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A NUTS-2 European Union interregional system of Social Accounting Matrices for the year 2017: The RHOMOLO V4 dataset

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Territorial Modelling and Analysis
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A NUTS-2 European Union interregional system of Social Accounting Matrices for the year 2017: The RHOMOLO V4 dataset

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Abstract. We describe the procedure used to construct a set of interregional NUTS-2 European Union Social Accounting Matrices for the year 2017, using official Eurostat national and regional account data, and auxiliary data on business and interregional trade flows derived from transport survey data. This procedure builds on the one presented by Thissen et al. (2019) for the year 2013. The new dataset is described by presenting some relevant features and the results of some characteristic simulations obtained with a new version of the RHOMOLO model, referred to as RHOMOLO V4, based on the new 2017 data.

Keywords: Regional data, Input-Output, social accounting matrices, trade flows, general equilibrium.

JEL Codes: C82, E16, R15, F14, F47.

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1 Introduction

In the European Union (EU), a significant part of the budget is used for regional policy, called cohesion policy, making it relevant for policymakers and citizens (Crucitti et al., 2022). Recent evidence on regional discontent (Rodríguez-Pose, 2017, Los et al., 2017) emphasizes the political importance of regional policymaking. The literature on regional economics highlights the importance of the spatial character of economic systems to explain regional economic phenomena. However, despite the attention drawn to issues related to regional inequality and economic development, reliable data at the regional level is often lacking and not comparable to national data in terms of quality and quantity. In particular, interregional trade flows are generally not measured by statistical offices. As a result, we have to rely on estimates (see, for instance, Fournier Gabela, 2020, for Japan, Liu et al., 2015, for China, and Génèreux and Langen, 2002, for Canada).

Based on the estimated trade flows among EU regions by Thissen et al. (2013a and 2013b), Thissen et al. (2019) describe the construction of a system of interregional Social Accounting Matrices (SAMs) with data from 2013 for all the NUTS-2 regions of the European Union (EU). NUTS stands for Nomenclature of Territorial Units for Statistics classification, and the NUTS-2 2016 definition is used in this analysis (see Table A1 in the appendix for the full list of regions).

SAMs are comprehensive, economy-wide datasets containing information on all the transactions between the economic agents of a specific economy for a certain period of time. SAMs are normally used for the calibration of multi-sectoral models like computable general equilibrium (CGE) ones (Mainar-Causapé et al., 2018). Stone (1947) was the first to work on data organised in SAMs, and the work by Pyatt and Thorbecke (1976) and Pyatt and Round (1985) led to their widespread use as a formal framework for economic analysis and planning.

The dataset described by Thissen et al. (2019) forms the basis for the calibration procedure of the spatial dynamic CGE RHOMOLO V3 model, whose complete mathematical description is offered by Lecca et al. (2018). The model, which has been developed by the JRC in collaboration with the Directorate-General for regional and urban policy (DG REGIO), is used for territorial ex-ante impact assessments of policies such as the cohesion and innovation policies (see Sakkas, 2018, on the European Social Fund; Di Comite et al., 2018, on the cohesion policy funds; and Christensen, 2018, on Horizon Europe). Several scientific articles also feature RHOMOLO V3 analyses (see, among others, Lecca et al., 2020; Di Pietro et al., 2021; Barbero et al., 2022a, 2022b, and 2023).

In this paper, we present a revised procedure to construct a similar dataset for 2017, which is used for the calibration of the latest version (V4) of the RHOMOLO model. We take advantage of recent developments in data availability and estimation techniques. First, Eurostat now publishes official EU intercountry supply, use and Input-Output tables (EU IC-SUIOTs – also referred to as FIGARO

tables¹). These tables form an ideal starting point for producing EU regional SAMs. Second, we use an improved technique to estimate the interregional Supply and Use Tables (SUTs), which form the basis for the SAMs of all the NUTS-2 regions of the EU.

The FIGARO tables were published for the first time in 2021. The goal is to have these updated and enriched annually. They link national accounts with data on business, trade and jobs for EU Member States and 18 main EU trading partners (Argentina, Australia, Brazil, Canada, China, India, Indonesia, Japan, Republic of Korea, Mexico, Norway, Russian Federation, Saudi Arabia, South Africa, Switzerland, Türkiye, the United Kingdom, and the United States). A rest-of-the-world (ROW) entity completes the FIGARO tables. A full description of the methodology used to produce the tables is provided by Remond-Tiedrez and Rueda-Cantucho (2019).

The mostly parameter-free methodology proposed by Simini et al. (2012) is the starting point for the estimation of the interregional trade flows between the NUTS-2 regions of the EU. This approach is compatible with methods of data construction and overcomes the shortcomings of often-used gravity-style estimations. The process combines data from different sources (some of them survey-based) into a consistent and complete dataset of interregional accounts for production (Supply tables) and demand (Use tables). Interregional trade is derived from freight transport, business travel, and flight microdata taken from (Thissen et al., 2019). Notably, the existence of trans-shipment locations was taken into account. The resulting regional tables are consistent with the national account data as presented in the FIGARO intercountry SUTs.

In a nutshell, the procedure used to produce the inter-regional SAMs for the EU comprises the following five steps:

1. Starting from the FIGARO intercountry SUTs (at the level of 64 NACE sectors and associated CPA products²), we use regional data (mainly on production and consumption) to obtain regional SUTs. We aggregate several sectors due to data limitations, reducing the 64 NACE sectors to 56 categories. Table A2 in the appendix lists both the 64 and the aggregated 56 NACE sectors.
2. Using trade priors for the regional trade flows based on Thissen et al. (2019), we disaggregate the intercountry trade flows of the Figaro tables into regional trade flows within and between countries.
3. The resulting regional SUTs are combined into interregional IO (input-output) tables. Since we have rectangular SUTs (the number of sectors and products are not identical), we use the standard industry technology assumption to determine the IO table, according to which the distribution of inputs and Gross Value Added (GVA) of the product that is moved from

¹ FIGARO stands for 'Full International and Global Accounts for Research in Input-Output analysis' and comprises the EU intercountry supply, use and Input-Output tables (EU IC-SUIOTs).

² NACE (the term is derived from the French *nomenclature statistique des activités économiques dans la communauté Européenne*) is the classification of economic activities in the EU, where CPA stands for the Classification of Products by these Activities.

a column to another is assumed to follow the structure in the column from which the product is moved (see Miller and Blair, 2009, pp. 212-213). This conversion of SUTs into IO tables is done for analytical purposes (national accounts data are organised in SUTs, but the IO structure is better suited for economic modelling).

4. We aggregate the regional data of step 3 from 56 CPA sectors to 10 NACE Rev. 2 sectors and merge all the non-EU regions and countries into the residual entity ROW. Also, we redistribute the direct interregional imports of final demand categories such that the flows of final demand elements between regions (direct imports of households, government, and firms - gross fixed capital formation, GFCF) are transferred to the corresponding final demand element and sector of the destination region, and to the corresponding sector as an intermediate output of the origin region.
5. We combine the interregional IO tables with data for the secondary distribution of income to create interregional SAM tables.

In the remainder of the paper, we provide more details on the procedure and we show some salient features of the new dataset. We also present the results of some basic simulations with the RHOMOLO V4 model calibrated with the 2017 data constructed here.

Section 2 briefly describes the intercountry FIGARO tables, and proceeds to explain the procedure in step 1 to regionalise them. Section 3 illustrates steps 2 and 3 of the procedure, which yield interregional SUTs for the goods and services categorised according to the 64 CPA and 56 NACE sectors. Section 4 illustrates the sectoral and geographical aggregation used for the RHOMOLO model (step 4 of the above list). Section 5 deals with step 5: the creation of the interregional SAMs starting from the IO tables. Finally, section 6 shows some features of the dataset, as well as some modelling simulations obtained with basic economic shocks. Section 7 concludes.

2 Regionalization of national SUTs

2.1 The FIGARO Tables

In this section, we provide a brief overview of the FIGARO data (Remond-Tiedrez and Rueda-Cantuche, 2019), the starting point of the first step of the procedure to produce inter-regional SAMs for the EU NUTS-2 regions.

The FIGARO data are organised in SUTs: these are matrices by sector and product categories describing how domestic production and imports of goods and services in an economy are used by industries for intermediate consumption and final use/demand. Products are classified according to the CPA system, while industries use the NACE Rev. 2 system. These classifications are fully aligned: at each level of aggregation, the CPA shows the primary and secondary products of the corresponding industries using the NACE classification.

The SUTs provide information on the structure of production and their costs and on the value added created during this production. They also show the flows of goods and services produced in the national economy, and between that

economy and the rest of the world. As such, they combine all the information of three accounts: goods and services, production, and generation of income. Table 1 presents all the elements of the National Accounts that can be found in FIGARO.

Table 1: National accounts elements in FIGARO

Code	Description
P1	Total Output
P2	Total Intermediate Consumption by Activity
D21X31	Taxes less subsidies on products
D29X39	Other net taxes on production
OP_NRES	Purchases of non-residents in the domestic territory
OP_RES	Direct purchase abroad by residents
B2A3G	Gross operating surplus
D1	Compensation of employees
B1G	Gross Value Added (GVA)
P3_S13	Government consumption
P3_S14	Household consumption
P3_S15	NPISH (non-profit institutions serving households) consumption
P51G	Gross Fixed Capital Formation (GFCF)
P5M	Changes in valuables and inventories

Data in FIGARO are disaggregated at the product level in the 64 CPA categories presented in Table A2 in the appendix. The level of detail of the data requires some elements to be classified as confidential. These gaps in the data are corrected during the regionalization phase using complementary regional data.

The data in FIGARO cover the 45 countries listed in Table 2. Information on the EU members, the UK, and the US is built-up by linking national accounts and data on business, trade and jobs. The data for the remaining countries, which are the main trading partners of the EU, come from the Inter-Country IO (ICIO) tables of the OECD. There is also a ROW region which simply collects any remaining data.

Table 2: Countries in the FIGARO database

Belgium	BE	Cyprus	CY	Slovakia	SK	Russian Federation	RU
Bulgaria	BG	Latvia	LV	Finland	FI	India	IN
Czechia	CZ	Lithuania	LT	Sweden	SE	China	CN
Denmark	DK	Luxembourg	LU	United Kingdom	GB	South Africa	ZA
Germany	DE	Hungary	HU	Norway	NO	Japan	JP
Estonia	EE	Malta	MT	Switzerland	CH	Korea, Republic of	KR
Ireland	IE	Netherlands	NL	Türkiye	TR	Indonesia	ID
Greece	GR	Austria	AT	United States of America	US	Australia	AU
Spain	ES	Poland	PL	Canada	CA	Saudi Arabia	SA
France	FR	Portugal	PT	Mexico	MX	Rest of the World	ROW
Croatia	HR	Romania	RO	Argentina	AR		
Italy	IT	Slovenia	SI	Brazil	BR		

2.2 Regionalization of production and use of country-level SUTs

Before we can start regionalising the FIGARO dataset, we have to make some minor corrections. The FIGARO dataset conforms to the official national account statistics of Eurostat and SUTs as constructed by the national Bureaus of Statistics. As a result, the data can pose problems for the regionalisation of the national tables since theoretically invalid numbers (mainly negative entries) are incidentally part of the tables. Although one can keep these negative numbers in the national tables, it makes little sense to regionalise them and spread erroneous values over the different regions. We, therefore, developed a procedure to correct for negative numbers where only positive numbers are theoretically possible.

This correction procedure is based on double bookkeeping since products produced in the Supply table are used in the Use table. Thus, all corrections must be made in two places of the original tables. The erroneous negative values have been set to zero, booking the associated correction in the row and column discrepancies of the original FIGARO tables. Subsequently, all elements of the row and column correction factors, including those in the original FIGARO tables, are set to zero and are booked in the columns of stocks that absorbed all the errors in the original tables.

After this preliminary step, step 1 in the procedure to construct the regional SAMs is the regionalisation of the country-level SUTs of the FIGARO dataset.

This procedure is based on mapping the national level data to publicly available NUTS-2 regional data as published by Eurostat in the regional accounts and the structural business statistics.

The Eurostat regional accounts provide data on GVA (NAMA_10R_3GVA – this can be seen as a proxy for Gross Domestic Product, GDP), household income (NAMA_10R_2HHINC), employment (NAMA_10R_3EMPERS in thousand persons, and NAMA_10R_2EMHRW in hours worked), and compensation of employees (NAMA_10R_2COE) for all the NUTS-2 regions of the EU and the 11 NACE Rev. 2 sectors included in Table 3 below. The classification is significantly less detailed than the FIGARO data, but it has the advantage of full geographical coverage and excellent availability over time (there are no missing values for 2017).

Table 3: Sectoral classification of the Eurostat regional accounts

Code	Nace Rev.2
A	Agriculture, forestry and fishing
B-E	Industry (except construction)
C	Manufacturing
F	Construction
G-I	Wholesale and retail trade, transport, accommodation and food service activities
J	Information and communication
K	Financial and insurance activities
L	Real estate activities
M_N	Professional, scientific and technical activities; administrative and support service activities
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

Note: The data are available also for the four following sectors which are aggregates of the ones in the Table: total economy, G-J, K-N, and O-U. Also, notice that sector B-E includes C, which is also available separately.

We use data from the Structural Business Statistics (SBS) dataset (also available from Eurostat) to obtain regional data with a more detailed sectoral disaggregation. We use the following NUTS-2 SBS data: wages (V13320, in millions of euros), employment (V16110, persons employed), and the number of firms (V11210, number of local units). The main drawback of the SBS dataset is that it contains missing values for some regions and divisions, mainly due to confidentiality issues caused by the granularity of the data or the strategic importance of certain subsectors. To fill in the gaps, we either performed imputations using the data on regions with similar levels of GDP per capita, or we used projections of SBS data from earlier years.

We use both the Eurostat regional accounts and the regional SBS data to regionalise the SUTs data, maintaining a high degree of sectoral granularity (we move from the 64 products of the national SUTs to 56 sectors in the resulting regional data – see Table A2 in the appendix). Due to the lack of SBS data for certain sectors, the regional accounts are used for the regionalization of Agriculture, forestry, and fishing (Sector A) and the public economic sectors (O, P, and Q). The SBS data are used for all the remaining economic sectors.

We outline below the strategy used to move from the square national SUTs having 64 NACE sectors and CPA products to the rectangular regional SUTs with 56 NACE sectors and 64 CPA products for all the FIGARO variables listed in Table 1. The precise definition and the sources of all the regional data used in the process are listed in Table A2 in the appendix. The first step is to aggregate the 64 sectors of the FIGARO tables into the 56 sectors for which the regional GVA data is available. Sectors A02 and A03 in FIGARO are aggregated into sector A02_03 for the final dataset; sectors K64, K65 and K66 into K; and sectors R90T92, R93, _S94, _S95, _S96, and T into R-T.

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

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

Indices r and k are used to indicate regions, and index l indicates countries. X_r is the column of the regional SUTs of region r , Y_l is the corresponding column of the national SUTs of country l that encompasses region r , I_k is the used indicator for region k , and S_l is the set of NUTS 2 regions of country l . The disaggregation formulas are used for all elements of the SUTs listed in Table 1, except for the changes in inventories and acquisitions less disposals of valuables. Please note that although the sectors in the columns have been aggregated into 56 sectors, the original classification of 64 CPA products is kept intact.

Different indicators I_k are used for the various columns of the SUTs which represent sector production and final demand (see Table A3 in the Appendix). Regional GVA is used to regionalise intermediate consumption and purchases of non-residents in the domestic territory, when available in the SBS data (for the agricultural sectors A01_03, we use data from Eurostat’s Economic accounts for agriculture; for Education P85, we use the number of students; for Health activities Q86, we use the number of hospital beds). Similarly, sectoral production is used to regionalize the data on taxes, gross operating surplus and compensation of employees. Regional household income is used to regionalise final consumption expenditure by the households; final consumption expenditure by the government, by non-profit institutions serving households (NPISH), and other government activities (O84, Q87_88) are regionalised according to population levels; and for GFCF we use the available regional data on

investments. Total regional output is simply the sum of regional GVA and the regionalised intermediate consumption. Changes in inventories is then used as a rebalancing element.

The columns of the regionalised supply and use tables have been split so that regional sector production and use add up to the national FIGARO SUTs. Therefore, the regionalised SUTs follow the format of the FIGARO tables (Rémond-Tiedrez and Rueda-Cantuche, 2019). However, also the origin of products in the Use table has to be taken into account as interregional and international trade is combined in the use of products. We discuss the regionalisation of interregional trade in the following section.

3 Construction of interregional SUTs and IO tables

The regionalised Use table obtained using the methodology described in the previous section has still to be regionalized for the origin of the products used. In other words, we still have to determine interregional trade given the total production of products from the supply tables and the total use of products in every region. We developed a standardized procedure to regionalize the trade within and between countries based on an error minimization function between a first estimate (the prior) and the final consistent estimate.

The information needed to regionalize the trade is a prior: a first estimate of the trade between different regions. We use a prior derived from transport micro data extensively described in Thissen et al. (2019). This trade prior P for the year 2013 was updated to the new NUTS-2 regional classification using the NUTS converter tool of the Urban data platform from the European Commission.³ Subsequently, this prior has been made consistent with the regionalized Use tables in the following way.

$$P_{p,r,r',s} = \tau_{p,c,r,r'} W_{p,c,r',s|r \in c}$$

$$\tau_{p,c,r,r'} = \frac{T_{p,r,r'}}{\sum_{r \in c} T_{p,r,r'}}$$

where $T_{p,r,r'}$ is the trade of product p from region r to region r' as taken from Thissen et al. (2019), and $\tau_{p,r,r'}$ is a multiplication factor that adds up to 1 for all producing regions r from the same country. P is the prior consistent with the format used in the Use table.

The trade between regions in the interregional Use table U is estimated by minimizing the root mean square weighted error and percentage error (RMSWEPE), a weighted combination of the root mean square error RMSE and

³ <https://urban.jrc.ec.europa.eu/nutsconverter/>

the root mean square percentage error RMSPE (used in Thissen et al., 2013c, 2014, and 2019) that can be written as follows:

$$\text{Min} \left(\sum \left(\frac{U_{p,r,r',s} - P_{p,r,r',s}}{P_{p,r,r',s}} \right)^2 + \omega \sum (U_{p,r,r',s} - P_{p,r,r',s})^2 \right)$$

where ω is a weight that makes the quadratic percentage error comparable to the quadratic error. This weight is equal to the squared average inverse of the average value \bar{P} of the elements of the prior matrix P . The weight can therefore be determined as:

$$\omega = \left(\frac{1}{\bar{P}} \right)^2$$

This minimization is done given the consistency constraints that the regionalised U adds up to the country Use tables of FIGARO and that the summation of all use by region of origin adds up to the production in the supply tables as described in the previous section.

The stocks have not been included in the minimization of the error described above. We do not take the priors of the stock changes into account since these are normally not related to trade flows but are commonly determined by a mismatch in timing between production and consumption, or created to match supply and demand. However, without being part of the optimization model, they would be determined by the estimation of all other trade flows. This could cause large stocks since the stocks can be both negative and positive with only national totals given. We, therefore, impose that all stock changes of regions within a country should have the same sign. Furthermore, we add an additional term to the objective function such that the sum of the squared negative final demand F (including stocks) is minimized. Finally, we add the minimization of the squared sum of positive and negative final demands to guarantee an even distribution of stocks when the negative numbers are minimized and prevent very small negative values. The exact formulation of the adjusted objective function is as follows

$$\text{Min} \sum \left(\frac{U_{p,r,r',s} - P_{p,r,r',s}}{P_{p,r,r',s}} \right)^2 + \omega \sum (U_{p,r,r',s} - P_{p,r,r',s})^2 + \sum_r (F_r^-)^2 + \frac{1}{2} \sum_r (F_r^- + F_r^+)^2$$

This model with a convex quadratic objective and linear constraints can be solved quickly and reliably using CPLEX as a solver on the GAMS software platform. The result is a regionalized interregional Use table that is both consistent with the regionalized supply table and the national FIGARO SUTs.

In the final step, we create an interregional IO table from the interregional SUTs. Since we have an unequal number of sectors and products, our choice of methodologies to create an IO table from SUTs is limited. We follow the standard textbook approach based on the so-called industry technology assumption to determine the IO table. This methodology is described in detail in Miller and Blair (2009, pp. 212-213).

4 IO aggregation

The Interregional IO table (IRIO) with 306 regions and 56 sectors has to be completed with the distribution of income linking value added to consumption in order to be used as the RHOMOLO dataset. Since the RHOMOLO model is designed considering a more aggregated level of sectors and regions, we aggregate these ending up with a final IRIO with 236 regions and 10 sectors. All the EU regions are kept as they are, while all the other remaining regions are merged into one ROW region. The 56 sectors are aggregated by summation into 10 broad industries, as shown in Table 4.

Table 4: Mapping between sectors in RHOMOLO and NACE Rev.2 sectors

Final sector	NACE Rev.2 sectors
A	A01, A02-03
B_E	B, D35, E36, E37T39
C	C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C33, C10T12, C13T15, C31_32
F	F
G_I	G45, G46, G47, H49, H50, H51, H52, H53, I
J	J58, J61, J59_60, J62_63
K_L	K, L68
M_N	M71, M72, M73, M69_70, M74_75, N77, N78, N79, N80T82
O_Q	O84, P85, Q86, Q87_88, O-Q
R_U	R_U

The reason for using aggregate sectors in the RHOMOLO model is twofold. First, it reduces the dimensionality of the model, allowing for a significantly faster simulation of policy experiments. Second, more disaggregated sectoral data are less reliable because they are more likely to be affected by availability or confidentiality issues. It will always be possible to create alternative aggregations if more detailed reliable information is available, allowing for more detailed analysis of certain sectors or EU trading partners.

The last element is the handling of imports of final demand. The RHOMOLO model assumes that final demand (households, government consumption, GFCF,

and stock changes) takes place only in the region itself. All final demand has therefore been aggregated and the corresponding interregional demand elements have been proportionally added to the intermediate demand.

5 Conversion into SAMs

The final step in producing the RHOMOLO dataset is to transform our current IRIO table into a SAM. SAMs form the base of most CGE models like RHOMOLO. A SAM is a table representing flows of all the economic transactions that take place in a given economy, with each cell showing payments from its column account to its row account. This is not different from an IO table. SAMs expand over IO tables by linking final consumption expenditures by institutional sectors to income earned in production (GDP) taking the redistributive role of the government into account, among other things.

To transform the IRIO tables into SAMs, we need to combine the IO data with data on the secondary distribution of income. Eurostat produces yearly the non-financial Annual Sector Accounts (ASA), recording the economic flows of institutional sectors to illustrate their economic behaviour and interactions between them. The ASA also provides a list of balancing items, such as value-added, operating surplus, disposable income, and savings, which add valuable information and can be used to link back to the data in the IRIO tables.

The ASA produces data for several institutional sectors, but we focus on the sectors represented in the IRIO tables: households (S.14-S.15), general government (S.13), and the rest of the world (S.2). In terms of flows, we use data on Taxes on income and wealth (D5), Transfers (D7), Social benefits (D62), Gross savings (B8G) and Gross operating surplus (B2A3G). These data are available at the national level, thus, we need to regionalize them in order to combine them with the IRIO tables. We use regional GDP shares to distribute the different national flows to the regions within each country.

The last adjustment required is the disaggregation of the compensation of employees (COE) into the three different skill categories featured in the RHOMOLO model. The shares of COE going to each of the skill categories for each region and sector are calculated by combining data on employment from the Regional accounts with the more granular data from the Labour Force Survey (LFS). The use of LFS microdata is required to obtain employment figures with both a sectoral and educational attainment level of disaggregation.

In the RHOMOLO model, we assume that there are three skill levels for employment, which are mapped from Educational attainment in the LFS data (as for the chosen sectoral aggregation, data availability dictates some of the modelling choices). The LFS presents three aggregates, High, Medium, and Low, based on the ISCED2011 categorization. In cases where there is no data for a particular combination of region, sector, and skill, the country-wide skill share is used. Wage shares are calculated by combining the region-sector-skill

employment shares with country-level data for median hourly earnings by educational attainment level. The process is described in detail below.

5.1 Employment and wage shares by educational attainment

We initially set the constraints regarding the working population of the regions. These are defined by the hours worked for the employed, which will ultimately vary between 35-45 hours per week depending on the regions and sectors. The associated skill shares from the LFS corresponding to these hours are then used to extract the skill-specific employed populations using the Eurostat series "Employment (thousand persons) by NUTS 3 regions [nama_10r_3empers]".

The first step is to import the hours worked and employment and fix any problematic cases. Zero values are replaced with missing values due to data paucity (respondents in the survey report that they are employed, but work zero hours). In some cases, not all skill categories are available within regions and sectors. In occurrences like this, the regional average across sectors is applied for each skill. If this is not available, the country average is applied. The same procedure is used when some sectors are missing.⁴

From the hours and level of employment, we construct hours per week per region per sector. We obtain the 95 and 25 percentiles of the distribution of hours per week to be used to get rid of outliers and unreliable values. For values exceeding these percentiles, we replace them with the region values and recheck the percentiles. If necessary, country values are used to replace extreme values leading to a distribution of hours worked between 35 and 45 hours. The replacements could affect either or both the level of employment and the hours worked. This is to ensure that the updated hours worked per week per employee fall between 95 and 25 percentiles of the distribution.

Then we obtain the employment shares as the share of the population working as Low, Medium or High skilled within a region-sector.

5.2. Wage shares and employment by region-sector-skill

The wage shares are calculated using the Eurostat "median hourly earnings, all employees (excluding apprentices) by educational attainment level [earn_ses_pub2i]" and the employment share. These wage shares are used to alter the compensation of employees and the wages and salaries in the SAMs.

Regional-sector employment is reported in the national accounts series "Employment (thousand persons) by NUTS 3 regions [nama_10r_3empers]". These are then broken down into skills using the employment shares.

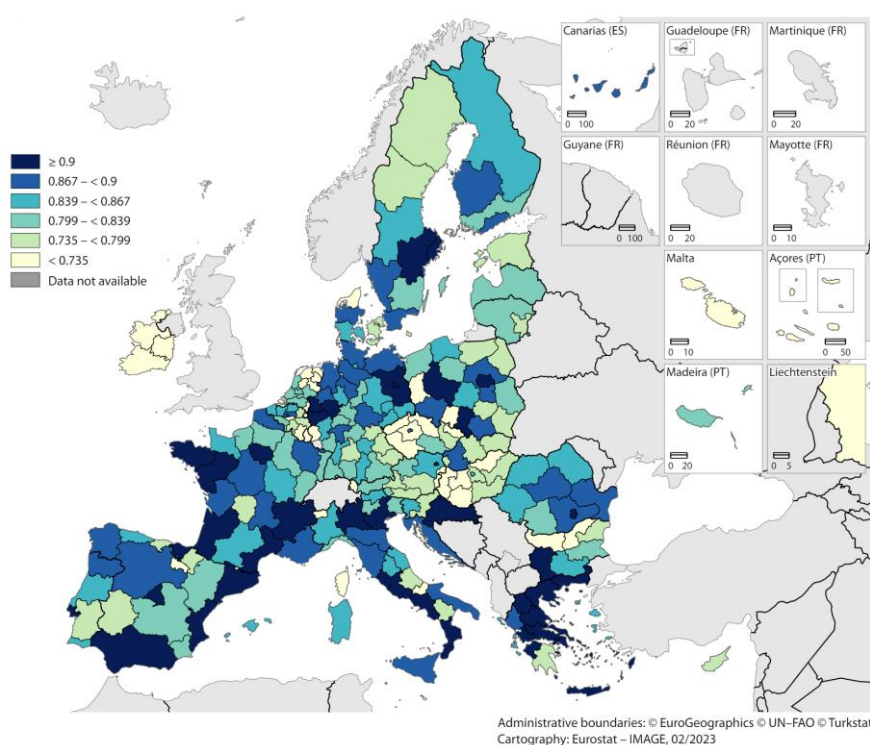
⁴ The Netherlands publish LFS data only at the country level. Thus, 12 copies of the country level hours and employment are created (each region representing 1/12th as there is no additional weighting applied).

6 Results

6.1 Data showcase: regional export analysis

The regional granularity of the new dataset allows for levels of analysis that are not possible to perform with publicly available data. As an example, in this subsection we analyse the destination of exports at the regional level. In particular, what share of the exports of a given region has its own country as a final destination? Figure 1 provides an answer to this question.

Figure 1: Share of trade with a region within the same country as destination



Source: authors' calculations.

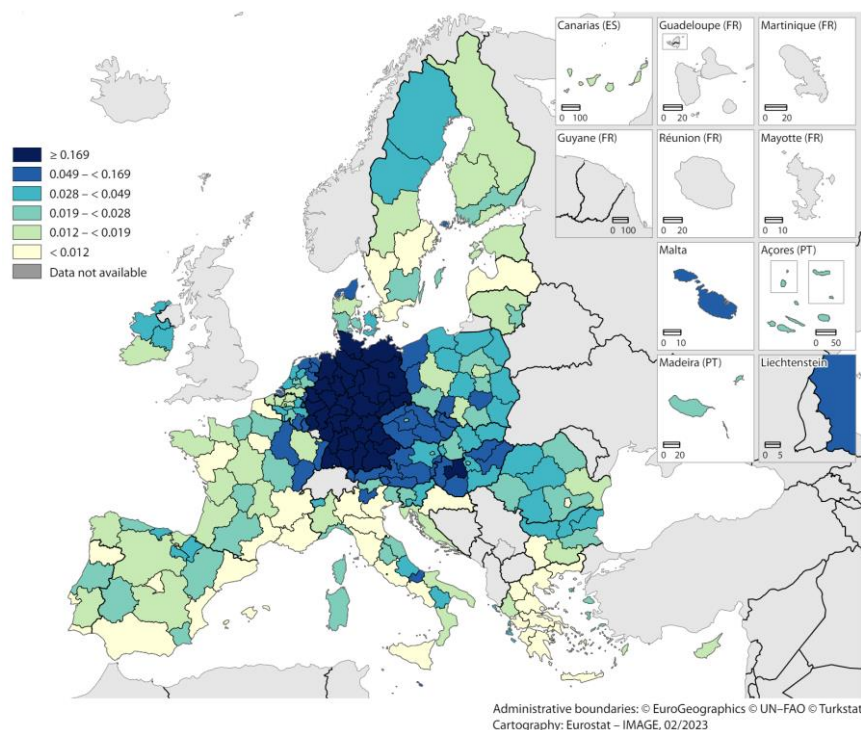
Figure 1 shows the within-country export intensity, meaning the share of trade flow volume that has the region as origin and a region in the same country as destination. Some regularities are immediately apparent. Capital regions tend to have a comparatively larger share of exports going to their own countries.

These exports come with particular intensity from services sectors, in particular Professional, administrative and support activities (M-N sectors) and Information and communication (J sector). In these sectors, the volume of the flows going from the capital region to the other regions in the country is larger than what we could expect given the GVA share of these sectors in the capital regional economy (not shown for simplicity). The economies of scale and network associated with these sectors and the ease of selling these services in other regions within a country would explain their tendency to agglomerate in the

most populated regions. The map also shows many large non-capital regions that are very dependent on their national markets, making them amenable to policies aimed at supporting the internationalization of their industries.

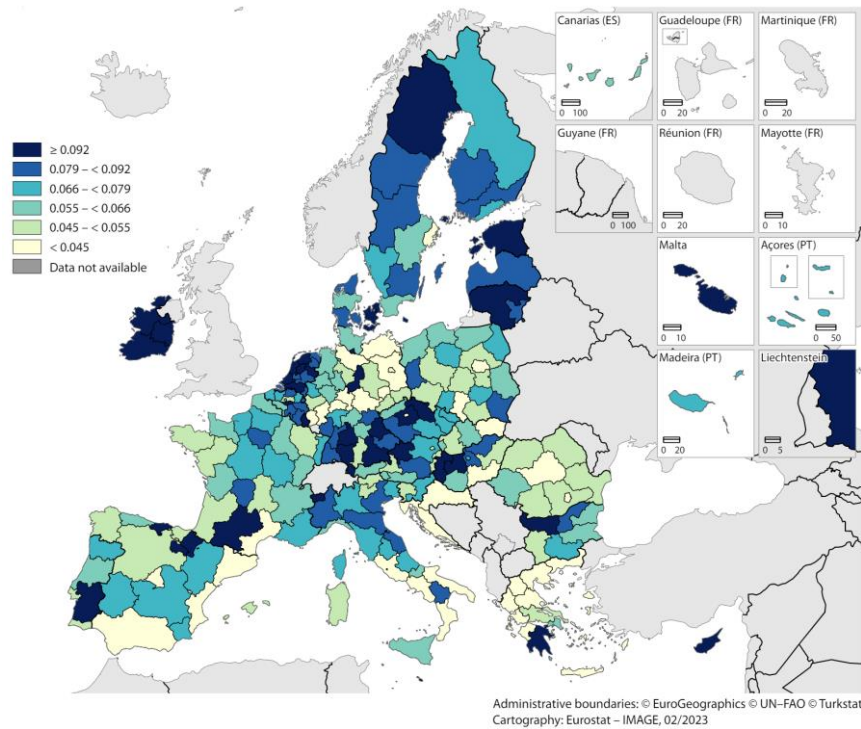
At the other end of the spectrum, we observe some regions with relatively low dependency on their national market as destination of their exports. While there are many reasons, we briefly explore two. First, Figure 2 shows the share of exports in a given region that has the German market as destination. A significant number of European regions are deeply connected to the German market. This includes most neighbouring areas to Germany in Austria, the Czech Republic, Hungary, Western Poland, Eastern Netherlands and Northeast France. In all cases, these exports are concentrated in the Manufacturing sector, either as intermediate inputs for the German manufacturing sector or as final goods for consumption: as in the case above, the size of the flows is larger than what we could expect given the GVA share of the manufacturing sector in the origin regions.

Figure 2: Share of trade with a German region as a destination



Source: authors' calculations.

Figure 3: share of trade with outside the EU as destination



Source: authors' calculations.

Second, Figure 3 shows the share of exports from a given region that have the ROW, understood as outside the EU, as destination. The regions with higher export intensity to the ROW are scattered around Europe, and a deeper analysis allows us to distinguish many different typologies. In some cases, this high intensity is simply the case of a strong relation with neighbouring countries outside the EU, like in the Baltics, Cyprus or Northern Sweden. Other regions have specialised in exporting manufactured goods, like cars for some regions in Hungary and Czechia or electronics in Southwest Ireland and Southern Netherlands. On the other hand, some regions have specialised in exporting services: financial services in Malta, Luxembourg and Cyprus; Information and communication services in Dublin or Trade related services in the Netherland or Denmark.

6.2 Model simulations

We now provide a series of results from simulation exercises performed with the macroeconomic RHOMOLO model based on the latest dataset (RHOMOLO V4). Being able to produce macroeconomic consistent results with the new dataset on a well-established model like RHOMOLO provides a definitive check of the data constructed according to the procedure explained above, both of the internal consistency of the data and how it relates to the actual data observed in the real world. We produce simulation results for the following three macroeconomic

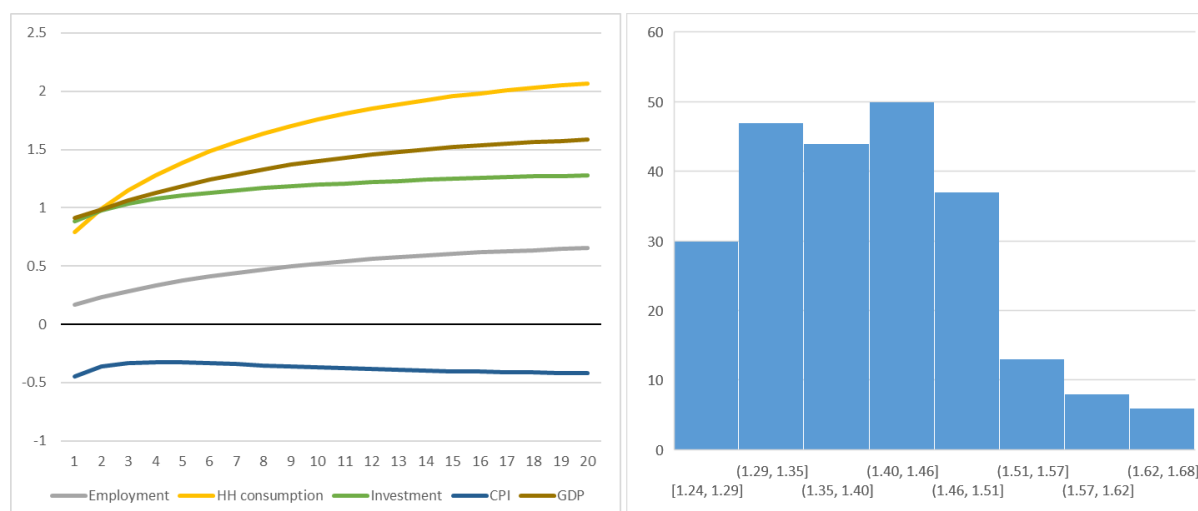
shocks: i) a total factor productivity (TFP) shock (purely supply-side); ii) a government consumption shock (purely demand-side); and iii) a transport cost shock (purely supply-side).

The results are dependent on the calibration of the RHOMOLO model, using a set of auxiliary data which is described in detailed in Lecca et al. (2018). Of particular relevance for the shocks described below is the calibration of the interregional transport costs. The costs are estimated as the population-weighted average costs of road transport between pairs of cities within the NUTS 2 regions. These costs correspond to the generalized transport costs (GTC) in euros, capturing the distance and time-related costs of the optimal route between each pair of regions for a representative truck, also taking into account the actual geography. These costs are subsequently mapped into a matrix of iceberg transport costs. A full explanation of the methodology can be found in Persyn et al. (2022), and an application to the transport infrastructure investments of the 2014-2020 European cohesion policy is described by Persyn et al. (2023).

- *Shock i): 1% permanent increase of TFP*

The results from simulating a 1% permanent increase of TFP in all regions of the EU can be seen in Figures 4 and 5. The left panel in Figure 4 shows the deviations from the baseline in percentage over a 20-year horizon for a set of basic indicators at the EU level: GDP, household consumption, investment, employment, and the consumer price index (CPI). The right panel shows a histogram with the distribution of the 10-year deviation from baseline of each region's GDP.

Figure 4: permanent increase of TFP (a) percent deviations from baseline, (b) 10-year GDP deviation from baseline distribution



Source: authors' calculations.

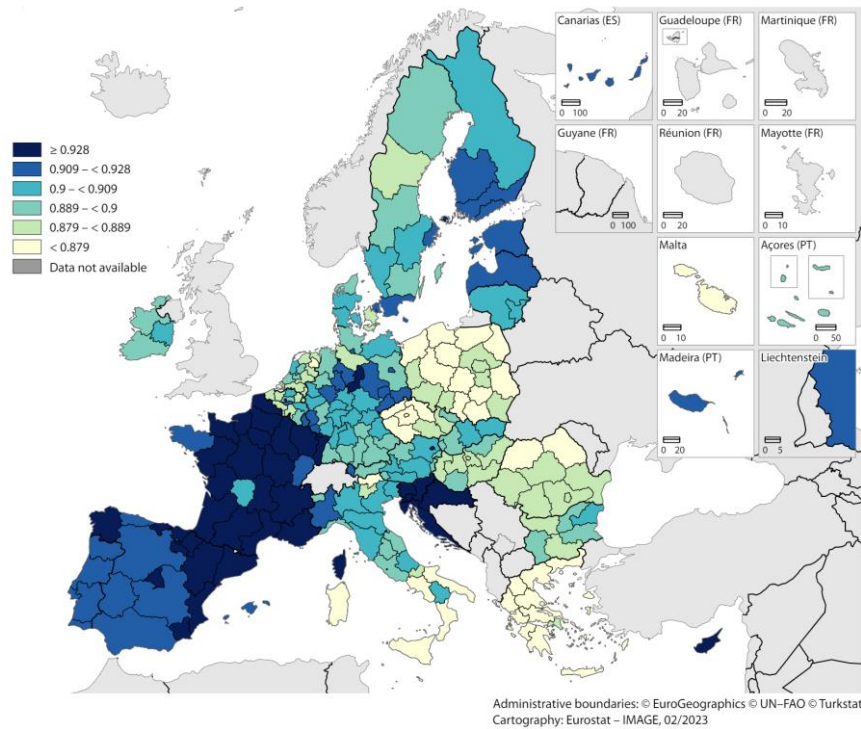
A TFP shock immediately increases production, as TFP is part of the production function. The increased productivity makes labour and capital more valuable. Firms hire more of both, leading to an improvement of the labour market and

more investment. Rising employment leads to higher wages, allowing the now wealthier households to increase their consumption, further stimulating the economy. The all-around improvements in technology enhance trade and lead to lower prices.

All the EU regions benefit from the shock, with a relatively compact distribution of the positive economic effect. Among other determinants, there is a moderate negative correlation between the saving rate in a region and the size of the GDP impact, a consequence of the aforementioned second-round demand effects: in regions with a low savings rate, households will tend to consume more of the newly created wages.

Also at the regional level, Figure 5 shows the GDP impact on the year following the shock. This exercise allows us to see results which are more directly linked to the dataset, less influenced by the dynamics of the model. On this very short run, one of the main determinants of the effect of increases to TFP on regional GDP is the labour share of the region. On impact, regions with higher labour shares experience larger effects on GDP, as labour demand increase more than in regions with lower shares, and capital has had no time to adjust through investment. Over time this effect reverses and regions with lower labour shares, and which are therefore more capital intensive, experience larger GDP increases. Following the shock, firms start adjusting their capital towards their desired levels by increasing investment. In more capital-intensive regions the demand for capital will increase more following the TFP shock. Consequently, all else equal, regions with lower labour shares will see larger levels of investment and subsequent larger increases to their regional GDP in the long term.

Figure 5: 1-year GDP deviation from baseline following a 1% TFP increase

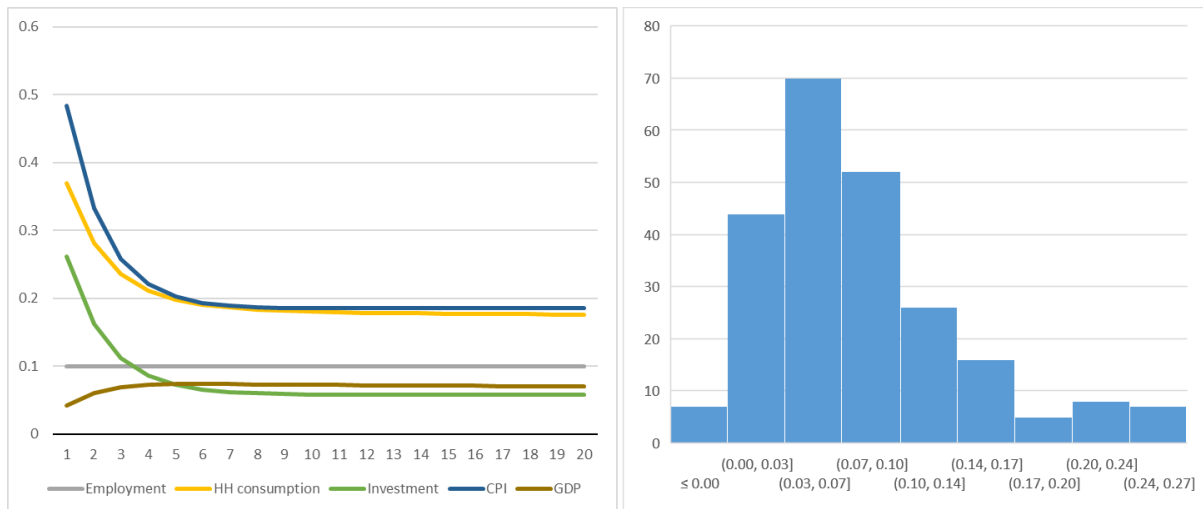


Source: authors' calculations.

- *Shock ii): 1% permanent increase in government consumption*

The second shock is a 1% permanent increase in government consumption in all EU regions. Contrary to the previous shock, which affects the economy primarily through the supply side, this shock is fundamentally a demand shock. The increased government consumption stimulates the economy as the firms increase production to cover the new demand. The extra production requires of additional workers and investment to be met, raising both. Furthermore, the extra demand also results in an increase in prices as the economy heats up.

Figure 6: 1% permanent increase of Government consumption (a) per cent deviations from baseline, (b) 10-year GDP deviation from baseline distribution

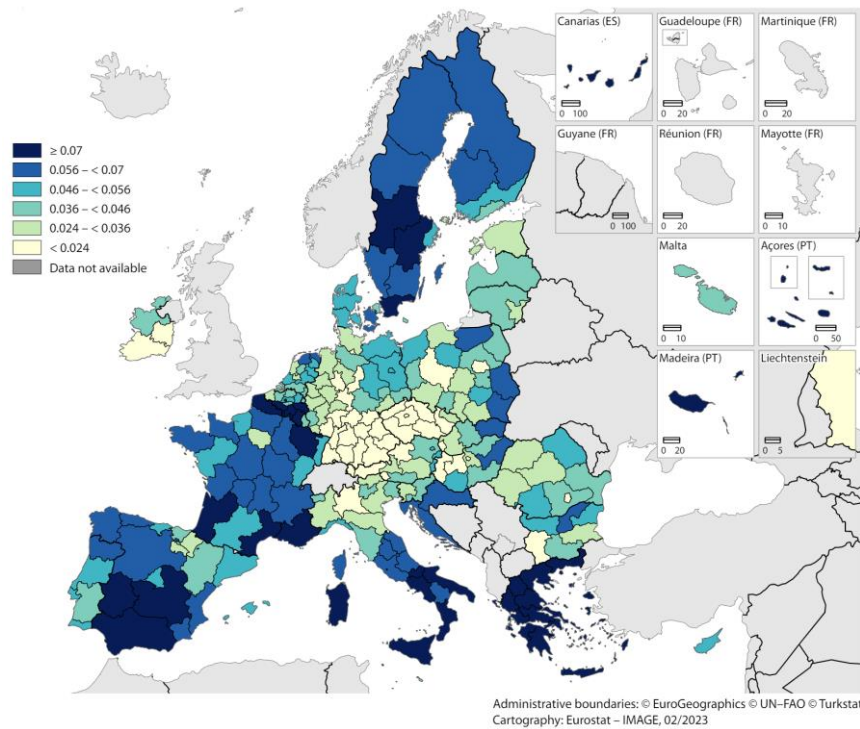


Source: author's calculations

As per Figure 6 (right panel), in terms of distribution, most regions appear concentrated around an increase of 0.05 per cent in GDP after 10 years, with a substantial number of regions to the right of that increase. Some negative values are also observed. Most of the negative cases can be explained by the loss of competitiveness induced by the increased prices mentioned above, combined with a relatively high dependence on exports outside the EU.

On impact (see Figure 7), the regions that benefit the most are those with a larger private consumption to GDP ratio. These regions present a larger propensity to consume and, therefore, the newly created government consumption will have a larger effect in those regions relative to other regions with lower shares.

Figure 7: 1-year GDP deviation from baseline following a 1% Government consumption increase

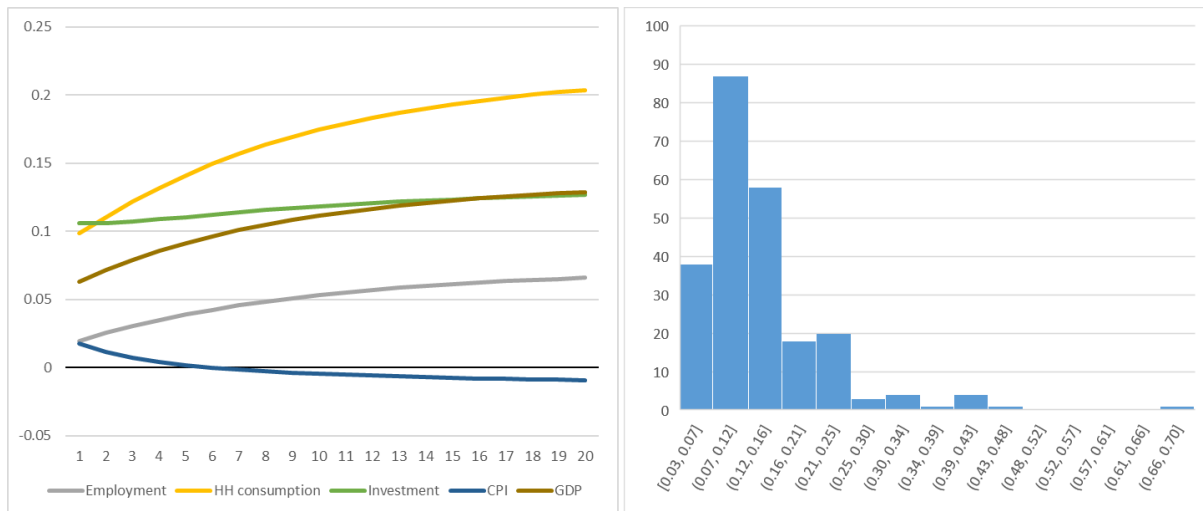


Source: authors' calculations.

- *Shock iii): 1% permanent decrease in transportation costs*

Finally, we show in Figures 8 and 9 the results for a permanent 1% decrease in transportation costs in all EU regions, another supply-side shock. Both firms and consumers benefit from the shock. On the firms' side, cheaper inputs lead to increased production, followed by higher investment and employment. Consumers now have access to cheaper imports, together with some additional wages due to the increased production. As for prices, we observe two competing effects: on one hand, the increased activity will tend to push prices up, while on the other hand, lower transportation costs translate to potential efficiency gains as producers can have access to cheaper inputs. At first, we see the former effect slightly dominating, but as time passes and firms have time to adjust, the latter dominates and prices go down.

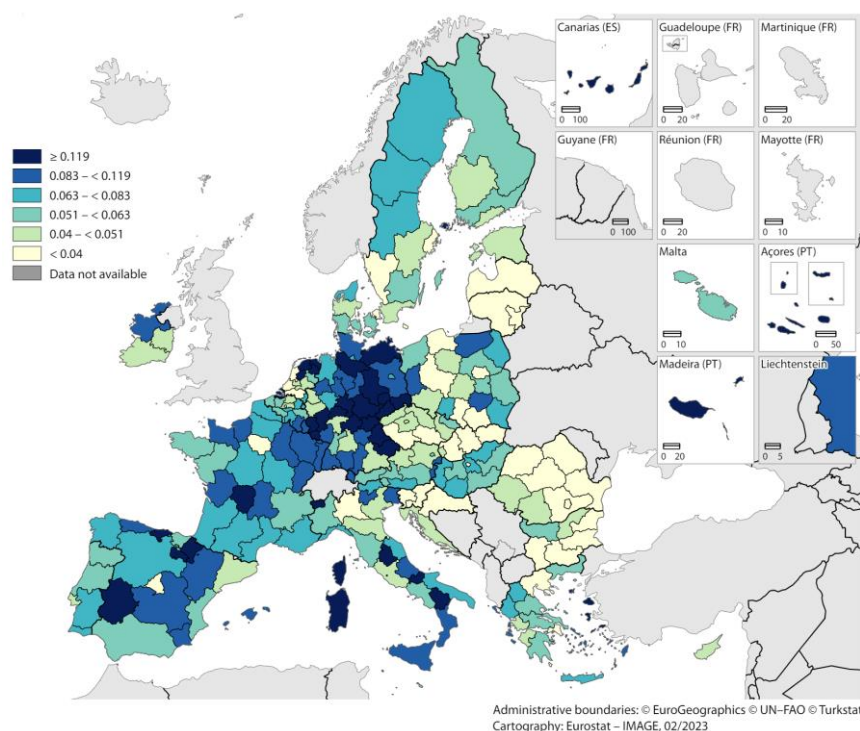
Figure 8: 1% permanent decrease of transport costs (a) per cent deviations from baseline, (b) 10-year GDP deviation from baseline distribution



Source: authors' calculations.

In terms of regions, the most interesting feature is the existence of some relatively extreme positive values. The impact of decrease in transportation costs has the largest effect on those regions that initially have relatively large transportation costs (islands like Madeira or Açores, mountain regions like the Aosta Valley in Italy, etc.) and in the regions whose imports come mainly from the EU. A similar picture can be seen on impact, as shown in Figure 9: regions with large relative transport costs have larger gains. However, we also observe relatively high gains in regions in and around Germany; these are regions with relatively strong trade flows as a percentage of GDP that benefit from the suddenly lower transport costs.

Figure 9: 1-year GDP deviation from baseline following a 1% reduction in transport costs



Source: authors' calculations.

7 Conclusions

We presented a procedure to construct a set of inter-regional SAMs for the whole EU for the year 2017. The FIGARO inter-country SUTs published by Eurostat constitute the starting point of the procedure followed to obtain the dataset. Eurostat regional data are used to regionalise those, and together with inter-regional estimated trade flows they are used to produce SAMs with additional information on the secondary distribution of income.

The resulting dataset is consistent with the Eurostat regional and national data used as inputs. We showed some of the unique features of the data related to the estimated trade flows, namely the proportion of regional trade directed towards, and coming from, the rest of the regions of their countries, or the economies abroad.

These data are used for the calibration of the latest version (V4) of the RHOMOLO model. We illustrated the results of three simple simulations carried out with the RHOMOLO V4 model, shocking TFP, government consumption, and transport costs.

Regional datasets are the basis of regional economic models such as the RHOMOLO model and are crucial for the economic analysis of regional systems and the spatial distribution of economic activity.

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List of abbreviations

ASA – Annual sector accounts

CGE – Computable general equilibrium

COE – Compensation of employees

CPA – Classification of products by activity

CPI – Consumer price index

EU – European Union

FIGARO – Full international and global accounts for research in input-output analysis

GAMS – General algebraic modelling system

GDP – Gross domestic product

GFCF – Gross fixed capital formation

GTC – Generalised transport cost

GVA – Gross value added

IC – Intercountry

ICIO – Intercountry input-output

IO – Input-output

IRIO – Interregional input-output

LFS – Labour force survey

NACE - Nomenclature statistique des activités économiques dans la communauté Européenne

NPISH – Non-profit institutions serving households

NUTS – Nomenclature of territorial units for statistics

OECD - Organization for economic cooperation and development

RMSPE – Root mean square percentage error

RMSWEPE – Root mean square weighted error and percentage error

ROW – Rest of the world

SAM – Social accounting matrix

SBS – Structural business statistics

SUIOT – Supply, use and input-output tables

SUT – Supply and use table

TFP – Total factor productivity

Appendix

Table A1: NUTS2 regions in the dataset (NUTS 2016 Classification)

EU 235 regions	Region Name		
AT11	Burgenland (AT)	DE27	Schwaben
AT12	Niederösterreich	DE30	Berlin
AT13	Wien	DE40	Brandenburg
AT21	Kärnten	DE50	Bremen
AT22	Steiermark	DE60	Hamburg
AT31	Oberösterreich	DE71	Darmstadt
AT32	Salzburg	DE72	Gießen
AT33	Tirol	DE73	Kassel
AT34	Vorarlberg	DE80	Mecklenburg-Vorpommern
BE10	Région de Bruxelles-Capitale / Brussels Hoofdstedelijk Gewest	DE91	Braunschweig
BE21	Prov. Antwerpen	DE92	Hannover
BE22	Prov. Limburg (BE)	DE93	Lüneburg
BE23	Prov. Oost-Vlaanderen	DE94	Weser-Ems
BE24	Prov. Vlaams-Brabant	DEA1	Düsseldorf
BE25	Prov. West-Vlaanderen	DEA2	Köln
BE31	Prov. Brabant Wallon	DEA3	Münster
BE32	Prov. Hainaut	DEA4	Detmold
BE33	Prov. Liège	DEA5	Amsberg
BE34	Prov. Luxembourg (BE)	DEB1	Koblenz
BE35	Prov. Namur	DEB2	Trier
BG31	Severozapaden	DEB3	Rheinhessen-Pfalz
BG32	Severen tsentralen	DEC0	Saarland
BG33	Severoiztochen	DED2	Dresden
BG34	Yugoiztochen	DED4	Chemnitz
BG41	Yugozapaden	DED5	Leipzig
BG42	Yuzhen tsentralen	DEE0	Sachsen-Anhalt
CY00	Kypros	DEF0	Schleswig-Holstein
CZ01	Praha	DEG0	Thüringen
CZ02	Střední Čechy	DK01	Hovedstaden
CZ03	Jihozápad	DK02	Sjælland
CZ04	Severozápad	DK03	Syddanmark
CZ05	Severovýchod	DK04	Midtjylland
CZ06	Jihovýchod	DK05	Nordjylland
CZ07	Střední Morava	EE00	Eesti
CZ08	Moravskoslezsko	EL30	Attiki
DE11	Stuttgart	EL41	Voreio Aigaio
DE12	Karlsruhe	EL42	Notio Aigaio
DE13	Freiburg	EL43	Kriti
DE14	Tübingen	EL51	Anatoliki Makedonia, Thraki
DE21	Oberbayern	EL52	Kentriki Makedonia
DE22	Niederbayern	EL53	Dytiki Makedonia
DE23	Oberpfalz	EL54	Thessalia
DE24	Oberfranken	EL61	Ipeiros
DE25	Mittelfranken	EL62	Ionia Nisia
DE26	Unterfranken	EL63	Dytiki Ellada
		EL64	Sτέρα Ellada

EL65	Peloponnisos	HU12	Pest
ES11	Galicia	HU21	Közép-Dunántúl
ES12	Principado de Asturias	HU22	Nyugat-Dunántúl
ES13	Cantabria	HU23	Dél-Dunántúl
ES21	País Vasco	HU31	Észak-Magyarország
ES22	Comunidad Foral de Navarra	HU32	Észak-Alföld
ES23	La Rioja	HU33	Dél-Alföld
ES24	Aragón	IE04	Northern and Western
ES30	Comunidad de Madrid	IE05	Southern
ES41	Castilla y León	IE06	Eastern and Midland
ES42	Castilla-La Mancha	ITC1	Piemonte
ES43	Extremadura	ITC2	Valle d'Aosta/Vallée d'Aoste
ES51	Cataluña	ITC3	Liguria
ES52	Comunidad Valenciana	ITC4	Lombardia
ES53	Illes Balears	ITF1	Abruzzo
ES61	Andalucía	ITF2	Molise
ES62	Región de Murcia	ITF3	Campania
ES63	Ciudad Autónoma de Ceuta	ITF4	Puglia
ES64	Ciudad Autónoma de Melilla	ITF5	Basilicata
ES70	Canarias	ITF6	Calabria
FI19	Länsi-Suomi	ITG1	Sicilia
FI1B	Helsinki-Uusimaa	ITG2	Sardegna
FI1C	Etelä-Suomi	ITH1	Provincia Autonoma di Bolzano/Bozen
FI1D	Pohjois- ja Itä-Suomi	ITH2	Provincia Autonoma di Trento
FI20	Åland	ITH3	Veneto
FR10	Ile-de-France	ITH4	Friuli-Venezia Giulia
FRB0	Centre – Val de Loire	ITH5	Emilia-Romagna
FRC1	Bourgogne	ITI1	Toscana
FRC2	Franche-Comté	ITI2	Umbria
FRD1	Basse-Normandie	ITI3	Marche
FRD2	Haute-Normandie	ITI4	Lazio
FRE1	Nord-Pas de Calais	LT01	Sostinės regionas
FRE2	Picardie	LT02	Vidurio ir vakarų Lietuvos regionas
FRF1	Alsace	LU00	Luxembourg
FRF2	Champagne-Ardenne	LV00	Latvija
FRF3	Lorraine	MT00	Malta
FRG0	Pays de la Loire	NL11	Groningen
FRH0	Bretagne	NL12	Friesland (NL)
FRI1	Aquitaine	NL13	Drenthe
FRI2	Limousin	NL21	Overijssel
FRI3	Poitou-Charentes	NL22	Gelderland
FRJ1	Languedoc-Roussillon	NL23	Flevoland
FRJ2	Midi-Pyrénées	NL31	Utrecht
FRK1	Auvergne	NL32	Noord-Holland
FRK2	Rhône-Alpes	NL33	Zuid-Holland
FRL0	Provence-Alpes-Côte d'Azur	NL34	Zeeland
FRM0	Corse	NL41	Noord-Brabant
HR03	Jadranska Hrvatska	NL42	Limburg (NL)
HR04	Kontinentalna Hrvatska	PL21	Małopolskie
HU11	Budapest		

PL22	Śląskie	RO11	Nord-Vest
PL41	Wielkopolskie	RO12	Centru
PL42	Zachodniopomorskie	RO21	Nord-Est
PL43	Lubuskie	RO22	Sud-Est
PL51	Dolnośląskie	RO31	Sud-Muntenia
PL52	Opolskie	RO32	București-Ilfov
PL61	Kujawsko-pomorskie	RO41	Sud-Vest Oltenia
PL62	Warmińsko-mazurskie	RO42	Vest
PL63	Pomorskie	SE11	Stockholm
PL71	Łódzkie	SE12	Ostra Mellansverige
PL72	Świętokrzyskie	SE21	Småland med öarna
PL81	Lubelskie	SE22	Sydsverige
PL82	Podkarpackie	SE23	Västsverige
PL84	Podlaskie	SE31	Norra Mellansverige
PL91	Warszawski stołeczny	SE32	Mellersta Norrland
PL92	Mazowiecki regionalny	SE33	Övre Norrland
PT11	Norte	SI03	Vzhodna Slovenija
PT15	Algarve	SI04	Zahodna Slovenija
PT16	Centro (PT)	SK01	Bratislavský kraj
PT17	Área Metropolitana de Lisboa	SK02	Západné Slovensko
PT18	Alentejo	SK03	Stredné Slovensko
PT20	Região Autónoma dos Açores	SK04	Východné Slovensko
PT30	Região Autónoma da Madeira		

Table A2: NACE elements in FIGARO (64 at the national level, 56 after regionalisation)

Code (64 activities)	Description	Code (56 activities)
A01	Crop and animal production, hunting and related service activities	A01
A02	Forestry and logging	A02-A03
A03	Fishing and aquaculture	A02-A03
B	Mining and quarrying	B
C10T12	Manufacture of food products, beverages, and tobacco products	C10T12
C13T15	Manufacture of textiles, wearing apparel, and leather and related products	C13T15
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	C16
C17	Manufacture of paper and paper products	C17
C18	Printing and reproduction of recorded media	C18
C19	Manufacture of coke and refined petroleum products	C19
C20	Manufacture of chemicals and chemical products	C20
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21
C22	Manufacture of rubber and plastic products	C22
C23	Manufacture of other non-metallic mineral products	C23
C24	Manufacture of basic metals	C24
C25	Manufacture of fabricated metal products, except machinery and equipment	C25
C26	Manufacture of computer, electronic and optical products	C26
C27	Manufacture of electrical equipment	C27
C28	Manufacture of machinery and equipment n.e.c.	C28
C29	Manufacture of motor vehicles, trailers and semi-trailers	C29
C30	Manufacture of other transport equipment	C30
C31_32	Manufacture of furniture and other manufacturing	C31_32
C33	Repair and installation of machinery and equipment	C33
D35	Electricity, gas, steam and air conditioning supply	D35
E36	Water collection, treatment and supply	E36
E37T39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services	E37T39
F	Construction	F
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	G45

G46	Wholesale trade, except of motor vehicles and motorcycles	G46
G47	Retail trade, except of motor vehicles and motorcycles	G47
H49	Land transport and transport via pipelines	H49
H50	Water transport	H50
H51	Air transport	H51
H52	Warehousing and support activities for transportation	H52
H53	Postal and courier activities	H53
I	Accommodation and food service activities	I
J58	Publishing activities	J58
J59_60	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities	J59_60
J61	Telecommunications	J61
J62_63	Computer programming, consultancy and related activities; information service activities	J62_63
K64	Financial service activities, except insurance and pension funding	K
K65	Insurance, reinsurance and pension funding, except compulsory social security	K
K66	Activities auxiliary to financial services and insurance activities	K
L68	Real estate activities	L68
M69_70	Legal and accounting activities; activities of head offices; management consultancy activities	M69_70
M71	Architectural and engineering activities; technical testing and analysis	M71
M72	Scientific research and development	M72
M73	Advertising and market research	M73
M74_75	Other professional, scientific and technical activities; veterinary activities	M74_75
N77	Rental and leasing activities	N77
N78	Employment activities	N78
N79	Travel agency, tour operator and other reservation service and related activities	N79
N80T82	Security and investigation activities; services to buildings and landscape activities; office administrative, office support and other business support activities	N80T82
O84	Public administration and defence; compulsory social security	O84
P85	Education	P85
Q86	Human health activities	Q86

Q87_88	Residential care activities; social work activities without accommodation	Q87_88
R90T92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities	R-T
R93	Sports activities and amusement and recreation activities	R-T
S94	Activities of membership organisations	R-T
S95	Repair of computers and personal and household goods	R-T
S96	Other personal service activities	R-T
T	Activities of households as employers; undifferentiated goods - and services - producing activities of households for own use	R-T

Table A3: List of NUTS-2 statistics for EU27

Data source	Availability	Sectoral/commodity details	Geographical details	Notes
Eurostat regional accounts – GDP, households’ incomes, employment and wages	2000-2019	11 NACE Rev. 2 sectors (covering the whole economy)	NUTS 1 2016 and NUTS 2 2016 regions of EU27 + NO + CH + IS + MK + TR + UK	
Eurostat SBS – employment and wages	2008-2019	89 NACE Rev. 2 divisions (covering sectors and private services)	NUTS 1 2016 and NUTS 2 2016 regions of EU27 + UK	The 89 divisions are aggregated up to the 56 sectors used in the regional dataset
Eurostat - Economic accounts for agriculture (agr_r_accts)	1980-2019	Detailed A sector products	NUTS 1 2016 and NUTS 2 2016 regions of EU27 + UK	
Eurostat - Hospital beds by NUTS 2 regions (hlth_rs_bdsrg)	1993-2020		NUTS 1 2016 and NUTS 2 2016 regions of EU27 + NO + CH + IS + MK + TR + RS	Used to regionalize Q sector GVA
Eurostat - Students enrolled by education level (educ_uoe_enra11)	2013-2020		NUTS 1 2016 and NUTS 2 2016 regions of EU27 + NO + CH + IS + MK + TR + RS	Used to regionalize P sector GVA

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