	Toscana
ITI2	Umbria
ITI3	Marche
ITI4	Lazio
LT00	Lietuva
LU00	Luxembourg
LV00	Latvija
MT00	Malta
NL11	Groningen
NL12	Friesland (NL)
NL13	Drenthe
NL21	Overijssel
NL22	Gelderland
NL23	Flevoland
NL31	Utrecht
NL32	Noord-Holland
NL33	Zuid-Holland
NL34	Zeeland
NL41	Noord-Brabant
NL42	Limburg (NL)
PL11	Lódzkie
PL12	Mazowieckie
PL21	Malopolskie

PL22	Slaskie
PL31	Lubelskie
PL32	Podkarpackie
PL33	Swietokrzyskie
PL34	Podlaskie
PL41	Wielkopolskie
PL42	Zachodniopomorskie
PL43	Lubuskie
PL51	Dolnoslaskie
PL52	Opolskie
PL61	Kujawsko-Pomorskie
PL62	Warminsko-Mazurskie
PL63	Pomorskie
PT11	Norte
PT15	Algarve
PT16	Centro (PT)
PT17	Área Metropolitana de Lisboa
PT18	Alentejo
PT20	Região Autónoma dos Açores (PT)
PT30	Região Autónoma da Madeira (PT)
RO11	Nord-Vest
RO12	Centru
RO21	Nord-Est
RO22	Sud-Est
RO31	Sud - Muntenia
RO32	Bucuresti - Ilfov
RO41	Sud-Vest Oltenia
RO42	Vest
SE11	Stockholm
SE12	Östra Mellansverige
SE21	Småland med öarna
SE22	Sydsverige
SE23	Västsverige
SE31	Norra Mellansverige
SE32	Mellersta Norrland
SE33	Övre Norrland
SI01	Vzhodna Slovenija
SI02	Zahodna Slovenija
SK01	Bratislavský kraj
SK02	Západné Slovensko
SK03	Stredné Slovensko
SK04	Východné Slovensko
UKC1	Tees Valley and Durham
UKC2	Northumberland and Tyne and Wear
UKD1	Cumbria
UKD3	Greater Manchester
UKD4	Lancashire
UKD6	Cheshire
UKD7	Merseyside
UKE1	East Yorkshire and Northern Lincolnshire
UKE2	North Yorkshire
UKE3	South Yorkshire
UKE4	West Yorkshire
UKF1	Derbyshire and Nottinghamshire
UKF2	Leicestershire, Rutland and Northamptonshire
UKF3	Lincolnshire
UKG1	Herefordshire, Worcestershire and Warwickshire
UKG2	Shropshire and Staffordshire
UKG3	West Midlands
UKH1	East Anglia
UKH2	Bedfordshire and Hertfordshire
UKH3	Essex
UKI1	Inner London - West
UKI2	Inner London - East
UKJ1	Berkshire, Buckinghamshire and Oxfordshire
UKJ2	Surrey, East and West Sussex
UKJ3	Hampshire and Isle of Wight
UKJ4	Kent
UKK1	Gloucestershire, Wiltshire and Bristol/Bath area
UKK2	Dorset and Somerset
UKK3	Cornwall and Isles of Scilly
UKK4	Devon
UKL1	West Wales and The Valleys
UKL2	East Wales
UKM2	Eastern Scotland
UKM3	South Western Scotland
UKM5	North Eastern Scotland
UKM6	Highlands and Islands
UKN0	Northern Ireland (UK)

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