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Regional Trade Flows and Input Output Data for Europe[1]

Olga Ivanova*, d'Artis Kancs** and Mark Thissen*

Abstract: The Regional Trade Flows and Input output Data for Europe are constructed at the regional NUTS2 level with sectoral NACE2 detail and developed for spatial macroeconomic modelling and social-economic analysis for answering a wide-range of policy questions, including policies related to investments in innovation, human capital, green infrastructure and Sustainable Development Goals. The Regional Trade Flows and Input output Data for Europe are particularly well suited for structural modelling such as spatial computable general equilibrium models, as all data are fully internally consistent. In the Regional Trade Flows and Input output Data all European regions are connected with each other via inter-regional trade flows, input use and output supply in form of regional trade matrices, input output tables and supply-use tables. This data base is result of a joint collaborative effort over a decade of several research institutes across Europe, including the Netherlands Environmental Assessment Agency (PBL), the European Commission (DG JRC) and the University of Groningen (Ivanova, Kancs and Stelder 2009, Thissen et al. 2014, Thissen et al. 2018, Ivanova, Kancs and Thissen 2019). Among others, the new EU Economic Modelling System (EU-EMS) developed within the EU Framework Programme for Research and Innovation makes use of the Regional Trade Flows and Input output Data for Europe.

Keywords: Inter-Regional Trade Flows, Input output Tables, data, Europe, spatial spillovers, SCGE, modelling.

JEL code: C68, D58, F12, R13, R30.

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[11] The authors are solely responsible for the content of the paper. The views expressed are purely those of the authors and may not under any circumstances be regarded as stating an official position of the European Commission.

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Introduction

The objective of this report is to provide a brief overview of the Regional Trade Flows and Input output Data for Europe. The Regional Trade Flows and Input output Data for Europe are constructed at the regional level (NUTS2) with sectoral detail (NACE2) and developed for being used in spatial macroeconomic modelling and social-economic analysis for answering a wide-range of policy questions, including policies related to investments in innovation, human capital, green infrastructure and Sustainable Development Goals (SDGs). The constructed Regional Trade Flows and Input output Data for Europe are particularly well suited for structural modelling such as spatial computable general equilibrium models, as all data are fully internally consistent. In the Regional Trade Flows and Input output Data all European regions are connected with each other via inter-regional trade flows, input use and output supply in form of regional trade matrices, input output tables and supply-use tables.

This data base is result of a joint collaborative effort over a decade of several research institutes across Europe, including the Netherlands Environmental Assessment Agency (PBL), the European Commission (DG JRC) and the University of Groningen. Work on the Regional Trade Flows and Input output Data for Europe started more than a decade ago with Ivanova, Kancs and Stelder (2009) and continued with Thissen et al. (2014), Thissen et al. (2018) and Ivanova, Kancs and Thissen (2019).

The new EU Economic Modelling System (EU-EMS) developed within the EU Framework Programme for Research and Innovation makes use of the Regional Trade Flows and Input output Data for Europe. We use the example of the EU Economic Modelling System illustrate the use of the Regional Trade Flows and Input output Data for Europe for modelling purposes. The EU-EMS is a newly developed spatial computable general equilibrium (SCGE) model that includes a representation of 62 countries of the world and one rest of the world region. The EU28 Member States are further disaggregated into 276 NUTS2 regions and each regional economy is disaggregated into 63 NACE Rev.2 economic sectors. Goods and services are consumed by households, government and firms and are produced in markets that are either perfectly or imperfectly competitive. The model is micro founded with the New Economic Geography theory and includes mechanisms such as monopolistic competition, increasing returns to scale and labour migration. Spatial interactions between regions are captured through trade of goods and services (which is subject to trade and transport costs), factor mobility and knowledge spillovers.

The report is structured in three parts. First, we provide an overview of the construction of national trade flows and input output tables for Europe (section 1). Second, we provide an overview of the construction of regional trade flows and input output tables for Europe (section 2). Third, we offer a modelling example that illustrates the use of regional trade flows and input output tables for Europe in a spatial macroeconomic model EU-EMS (section 3). As usual, the final section concludes.

1 Construction of National Trade Flows and Input output Tables

In order to construct consistent national trade flows and input output tables for Europe, the starting point is national supply and use tables which also serve as the underlying building blocks for the regional tables. To ensure meaningful series over time, we start from output and final consumption series given in the national accounts and benchmark national supply and use tables to these time-consistent series. Supply and use tables provide a consistent starting point for our data base as they provide information on both products and (using and producing) industries. A supply table provides information on products produced by each domestic industry and a use table indicates the use of each product by an industry or final user. The linking with international trade data, that is product based and socio-economic data, that is mainly industry-based, can be established in a supply and use framework.

Our objective is to construct consistent supply and use tables for Europe that satisfy two basic accounting identities: for each product total supply must equal total use, and for each industry the total value of inputs (including intermediate products, labour and capital) must equal total output value; supply of products can either be from domestic production or from imports. The construction of consistent national trade flows and input output tables for Europe consist of several steps. In the first step of the national data construction process, we benchmark the national supply and use tables to time-series of industrial output and final use from national account statistics. From Eurostat, supply and use tables are only available for a limited set of years (i.e. every five years) and once released by the national statistical institute revisions are rare. This compromises the consistency and comparability of these tables over time as statistical systems develop, new methodologies and accounting rules are used, classification schemes change and new data become available. These revisions can be substantial, especially at a detailed industry level. By benchmarking the supply and use tables on consistent time series from the National Accounting System, tables can be linked over time in a meaningful way. In a second step, the national supply and use tables are combined with information from international trade statistics to construct what we call international supply and use tables. Third, an additional breakdown of imports is undertaken. The international supply and use tables for each country are then combined into a European input output table.

Three types of data are being used to construct consistent supply and use tables for Europe, namely national accounts statistics, supply-use tables and international trade statistics. All these data are publicly available. For our purpose, the data are harmonised in terms of industry- and product-classifications both across time and across countries. The underlying classification list has 59 products and 35 industries based on the European Statistical Classification of Products by Activity and NACE rev2 classifications. This level of detail is chosen on the basis of initial data-availability exploration and ensures a maximum of detail without the need for additional information that is not generated in the system of national accounts. The adopted 35-industry classification is consistent with the WIOD[4] and EU KLEMS[5] databases. The WIOD data have an additional breakdown of the transport sector, as these industries are important in linking trade across countries and regions and in the transformation to alternative price concepts (from purchasers' to basic prices, see below). Hence, these sectoral tables can be easily linked to the national WIOD data and additional variables on investment, labour and productivity in the EU KLEMS data. The product disaggregation is based on the level of detail that is available in national supply and use tables produced by European national statistical offices, following Eurostat regulations and is more detailed than the industry list. As noted by Thissen et al. (2018), non-survey methods to split up a use table into imported and domestic are best applied at a high level of product detail. To arrive at a common classification, correspondence tables are made for each national supply and use table bridging the level of detail and classifications in the country to our classification. This involved aggregation/disaggregation based on an additional detailed data. Further, national supply and use tables are checked for consistency and adjusted to common statistical concepts (e.g. regarding the treatment of Financial Intermediation Services Indirectly Measured and purchases abroad). Undisclosed cells due to confidentiality concerns are imputed based on additional information.

From Eurostat, national supply and use tables are only infrequently available and are often not harmonised over time. Therefore they are benchmarked on consistent time-series from the national account statistics in a second step. From the national account statistics data time series on gross output and value added by industry, total imports and total exports and final use by

[4] The World Input-Output Database (WIOD) has been developed within the EU Framework Programme for Research and Innovation (Grant Agreement no: 225281). More information on the WIOD project can be found at www.wiod.net.

[5] The Capital, Labour, Energy, Materials and Service (EU KLEMS) database has been developed within the EU Framework Programme for Research and Innovation. More information on the EU KLEMS project can be found at www.euklems.net.

use category are taken. These data are used to generate time series of supply and use tables using the so-called supply and use table iterative proportional fitting method. This method is akin to the well-known bi-proportional updating method for input output tables known as the RAS-technique. This technique is adapted for updating supply and use tables.

Time series of supply and use tables are derived for two price concepts: basic prices and purchasers' prices. Basic price tables reflect the costs of all elements inherent in production borne by the producer, whereas purchasers' price tables reflect the amount paid by the purchaser. The difference between the two is the trade and transportation margins and net taxes. Both price concepts have their use for analysis depending on the type of the data purpose. Supply tables are always at basic price and often have additional information on margins and net taxes by product (Eurostat 2019).[6] The use table is typically at a purchasers' price basis and hence needs to be transformed into a basic price table. The difference between the two tables is given in the so-called valuation matrices (Eurostat 2019). These matrices are not available from public data sources and hence need to be estimated. Following WIOD,[7] we distinguish four types of margins: automotive trade, wholesale trade, retail trade and transport margins. The distribution of each margin type varies widely over the purchasing users and we use this information to improve our estimates of basic price tables.

The next step is a breakdown of the use table into domestic and imported origin. As margins are only generated by the domestic industries, a breakdown of the use table at basic price is made. Ideally, we would like to use additional information based on firm surveys that inventory the origin of products used. However, this type of information is hard to elicit and only rarely available. Therefore, we use a non-survey imputation method that relies on a classification of detailed products in the international trade statistics into three use categories. Our basic data are import flows of European countries from all partners in the world at the Harmonised Commodity Description and Coding Systems (HS) 6-digit product level taken from the UN COMTRADE database.[8] Based on the detailed product description at the HS 6-digit level, products are allocated to three use categories: intermediates, final consumption, and investment. This resembles the well-known correspondence between the about 5,000 products listed in HS6 and the Broad Economic Categories, as made available from the United Nations Statistics Division. These Broad Economic Categories can then be aggregated to the broader use categories. This correspondence is revised to better fit the purpose of linking the trade data to the supply and use tables.

For the services trade, no standardised database on bilateral trade flows exists. These are collected from various sources (including OECD, Eurostat, IMF and WTO), checked for consistency and integrated into a bilateral service trade database. As the services trade is taken from the balance of payments statistics, it is originally reported at balance of payment codes. For building the shares a mapping to products is applied. For these service categories, there does not exist a breakdown into the use categories mentioned above; thus we either use available information from existing import use or symmetric import input output tables; for countries where no information is available we apply shares taken from other (similar) countries.

Based on WIOD use-category classification, we allocate imports across use categories in the following way. First, we used the share of use the category of intermediates, final consumption or investment to split up total imports as provided in the supply tables for each product. The resulting numbers for intermediates are allocated over using industries by proportionality assumption. Similarly, the final consumption is allocated over the consumption categories (final consumption expenditure by households, final consumption expenditure by non-profit organisations and final consumption expenditure by government). Investment is allocated to

[6] https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/data/database
[7] https://www.wiod.net
[8] https://comtrade.un.org/

column gross fixed capital formation. This yields the import use table. Finally, each cell of the import use table is split up to the country of origin, where country import shares might differ across use categories, but not within these categories.

Note that here are discrepancies between the import values recorded in the National Accounts on the one hand, and in international trade statistics on the other. Some of them are due to conceptual differences, and others due to classification and data collection procedures. As we rely on national account statistics as our benchmark, we apply shares from the trade statistics to the national account statistics series. Thus, to be consistent with the imports as provided in the supply and use tables, we use only shares derived from the international trade statistics rather than the actual values.

As a final step, international supply and use tables are transformed into a European input output table. Input output tables are symmetric and can be of the type, describing the amount of products needed to produce a particular good or service, or of the industry-by-industry type, describing the flow of goods and services from one industry to another. In case each product is only produced by one industry, the product-by-product and industry-by-industry tables are the same. However, the larger the share of secondary production, the larger is the difference between the product-by-product and industry-by-industry tables. The choice for between the two depends on the type of the research question and data construction purpose. For a macroeconomic modelling purpose, our data base relies on industry-type tables as the additional data, such as employment or investment, is often only available on an industry basis. Moreover, the industry-type table retains best the links with national account statistics.

Input output tables are constructed on the basis of a supply and use table at basic prices based on additional assumptions concerning technology. We use the so-called "fixed product-sales structure" assumption stating that each product has its own specific sales structure irrespective of the industry where it is produced. Sales structure here refers to the proportions of the output of the product in which it is sold to the respective intermediate and final users. This assumption is most widely used, not only because it is more realistic than its alternatives, but also because it requires a relative simple mechanical procedure. Furthermore, it does not generate any negatives in the input output tables that would require manual rebalancing.

2 Construction of Regional Trade Flows and Input output Tables

The construction of the time series of multiregional input output tables at the NUTS2 level is based on a top-down approach where national accounts in the format of national supply and use tables are constructed and readily available as detailed in section 1 (Thissen et al. 2018, Oosterhaven 2019). As for the national tables detailed in section 1, a supply and use framework is used rather than an input output framework. An input output framework uses the assumption that every sector produces only one good. As noted above, there are two types of input output matrices: product-by-product matrices and sector-by-sector matrices. Product-by-product input output matrices are generally constructed around the product classification, and sectors are therefore adjusted or mixed in such a way that only one sector produces only one product. Sector-by-sector input output matrices are generally constructed around the sector classification, and products are therefore adjusted or mixed in such a way that only one sector makes only one product. This implies that, depending on the type of input output table, either sectors are not comparable across countries and not comparable with regional sector statistics, or products are not comparable across countries and not comparable with trade statistics. In our case, both a regional trade database, and production and consumption data of different actors in different regions are used. The focus is thus intentionally on the regionalisation of both trade and the regional use and supply of products by different economic actors. The regionalisation of a complete supply and use framework is then the only option available.

The European supply and use tables are taken as the starting point of the Regional Trade Flows and Input Output Data base for Europe construction. The country-level database makes a detailed distinction between final and intermediate goods trade. The supply and use tables provide detailed information on bilateral trade for 40 countries and the rest of the world. The data include 59 product categories, among which services, according to the European Statistical Classification of Products by Activity. These data are consistent with countries' national accounts. The international supply and use tables are first adjusted so as to (a) account for the distribution of the re-exports over (most likely) origin and destination countries, and (b) to ensure consistency in bilateral trade flows (i.e., trade matching: exports from i to j equal imports of j from i), and (c) that exports and imports of each country add up to their national accounts totals as presented in the national data (see section 1). Both adjustments have to be done before the regionalisation because otherwise inconsistencies would have to be regionalised as well. The regionalisation of inconsistencies is theoretically not possible since they do not exist in reality and therefore cannot be based on an actual information.

Subsequently, information on the sector production, investment and income development from the Eurostat regional accounts is added. After these are made consistent with the above detailed national accounts, the data are used to regionalise the national tables, the construction of which is detailed in section 1. As the outcome of this regionalisation procedure, regional supply and use tables for each of the 256 European NUTS2 regions, for 14 sectors and 59 product groups for each year are obtained. Where available, regional survey based information on supply and use of different sectors is added. In particular, regional supply and/or use tables are available for Scotland and Wales, as well as Italy (five NUTS1 regions), Finland (21 NUTS3 regions) and Spain (15 NUTS2 regions). These tables are added as additional priors to the estimation. Regional trade flows are taken from the PBL Netherlands Environmental Assessment Agency regional trade data base for the year 2000 as a prior to the estimations of inter-regional trade flows.

Employing the regionalised supply and use tables, the PBL regional trade data and the survey based regional supply and use tables as a prior, the regional supply and use tables are estimated for Europe for every year. The estimation approach is based on a constrained non-linear minimisation approach that guarantees a consistency of the regional tables with the national tables (for more details, see Thissen et al. (2018)). This consistency implies that adding up the regionalised supply and use tables results in corrected national supply and use tables. The interregional supply and use tables that contain trade, matched bilateral trade flows but no re-exports.

3 Application example of the data: EU Economic Modelling System

The Regional Trade Flows and Input output Data for Europe are developed for being used in spatial macroeconomic modelling and social-economic analysis for answering a wide-range of policy questions, including policies related to investments in innovation, human capital, green infrastructure and Sustainable Development Goals (SDGs). Hence, SDG modelling, economic analyses and macroeconomic models that are implemented at the regional level with sectoral detail are the main beneficiaries of the Regional Trade Flows and Input Output Data for Europe. Regional Trade Flows and Input output Data for Europe are particularly well suited for structural modelling such as spatial computable general equilibrium models, as these data are fully internally consistent. This means that all European regions at the regional level (NUTS2) with sectoral detail (NACE2) are connected with each other via inter-regional trade flows, input use and output supply in form of regional trade matrices, input output tables and supply-use tables.

In this section, we use the example of the new EU Economic Modelling System (EU-EMS) that has been developed within the EU Framework Programme for Research and Innovation Horizon 2020 to illustrate the use of the Regional Trade Flows and Input Output Data for Europe for modelling purposes. First, we introduce the EU-EMS and outline the main structural relationships with the main emphasis on the modelling of innovation and human capital. Second, it details the empirical implementation of the EU-EMS and explains how it makes use of the Regional Trade Flows and Input Output Data for Europe.

3.1 Overview of the EU Economic Modelling System[9]

The employed EU Economic Modelling System (EU-EMS) is a newly developed spatial computable general equilibrium (SCGE) model built by the PBL Netherlands Environmental Assessment Agency within the EU Framework Programme.[10] The model includes a representation of 62 countries of the world and one Rest of the world region. The EU28 Member States are further disaggregated into 276 NUTS2 regions and each regional economy is disaggregated into 63 NACE Rev.2 economic sectors. Goods and services are consumed by households, government and firms and are produced in markets that are either perfectly or imperfectly competitive. The model includes New Economic Geography features such as monopolistic competition, increasing returns to scale and labour migration. Spatial interactions between regions are captured through trade of goods and services (which is subject to trade and transport costs), factor mobility and knowledge spillovers. This makes EU-EMS a particularly well suited modelling tool for analysing policies related to the human capital, R&I and innovation of which we will make use in the present study.

The theoretical underpinning of modelling innovation and the factor productivity growth follows Griffith et al. (2001) and Acemoglu et al. (2007), where firms invest into both innovation (knowledge production) and adoption of technologies from the world technology frontier. In this framework, the selection of high-skill workers and firms is more important for innovation than for adoption. Regions and countries at early stages of development pursue an investment-based strategy, which relies on existing firms and managers to maximise investment but sacrifices selection. Closer to the world technology frontier, economies switch to an innovation-based strategy with short-term relationships, younger firms, less investment, and better selection of firms and managers. Griffith et al. (2001) propose a general equilibrium model of endogenous growth with both channels of productivity adjustments to R&D investments. Griffith et al. augment the conventional quality ladder model to allow the size of innovations to be a function of the distance behind the technological frontier. Griffith et al. find a strong empirical evidence for the second channel of R&D in the adoption of knowledge.

Following Griffith et al. (2001) and Acemoglu et al. (2007), we assume that R&D affects the development of TFP through two channels. The first is the knowledge creation or stimulation of innovation that has received a lot of attention in both the theoretical and empirical literature. The second channel is the adoption or imitation of knowledge that has been created in other regions, countries and sectors. As in Griffith et al. (2001) and Acemoglu et al. (2007), the following relationship between the R&D investment and productivity growth is specified in EU-EMS:

$$\ln \mathrm{A_{ijt}} = \beta \Delta \ln \mathrm{A_{Fjt}} - \delta_1 \ln\left(\frac{A_i}{A_F}\right)_{jt-1} - \delta_2 \ln\left(\frac{R}{Y}\right)_{ijt-1} \ln\left(\frac{A_i}{A_F}\right)_{jt-1} - \delta_3 H_{ijt-1} \ln\left(\frac{A_i}{A_F}\right)_{jt-1} + \rho_1 \left(\frac{R}{Y}\right)_{ijt-1} + \rho_2 H_{ijt-1} + u_{ijt} \quad (1)$$

where the TFP growth, $\Delta \ln \mathrm{A_{Fjt}}$, over a certain period of time depends on the knowledge adoption that is captured by the growth of the technological frontier, $\Delta \ln \mathrm{A_{Fjt}}$, and interaction between the technological gap, $\ln(A_i/A_F)_{jt-1}$, and the R&D per unit of sectoral output,

[9] See Ivanova, Kancs and Thissen (2019) for a formal description of the EU-EMS.

[10] European Union's Horizon 2020 Research and Innovation Programme, grant agreement No 727114.

$(R/Y)_{ijt-1}$, as well as the interaction between the technological gap, $\ln(A_i/A_F)_{jt-1}$, and the human capital, H_{ijt-1}. The level of the human capital and R&D capture the absorptive capacity of the particular sector. The TFP growth is also linked to the knowledge creation that is captured by the R&D stock, $(R/Y)_{ijt-1}$, and the human capital stock, H_{ijt-1}.

Once parameterised, the employed macroeconomic model will help us to analyse how the EIT investment support in knowledge and human capital affects the supported regional economies and to what extent the investment support may spill over to other (non-supported) regions.

3.2 Empirical implementation of the EU-EMS

The EU-EMS database has been constructed by combining national, European and international data sources;[11] it contains a detailed regional level (NUTS2 for EU28 plus 34 non-EU countries) multi-regional input output (MRIO) table for the world. The main datasets used for the construction of MRIO include the OECD database, the BACI trade data, the Eurostat regional statistics and national Supply and Use tables as well as detailed regional level transport database ETIS-Plus from the DG MOVE.[12] The current EU-EMS version is calibrated to the 2017 Regional Trade Flows and Input output Data for Europe.

The EU-EMS database has a detailed sectoral and regional dimensionality, EU28 Member States are disaggregated as 276 NUTS2 regions. Both sectoral and geographical dimensions of the model are flexible and can be adjusted to the needs of specific policy or research question. The sectoral and geographical details of EU-EMS are summarised in Tables 3 and 4, respectively.

Regional structure

In total, the EU-EMS contains 62 countries of the world, which are reported in Table 3 below. Being built upon the framework of spatial general equilibrium modelling and incorporating the representation of 276 NUTS 2 regions in the EU and 34 non-EU countries of the world, the EU-EMS has an extremely detailed and rich structure of spatial interconnections between regions. For example, regional economies are connected via an inter-regional trade of goods and services, relocation of factors and economic activity and income flows. The trading of goods between regions is costly, as it is necessary to pay for the services of the transportation sector. Transportation costs in EU-EMS are both good-specific and differentiated between the origin and destination regions. The inter-regional trade flows data at the level of NUTS2 are unique, as these data are not available from official statistical sources. These unique inter-regional trade flows data are used also by other regional models of the European Commission (e.g. Thissen et al. 2019).

Table 1 Overview of countries represented in EU-EMS

Code	Country	Code	Country
AUS	Australia	ARG	Argentina
AUT	Austria	BGR	Bulgaria
BEL	Belgium	BRA	Brazil
CAN	Canada	BRN	Brunei Darussalam
CHL	Chile	CHN	China
CZE	Czech Republic	CHN.DOM	China Domestic sales
DNK	Denmark	CHN.PRO	China Processing
EST	Estonia	CHN.NPR	China Non processing goods exporters
FIN	Finland	COL	Colombia

[11] http://themasites.pbl.nl/winnaars-verliezers-regionale-concurrentie/

[12] http://viewer.etisplus.net/

FRA	France	CRI	Costa Rica
DEU	Germany	CYP	Cyprus
GRC	Greece	HKG	Hong Kong SAR
HUN	Hungary	HRV	Croatia
ISL	Iceland	IDN	Indonesia
IRL	Ireland	IND	India
ISR	Israel	KHM	Cambodia
ITA	Italy	LTU	Lithuania
JPN	Japan	LVA	Latvia
KOR	Korea	MLT	Malta
LUX	Luxembourg	MYS	Malaysia
MEX	Mexico	PHL	Philippines
MEX.GMF	Mexico Global Manufacturing	ROU	Romania
MEX.NGM	Mexico Non-Global Manufacturing	RUS	Russian Federation
NLD	Netherlands	SAU	Saudi Arabia
NZL	New Zealand	SGP	Singapore
NOR	Norway	THA	Thailand
POL	Poland	TUN	Tunisia
PRT	Portugal	TWN	Chinese Taipei
SVK	Slovak Republic	VNM	Viet Nam
SVN	Slovenia	ZAF	South Africa
ESP	Spain	RoW	Rest of the World
SWE	Sweden		
CHE	Switzerland		
TUR	Turkey		
GBR	United Kingdom		
USA	United States		

Sectoral classification

In EU-EMS, economies (regions within EU, countries outside EU) differ by the type of production sectors, which dominate overall production activities in the region. Some specialise in traditional sectors like agriculture, whereas others specialise in skill- and knowledge-intensive sectors such as finance and industry. Different economic sectors are characterised by a different degree of agglomeration and its importance for innovation, as innovation activities tend to be highly concentrated in space (Brandsma and Kancs 2015). Traditional sectors do not experience any agglomeration effects whereas skill- and knowledge-intensive sectors do and that may result in some sectors growing faster than others.

In order to capture inter-sectoral differences in the innovation activity and performance – which are of a particular relevance for the present study – we have regrouped all economic sectors into six broad groups following the Eurostat classification of the economic sectors according to their R&D intensity: (1) Traditional, (2) Low-tech industry, (3) Medium-tech industry, (4) High-tech industry, (5) Knowledge intensive services and (6) Other services (see Table 4). This classification follows the Eurostat's definition, where for the purpose of our analysis we merge together groups "High-technology" and "Medium-high technology" into "High-technology". These aggregated groups of sectors are also used in the econometric analysis for the estimation of key innovation parameters in the model that as detailed below uses the EU-KLEMS database.

Table 2 Sectoral classification of *EU-EMS*

Sectoral classification	*NACE Rev2 codes*	*Description of the sectors*

Traditional	A01 A02 A03 B	Products of agriculture, hunting and related services; Products of forestry, logging and related services; Fish and other fishing products; aquaculture products; support services to fishing; Mining and quarrying
Low-technology manufacturing	C10-C12 C13-C15 C16 C17 C18 C31_C32	Food products, beverages and tobacco products; Textiles, wearing apparel and leather products; Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials; Study and study products; Printing and recording services; Furniture; other manufactured goods
Medium-technology manufacturing	C19 C22 C23 C24 C25 C33	Coke and refined petroleum products; Rubber and plastics products; Other non-metallic mineral products; Basic metals; Fabricated metal products, except machinery and equipment; Repair and installation services of machinery and equipment
High-technology manufacturing	C21 C26 C20 C27 C28 C29 C30	Basic pharmaceutical products and pharmaceutical preparations; Computer, electronic and optical products; Chemicals and chemical products; Electrical equipment; Machinery and equipment n.e.c.; Motor vehicles, trailers and semi-trailers; Other transport equipment
Knowledge intensive service sectors	H50 H51 J58 J59_J60 J61 J62_J63 K64 K65 K66 M69_M70 M71 M72 M73 M74_M75 N78 N80-N82 O84 P85 Q86 Q87_Q88 R90-R92 R93	Water transport services; Air transport services; Publishing services; Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services; Telecommunications services; Computer programming, consultancy and related services; information services; Financial services, except insurance and pension funding; Insurance, reinsurance and pension funding services, except compulsory social security; Services auxiliary to financial services and insurance services; Legal and accounting services; services of head offices; management consulting services; Architectural and engineering services; technical testing and analysis services; Scientific research and development services; Advertising and market research services; Other professional, scientific and technical services; veterinary services; Employment services; Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services; Public administration and defence services; compulsory social security services; Education services; Human health services; Social work services; Creative, arts and entertainment services; library, archive, museum and other cultural services; gambling and betting services; Sporting services and amusement and recreation services
Other service sectors	C33 D35 E36 E37-E39 F G45 G46 G47 H49 H52 H53 I L68B L68A N77 N79 S94 S95 S96 T U	Repair and installation services of machinery and equipment; Electricity, gas, steam and air-conditioning; Natural water; water treatment and supply services Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services; Constructions and construction works; Wholesale and retail trade and repair services of motor vehicles and motorcycles; Wholesale trade services, except of motor vehicles and motorcycles; Retail trade services, except of motor vehicles and motorcycles; Land transport services and transport services via pipelines; Warehousing and support services for transportation; Postal and courier services; Accommodation and food services; Real estate services (excluding imputed rent); Imputed rents of owner-occupied dwellings; Rental and leasing services; Travel agency, tour operator and other reservation services and related services; Services furnished by membership organisations; Repair services of computers and personal and household goods; Other personal services; Services of households as employers; undifferentiated goods and services produced by households for own use; Services provided by extraterritorial organisations and bodies

3.3 Parameter estimation

Total factor productivity

The econometric framework is designed to estimate parameters for the underlying macro-economic model; it represents private R&D decisions and productivity developments at the level of economic sectors. In line with the theoretical framework introduced in the previous section, the total factor productivity is determined both by innovation and adoption process that are present also in the multifactor productivity equation. This formulation constitutes a reduced form representation of the canonical Schumpeterian growth theory, where innovation-imitation processes lie at the heart of the productivity growth and allow poorer countries to catch-up with the richer ones.

The econometrically estimable equation of the multi-factor productivity growth is derived from the theoretical framework (equation 1) and takes the following form:

$$\ln\left(\frac{TFP_{cst}}{TFP_{cst-1}}\right) = b_1 \ln\left(\frac{TFP^*_{st}}{TFP^*_{st-1}}\right) + b_2 \ln\left(\frac{TFP_{cst-1}}{TFP^*_{st-1}}\right) + b_3 H_{t-1} + b_4 H_{t-1} \ln\left(\frac{TFP_{cst-1}}{TFP^*_{st-1}}\right) + b_5 RD_{t-1} + b_6 RD_{t-1} \ln\left(\frac{TFP_{cst-1}}{TFP^*_{st-1}}\right) + d_s + d_{sc} + e_{sct} \qquad (2)$$

where subscripts *c, s* are country and sector indexes respectively, while *t* denotes the time period. The level of the total factor productivity is given by *TFP*, with *TFP** being the leader's total factor productivity. Variable *H* denotes the level of the human capital stock as measured by the share of highly skilled workers in the total employment, and *RD* is the level of R&D intensity as measured by private expenditures per value added (output).

The first two terms on the right-hand-side in equation (2) are standard in the literature and measure the productivity growth at the frontier and the technological gap between frontier and non-frontier sectors ("catch-up" term) respectively. The productivity growth of the technological leader captures the link between the TFP growth for the catching-up sector through the innovation and knowledge spillovers. The catch-up term aims to explain how the adoption of new technologies affect the innovation process of different sectors. The intuition behind is that there are greater potentials in adopting new technologies the higher the technological gap is. In this setup, the adoption of the existing technology and knowledge could occur via different channels (machinery and equipment, trade, employment, networks etc.) that show up in the productivity gap between industries.

As can be seen from equation (2), our framework for modelling innovation and productivity follows closely Griffith et al. (2001) and Acemoglu et al. (2007), where two channels of adjustment are at work between R&D and the productivity growth. Firstly because higher R&D spending could create new knowledge and secondly because it facilitates the adoption of knowledge or technology created elsewhere. For this reason, we include in our regressions the interactions between R&D and productivity gap. Benhabib and Spiegel (2005) have proposed that a similar idea holds for the human capital. On the one hand, higher human capital could create more knowledge in the economy. On the other hand, could increase the ability of a firm to adopt new technologies. To control for the possible latter effect, we have included another interacting term between human capital and productivity gap in the estimable equation.

For econometric estimations, we combine four different databases that provide data about variables in the estimable equation (2). For sectoral level data, we use the EU-KLEMS database which covers 28 countries of which most of them are OECD countries until the year 2016. Depending on the variable, these data series span a long time period starting from around 1970 for mainly Western European countries, Korea and Japan and from the 1990s from non-Western

European countries. In these database, information is contained for 107 categories of industries, of which 37 categories form head categories at a 2-digit level of which one is at a 1-digit level for total industries. The coverage of services counts 45 sectors in which both 3-and 2-digit category levels are included. Within the business services category, 12 out of totally 32 represent head categories on a 2-digit level. The personal services category has in total 7 head categories on 2-digit level of which two services sector no data is given. We use the latest release of the database from the end of 2019 that provides NACE Rev.2 sectoral classification presented in Table 4 above. For measuring the human capital stock, we use OECD country level data on the share of highly skilled people in the total employment. Finally, we complement our dataset with OECD's main science and innovation indicators (MSTI). From the MSTI database, we use series on government-financed expenditures on R&D, on education and social programs as a percentage of government budget allocations for R&D, and on government expenditures on R&D policies in OECD countries.

Table 3 Sector-specific multi-factor productivity estimates

	Pooled	Traditional	High-tech Manufact.	Medium-tech Manufact.	Low-tech Manufact.	Knowledge intensive services	Other services
D.TFP*	0.100**	0.24***	0.20***	0.036	0.041	0.049**	0.034
Gap	-0.47***	-0.21***	-0.22***	-0.51***	-0.13***	-0.077***	-0.14***
HC	0.027						
HC # Gap	0.29**						
RD	0.26						
RD # Gap	0.47*						
Time Dummy	No	No	No	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Sector FE	Yes	Yes	No	No	No	No	No
Country FE	No	No	Yes	Yes	No	No	No
Observations	5750	372	744	572	788	1863	1411
Adjusted R^2	0.354	0.389	0.345	0.324	0.203	0.328	0.277

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

We estimate equation (2) using the least square dummy approach (or within group estimator), where we add three different types of dummy variables that capture industry specific fixed effects (d_s), country-industry specific fixed effects (d_{sc}) and country specific trends (d_{ct}). Estimation results are reported in Table 5.

Table 5 reports the main results of parameter estimation for the multi-factor productivity. According to these results, there is a fairly consistent pattern across most sectoral parameters regarding the two main determinants of the productivity growth. In line with the underlying innovation-imitation Schumpeterian growth mechanics, our estimation results suggest that both innovations taken at the technological frontier (*D.TFP**) and the absorptive capacity of sectors to use new technologies (*Gap*) are essential drivers to productivity growth for the great majority of sectors.

Our econometric estimates suggest that the technological leader's productivity growth is positive and statistically significant, implying that there are important positive spillovers from technological innovations occurring at the frontier that help to increase the pace of innovations in follower regions. The strength of such spillovers appears to vary across industries with the strongest among them found in industries comprising the traditional sector. Spillovers are statistically insignificant also for the medium and low-tech manufacturing sector, as well as for the service industry, which are knowledge extensive. These estimates also suggest that the spillover effects from frontier growth differ between sectors with respect to the technology needed or used within the manufacturing sector.

A similar, yet even more robust estimation result across different industries, is for the catch-up term. According to our estimations, there are significant potentials for closing the productivity gap within industries by either adopting or investing in new technologies. These results hold true for all sectors. As expected, the catch-up is stronger for knowledge extensive service industries compared to knowledge intensive sectors.

The estimation results for other model parameters determining the TFP growth are more nuanced. Among others, there is a significant inter-sectoral variation, implying that different economic sectors respond to different drivers of the TFP growth in a different way and with a different intensity. These results are in line with Kancs and Siliverstovs (2016, 2019) and underline the importance to distinguish between technological and skill intensities between sectors, as proposed in the present study. These estimated TFP coefficients will be used to parameterise the theoretical model and for the policy scenario construction. For those sectors, for which the estimation results are not significantly different from zero or are not sufficiently robust, we use pooled sample estimates.

Private R&D investment

The econometric estimation of multi factor productivity parameters is complemented by an econometric estimation of the private R&D intensity's development over time, t. To estimate R&D intensity parameters, we follow Griffith et al. (2001) and assume that the R&D decision follows an AR(1) process with a constant term:

$$RD_{cst} = a * RD_{cst-1} + c + e_{cst} \quad (15)$$

where a and c are the parameters to be estimated and e_{cst} is the error term. This specification assumes that current R&D investment are affected by past R&D investments with the elasticity a, which determines their persistence over time. The inclusion of the constant term c determines the average R&D expenditures around which all R&D decisions deviate in each period.

The data used to estimate equation (15) are based on the EU-KLEMS dataset as described above. Following the standard approach in literature, our measure of the RD intensity is based on private R&D expenditures as a share of the value added - defined as the output of each industry excluding intermediate goods - in constant prices. On average, R&D expenditures are equal to roughly 3 per cent of total value added, with the highest shares being observed in industries comprising the high-tech manufacturing sector equal to roughly 10 per cent of total value added while the lowest R&D investments as a fraction of value added is found within the traditional sector and equal about 0.9 percent.

The estimation methodology is based on standard dynamic panel estimators of Arellano and Bond. The estimation results are reported in Table 6. They suggest that in most sectors the R&D investment exhibits a significant degree of persistence over time. This means that the levels of the R&D investment do not significantly change from one period to another and to a large extent persist over periods. Exception to this finding is the medium-tech sector, where the estimated elasticity for the medium-tech manufacturing is not statistically different from zero.

Table 4 Sector-specific private R&D investment estimates

	Pooled regression	Traditional	Manufact.	Services	High-tech Manufact.	Low-tech Manufact.	Knowledge intensive services	Other services
RD_{t-1}	0.976***	0.990***	0.902***	0.986***	0.958***	0.928***	0.985***	0.907***

cons	0.00129***	0.000278*	0.00640	0.000326***	0.00627**	0.00161***	0.000522***	0.000366***
Obs.	7347	472	2646	4229	925	996	2375	1854

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

These estimated R&D coefficients will be used to parameterise the theoretical model. Specifically, based on this equation we make projection for the development of the RD intensity across sectors in the future, and therefore are able to calculate the expected long-run values for the research intensity. For example, under standard stationarity assumptions, calculating the long-run first moment of the variable RD in equation (15), we are able to uncover the expected value to which R&D investment decision are expected to evolve in the long-run.

4 Conclusions

The objective of this report was to provide a brief overview of the Regional Trade Flows and Input output Data for Europe. These data are already being employed in a number of model-based assessments of the European Institute of Innovation and Technology investments and the European Investment Bank investments.

The Regional Trade Flows and Input output Data for Europe are constructed at the regional NUTS2 level with sectoral NACE2 detail and developed for being used in spatial macroeconomic modelling and social-economic analysis for answering a wide-range of policy questions, including policies related to investments in innovation, human capital, green infrastructure and Sustainable Development Goals. The constructed Regional Trade Flows and Input output Data for Europe are particularly well suited for structural modelling such as spatial computable general equilibrium models, as all data are fully internally consistent. In the Regional Trade Flows and Input output Data all European regions are connected with each other via inter-regional trade flows, input use and output supply in form of regional trade matrices, input output tables and supply-use tables.

This data base is result of a joint collaborative effort over a decade of several research institutes across Europe, including the Netherlands Environmental Assessment Agency (PBL), the European Commission (DG JRC) and the University of Groningen. Work on the Regional Trade Flows and Input output Data for Europe started more than a decade ago with Ivanova, Kancs and Stelder (2009) and continued with Thissen et al. (2014), Thissen et al. (2018) and Ivanova, Kancs and Thissen (2019).

The new EU Economic Modelling System (EU-EMS) developed within the EU Framework Programme for Research and Innovation makes use of the Regional Trade Flows and Input output Data for Europe. We use the example of the EU Economic Modelling System illustrate the use of the Regional Trade Flows and Input output Data for Europe for modelling purposes.

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