Thesis Research Project

MSc Industrial Ecology

Comparison between a bottom-up and a top-down approach for the compilation of environmental extensions for the Multi-Region Input-Output database EUREGIO

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Acronyms

BUA Bottom-up accounts. iii–vi, 5–7, 15, 19–30, 32–34, 38, 40, 42–47, 59, 61, 64, 79, 82, 87, 89, 90

CBA Consumption-based Accounts. iv, v, 2, 3, 19, 32, 33, 35, 36, 41, 44–47

CES Consumer Expenditure Surveys. 3

CF Carbon Footprint. 3

CoM Covenant of Mayors. 1, 2

CRF Common Reporting Framework. 5

DHW Domestic Hot Water. 17

EC European Commission. 1

EEIO Environmentally Extended Input-Ouput. 2, 3, 19, 24, 31, 42, 44, 46

EEIOA Environmentally Extended Input-Ouput Analysis. 2, 19

FD Final Demand. iv–vi, 15, 19, 24, 28, 30–33, 35–42, 64, 88–90

GFCA Global Framework for Climate Action. 1

GHG Greenhouse Gas. 2, 3, 5, 45

GIS Geographic Information System. 4, 6, 8, 15, 19, 46

HH Households. v, 3, 15–17, 20, 21, 23–25, 36–39, 46, 47, 52, 54, 64, 88

IE Industrial Ecology. 2

IEA International Energy Agency. 14, 16

INDC Intended Nationally Determined Contribution. 1

IO Input-Output. 2, 3, 10, 31, 44, 45

IPCC Intergovernmental Panel on Climate Change. 1

IQR Interquartile Range. 21–23, 32–34, 43

MRIO Multi-regional Input-Output. iii, viii, 3–6, 8, 19, 47

NAMEA National Accouting Matrix including Environmental Accounts. 12, 15, 44

NDC Nationally Determined Contribution. 1, 2

NFR Nomenclature For Reporting. 5

PBA Production-based Accounts. iv–vi, 2–5, 19, 21, 24, 28, 31, 33, 35, 36, 44–47, 83, 84

RQ Research Question. 3, 46, 47

SEEA System of Environmnetal-Economic Accounting. 5, 12, 44, 45

SNA System of National Accounts. 8, 12, 44, 45

SNAP Selected Nomenclature for Air Pollution. vi, 10, 70

SUT Supply and use tables. 12, 14, 15, 44

TDA Top-down accounts. iii, v, 5–7, 15, 18–30, 32–34, 40, 42, 44, 46, 54, 60, 62, 64, 79, 87, 89, 90

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Abstract

In this thesis two different approaches for the construction of environmental extensions compatible with the MRIO database EUREGIO are compared alongside with the latest literature on consumption-based accounts. To date, few studies have focused on the provision of sub-national accounts at the NUTS2 level of detail and never production-based accounts have been compiled for the European NUTS2 level of detail. The first approach described as the bottom-up approach uses TNO's MACC emission inventory for the year 2010 which compiles spatially explicit emission data at the source for 9 different pollutants across Europe with a 0.1° x 0.05° longitude-latitude resolution for over 250 source sectors. The second approach described as the top-down approach uses NAMEA data from EUROSTAT by disaggregating it to the regional level following a linear approach based on the regional economic output of a sector compared to the national economic output of the same sector. The two different approaches for the compilation of environmental extensions are compared both at the production-based accounts and the consumption-based accounts level mapping the existing relative difference across sectors at the national and regional level. The level of heterogeneity in the magnitude of the relative difference of the accounts increases proportionally with geographic detail underlying the fact that a bottom-up construction is able to better grasp the regional scale. This is ever more prominent when looking at particular sectors such as the utilities sectors *ss2* and *ss5*. Of the analysed NUTS2 European regions, the carbon footprint of 74% of the regions presents an upwards deviation of more than 4% compared to the benchmark study with footprints ranging from 2 to 46 tCO_2/cap for Umbria (IT) and Souther Finland (FI) respectively. The obtained results highlight the advantage of the bottom-up approach for more accurate distribution of the emissions at the regional scale from industries to the consumers resonating with similar conclusions from other authors. Despite this, several recommendations are made to improve the quality of the bottom-up approach with possible future applications.

Part 1

Introduction

In a recent publication by the Intergovernmental Panel on Climate Change (IPCC), a comparative assessment has been made on the differences between global warming of 1.5°C and 2°C above pre-industrial levels and the irrevocable consequences of climate change (IPCC, 2018). The consequences of uncontrolled global warming for natural and human systems presented in the special report have again ignited public debate on the lack of swift and concerted actions to curb global warming (UN, 2018; UNFCCC, 2018). Government inertia towards coordinated efforts to combat climate change across the world, has made way for decentralized actors spearheading ambitious mitigation policies at a regional level in Europe and abroad (Bertoldi, Kona, Rivas, & Dallemand, 2018; Fuhr, Hickmann, & Kern, 2018; Hsu, Weinfurter, et al., 2018; Kona, Bertoldi, Monforti-Ferrario, Rivas, & Dallemand, 2018; Lombardi, Pazienza, & Rana, 2016; Nrg4SD, 2017; Pablo-Romero, Pozo-Barajas, & Sánchez-Braza, 2015; Pasimeni et al., 2014).

While some countries are on track to reach their pledged Intended Nationally Determined Contributions (INDCs) and Nationally Determined Contributions (NDCs), an overarching 2/3 of the world's largest emitters are not on track to respect their pledged reductions (Kuramochi et al., 2017) [1]. Examples include Australia, Canada, the EU and the US. Current political turmoil spurred by Trump's intention to withdraw from the Paris agreement made the world plunge in doubt as to whether nation states are the key-holders in the fight against climate change (Hsu, Weinfurter, et al., 2018). On a positive note, despite Trump's administration decision to withdraw from the Paris agreement and thus not respect the US's NDC, regional and local governments in the US alone through locally pledged targets will allow the US to at least respect the NDC by 50 % (Hsu, Weinfurter, et al., 2018)

Local governments hold the key to validate nation-wide climate mitigation policies through the creation of local legitimacy for the central government's policy (Hsu, Widerberg, et al., 2018). At the same time, local governments can provide a basis for the experimentation of broader climate change reduction policies due to their bottom-up approach and reduced amount of involved stakeholders (Fuhr et al., 2018). The perception of urgency to act now at a local scale engages local powers to move towards having cleaner air to breathe and satisfy the ambitious of its citizens. This has led to an exponential growth of local and regional initiatives that go beyond national targets like the NDCs. Currently, the NAZCA[2] platform counts more than 19,100 actions from more than 12,400 stakeholders worldwide.

From a governance perspective, coordinated efforts by local governments will operate as validation playgrounds for the up-scaling of nation-wide policies thus creating a sense of confidence by the centralized government to carry forward more ambitious policy designs (Fuhr et al., 2018). The up-scaling potential of local validated policies may hold the key for the future of policy diffusion in global climatic governance. Examples on the development of a Global Framework for Climate Action (GFCA) for non-state actors has been developed by Chan and Pauw (2014) or the comprehensive framework for effective non-state action by Chan et al. (2015), are examples of ambitious efforts towards harmonization at a sub-national scale. Even though these initiatives represent concrete actions towards combating climate change, the measurement of their combined impact lacks coordination on the political arena (Bertoldi et al., 2018). Nevertheless, such initiatives are definitely a cornerstone towards building more resilient regions worldwide.

In Europe, following the 2020 EU climate and energy package, the European Commission (EC) in partnership with European Cities Networks launched in 2008 the EU Covenant of Mayors (CoM) with the aim of disseminating local/regional strategies to mitigate climate change.

On a global level, a multitude of governance platforms have been created with the aim of bridging

[1] More information can be found through PBL's "climate pledge NDC tool" http://themasites.pbl.nl/climate-ndc-policies-tool/

[2] http://climateaction.unfccc.int

the gap between national and local scales as shown in table 1. Recently, during the COP 23 climate summit of local and regional leaders in Bonn in 2017, a pioneering effort resulted in the redaction of the Bonn-Fiji commitment (ICLEI, 2018). This document has been signed by members of local cities and regions representing over 800 million people. The commitment shows the engagement/ambition of regional leaders to find concrete alternatives to go beyond NDCs and thus respect the Paris Agreement signed in 2016. The document outlines the engagement of the represented community and sets as targets for the future:

- A reduction of CO_{2eq} emissions of 26.8 Gt by 2050 compared to 1990 levels
- Implementation of the Paris Agreement goals according to the 2030 agenda for sustainable development
- Report CO_2 emissions to ICLEI's local and regional climate registry platform *Carbonn*[3]

Table 1: Global examples of governance platforms to support local decision-making structures.

Name	Size of network	Website
EU Covenant of Mayors	7316 EU cities	www.eumayors.eu
ICLEI - Local Governments for Sustainability	1500 cities	iclei.org/en/Home.html
100 Resilient Cities	97 cities	www.100resilientcities.org
C40 - Cities Climate Leadership Group	92 cities	www.c40.org
CNCA - Carbon Neutral Cities Alliance	20 cities	carbonneutralcities.org/cities/

One handicap of the majority of the initiatives presented in table 1 is a severe lack of knowledge on the dimension and scale of the upstream emissions (Croci, Lucchitta, Janssens-Maenhout, Martelli, & Molteni, 2017). This in turn results in initiatives not being able to tackle them and leaving them aside during in their mitigation goals. Furthermore, when it comes to goal-setting, cities and regions elaborate their mitigation plans choosing a methodology/initiative that better suits their needs given the plethora of methodologies available. This makes comparison between initiatives more challenging (Hsu, Widerberg, et al., 2018).

As a step towards helping bottom-up initiatives like the CoM to make more informed decisions, having regional-based Greenhouse Gas (GHG) footprints helps to identify bottlenecks and can contribute to the discussion on the mitigation of upstream emissions triggered by the consumption of products by citizens in regions. Regional-based GHG footprints can be calculated using a combination of economic trade databases and emission inventories. In the field of Industrial Ecology (IE), this is performed through Environmentally Extended Input-Ouput Analysis (EEIOA) to grasp the full extent of the environmental pressures of cities and regions in the global economy (Suh & Kagawa, 2005).

Recently, more studies have been developed with the aim of shedding light on the magnitude of city-scale or regional GHG footprints (Barrett et al., 2013; Cellura, Longo, & Mistretta, 2011; Ivanova et al., 2017; Kanemoto, Moran, & Hertwich, 2016; Miehe, Scheumann, Jones, Kammen, & Finkbeiner, 2016; Minx et al., 2013; Moran, Kanemoto, et al., 2018; Shirley, Jones, & Kammen, 2012; Steen-Olsen, Wood, & Hertwich, 2016; Wiedenhofer et al., 2017) although these have relied in national-to-regional approaches to infer inter-regional trade which is linked with the carbon spillovers (Moran, Wood, & Rodrigues, 2018). To improve accuracy at the regional level, disaggregated Environmentally Extended Input-Ouput (EEIO) systems at the regional level are needed which can better grasp the dynamics of regional trade and emissions (Fry et al., 2018). Bachmann, Roorda, and Kennedy (2015) have developed a regionalised Input-Output (IO) system but only focusing on Canada and not coupled with environmental data. Hence to date, no regionalised EEIO system exists that is able to characterize at the regional level the composition of Production-based Accounts (PBA) and the nature, origin and size of Consumption-based Accounts (CBA).

[3]https://carbonn.org

1.1 Research gap

To address the needs of policy making in the regional context decision-makers must possess information on the impacts of policies catered for the regional scope. Ivanova et al. (2017) have for the first time characterized GHG footprints of HHs across European regions using Exiobase 2.3 MRIO system and sub-national Consumer Expenditure Surveys (CES). The novelty in the research resides in the use of CES to disaggregate the final demand matrix of the MRIO system into sub-national NUTS2 coefficients. This method has been elaborated by Steen-Olsen et al. (2016) and allows for the disaggregation of a country's final demand into sub-national coefficients dependent on regional CES. Ivanova et al. (2017) subsequently used national PBA to calculate CBA at the regional level. In another example, Miehe et al. (2016) have calculated the household Carbon Footprint (CF) of German regions using the EUREAPA MRIO database. Again, CES were used to disaggregate final demand and industrial activity-based emission factors allowed to translate economic activity in CF.

In light of the above paragraphs, there exists the need to address the regional scope with dedicated datasets that are constructed with regional-based information to assess the variations of GHG footprints when the latter are calculated using a top-down approach (national data) or a bottom-up approach (regional data). Furthermore, in Ivanova et al. the PBA are at the national scale which means that to date never a regionalised IO system has been used with a bottom-up approach to compile both regional PBA and CBA. To answer this, a regionalised EEIO system will be described in this thesis with the aim of addressing the regional need from a bottom-up perspective. For this, Thissen, Lankhuizen, van Oort, Los, and Diodato (2018) have developed the first IO system at the European NUTS2 level with 14 extra-European regions for the year 2010. This IO system will be combined with a bottom-up emission inventory from TNO with information on 9 different pollutants. The findings will be compared with a set of regional environmental accounts obtained using national data (top-down approach).

1.2 Research questions

To streamline the research in a systematic way, the following main Research Question (RQ) is formulated:

> *There are many factors affecting carbon footprints at the regional level, how do these compare using a bottom-up versus a top-down approach in the construction of emission accounts?*

In order to answer the main RQ, the following sub-RQ are used:

1. *How to convert a grid-based inventory into compatible regional environmental extensions?*
2. *What are the differences in production-based accounts and consumption-based accounts when using a bottom-up approach versus a top-down approach to assemble environmental extensions?*
3. *What are the differences in consumption-based accounts per capita compared to the benchmark results described in Ivanova et al. (2017)?*

The answer to the first sub-RQ will yield a systematic methodology to convert the emission inventory into a compatible format with the IO system. Sub-RQ 2 will guide the analysis part where a comparison of both approaches will be made using the concept of relative difference towards the baseline scenario. The last sub-RQ will compare the the benchmark literature with the results obtained using the EEIO system described in this thesis.

Part 2

Methodology

The methodology section describes the transformation steps required to derive environmental extensions from a bottom-up emission inventory compatible with a sub-national MRIO. The transformations steps include Geographic Information System (GIS) manipulations, concordance between sectors, regional alignment following the regions present in the MRIO and finally going from an inventory to PBA. The outlined methodology is detailed enough to provide the reader with a reasonable picture of how to reproduce the methodology if needed. Most of the information such as supporting tables and figures will be placed in the appendix section to reduce the size of the methodology section. The Python code can be found in https://github.com/leoIE3.

In the following sections of the methodology, the used datasets are explained in detail followed by the necessary spatial transformations to perform on the emission inventory. Afterwards, the integration of the emission inventory with the EUREGIO MRIO model is further detailed with an insight into the sector matching between datasets that ends with the compilation of a concordance matrix.

In figure 1, an overview of the steps for both the geographic operations and the sector concordance is given.

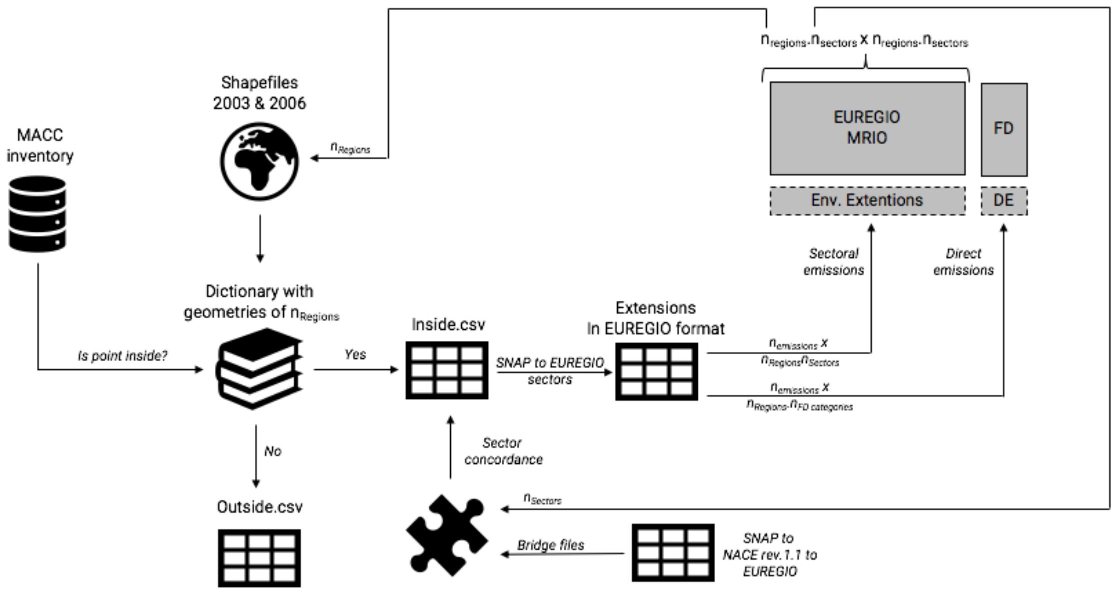


Figure 1: Flowchart of the procedural steps to obtain EUREGIO compatible environmental extensions from the MACC inventory.

2.1 Description of the used datasets

The following datasets for the year 2010 are used in the methodology section:

- MACC emission inventory - *bottom-up construction*
- Eurostat-derived environmental accounts - *top-down construction*
- EUREGIO MRIO system
- Eurostat's 2003 and 2006 shapefiles for Europe's NUTS 2 regions

- TNO's bridge table between SNAP nomenclature and NACE rev. 2
- PBL's bridge table between EUREGIO, NACE rev. 1.1 and WIOD

2.1.1 MACC emission inventory

The MACC emission inventory compiles emissions related with air-quality modelling with the aim of providing to air-quality modellers high-quality spatially explicit information on the most common air pollutants (Denier van der Gon et al., 2017; Kuenen, Visschedijk, Jozwicka, & Denier van der Gon, 2014). It can be seen as a bottom *bottom-up construction* of emissions due to the fact that emissions are spatially distributed across Europe and thus can be linked with sub-national consumption of economic units. Henceforth these PBA are called Bottom-up Accounts (BUA).

Emissions in the MACC inventory for the year 2010 are available for 9 pollutants (CO_2, CO, CH_4, NO_x, SO_2, NH_3, $NMVOC$, PM_{10}, $PM_{2.5}$) distributed over 250 sectors of activity based on a hybrid nomenclature based on Common Reporting Framework (CRF) for GHGs and Nomenclature For Reporting (NFR) for air pollutants. Henceforth, for the sake of simplicity, the combined hybrid nomenclature will be called hybrid SNAP nomenclature.

The emissions are spatially distributed through Europe following a 0.1° x 0.05° longitude-latitude resolution. Emissions can be either from a point-source location or calculated using an area-source approach (see figure 2). Area-sources are calculating using proxies such as population density, road networks and other other similar metrics. Area-sources were the main source for emissions based on residential combustion, road transport and agriculture. For a detailed explanation of the used datasets behind the compilation of the MACC inventory, the dispersion models used and analysis of the results of the MACC inventory, please refer to Kuenen et al. (2014). All hybrid SNAP sectors used in the MACC inventory are shown in appendix B table 21.

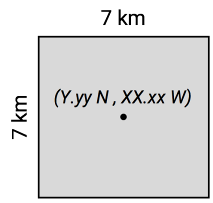


Figure 2: Representation of a point in space where the latitude/longitude pair represents the center-point of a 7x7 km^2 surface.

2.1.2 Eurostat-derived environmental accounts

Eurostat-derived environmental accounts, henceforth referred to as Top-down Accounts (TDA), are used as baseline scenario for the comparison of the BUA. The TDA, follow the guidelines laid out in the System of Environmnetal-Economic Accounting (SEEA) (United Nations et al., 2012) at a national level, although its regionalisation no longer follows the principle. These accounts are fully compatible with the MRIO system in terms of sector and regional resolution and are available for CO_2, CH_4 and N_2O. The metadata used to compile the regionalised TDA can be obtained from table *Air emissions accounts by NACE Rev. 2 activity [env_ac_ainah_r2]*.

The regionalized TDA are compiled using regional factors as proxies to the allocation of national emissions coming from accounts published by Eurostat for the year 2010 (for more information see the manual on the compilation of air emissions accounts by the Eurostat (European Union, 2015)). The accounts published by the Eurostat are initially compiled at a national level and thus need to be decomposed into regional equivalents for compatibility with EUREGIO. The decomposition of national accounts into regional accounts was done using for example population density proxies for the allocation of direct emissions to households, regional sector output divided by total national sector output and other similar ratios for the breakdown of industrial accounts. In the BUA, point-source datasets and other proxies are used spatially distribute stationary combustion emissions over regions, whereas in the TDA, only monetary proxies are used for the disaggregation of emission data for industries. The latter induces a linear distribution of total national emissions to the regional sphere. Equation 1 analytically depicts the disaggregation of national accounts into regional equivalents. Let E be the emissions, s a given sector, p a given pollutant, R all the regions of country c and x the economic output of sector s, the national emissions of sector s and pollutant p can be decomposed as:

$$E_{s,p,c} = \sum_{r=1}^{R} E_{s,p,r} = \sum_{r=1}^{R} \frac{x_{s,r}}{x_{c,s}} \times E_{s,p,c} \tag{1}$$

2.1.3 EUREGIO MRIO system

The EUREGIO MRIO system is comprised of 266 regions of which 252 are in Europe and the remainder 14 are outside of Europe. It has been compiled for the year 2010 and includes highly detailed trade statistics for countries and European NUTS 2 regions (Thissen et al., 2018). It details economic data on 18 industry sectors as shown in appendix B table 17.

The European regions in EUREGIO are both single countries or regions of a country. For example Estonia is a single region whereas Portugal is represented by 5 NUTS 2 regions. Therefore, EUREGIO is a mix of NUTS 2 European regions, European countries and countries outside of Europe. For a detailed view on all regions of EUREGIO please refer to appendix B table 18.

2.1.4 Eurostat's 2003 and 2006 shapefiles for Europe's NUTS 2 regions

Shapefiles are commonly used in GIS programming because they compile a multitude of GIS relevant information such as geometries and points to name a few. They are a common processing requisite for many Python-based libraries that intend to make spatial transformation algorithms.

Being the MACC inventory a spatially characterized emission inventory, each point in space of the inventory has to be interpreted and assigned to a corresponding region of EUREGIO. Two shapefiles are needed to represent the NUTS 2 regions of EUREGIO since the compilation of the MRIO uses different NUTS 2 versions hence the need to use both 2003 and 2006 files. The shapefiles were obtained from the EUROSTAT[4] and for a resolution of 1:10.

2.1.5 TNO's bridge table between SNAP nomenclature and NACE rev. 2

This bridge table provided by TNO is extremely useful because it allows for an almost straightforward way of matching SNAP sectors with NACE rev. 1.1. As said before, the SNAP nomenclature used in the MACC inventory is a hybrid one thus for inconclusive matches, either the GNFR or the NFR codes have to be used to understand the nature of the hybrid SNAP code.

2.1.6 PBL's bridge table between EUREGIO, NACE rev. 1.1 and WIOD

This bridge table makes a link between NACE rev. 1.1 sectors, EUREGIO sectors and WIOD industry codes as described in appendix B table 20.

[4] https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts#nuts16

2.1.7 Bottom-up Accounts versus (BUA) Top-down Accounts (TDA)

Throughout this report, the acronyms BUA and TDA will be used extensively. They refer to the bottom-up approach and the top-down approach to construct environmental accounts compatible with EUREGIO. Both approaches are represented in figure 3. The BUA starts from scattered XY points and clusters them by NUTS 2 region and sector code. Hence emissions are constructed based on local point-sources and area-sources. Conversely, in the TDA national emissions are disaggregated to fit into NUTS 2 regions using equation 1.

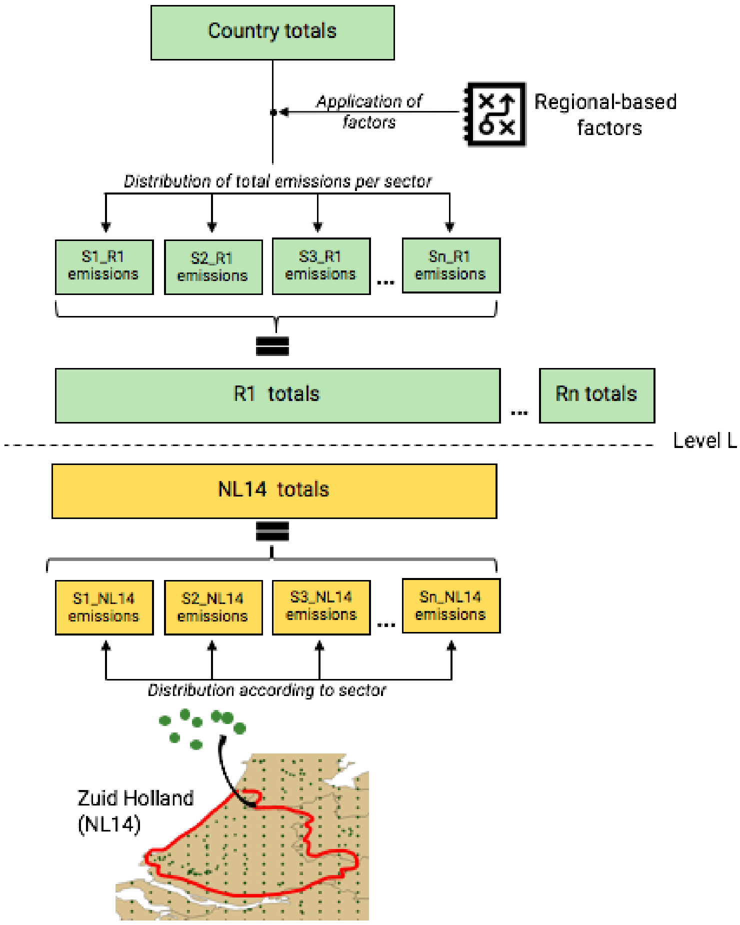


Figure 3: The top-down approach in allocating emissions to regions (PBL) versus the bottom-up approach of clustering emissions from a gridded inventory into emissions from regions (MACC).

Given that the MACC inventory has no emissions from sources outside of Europe, emissions for the 14 regions not belonging to Europe are the same in both BUA and TDA as depicted in figure 4.

2.2 Grid-based emission inventory

Several studies have been done on the transformation of national emissions inventories to produce environmental extensions for MRIO models. Examples include the WIOD database (Genty, Arto, & Neuwhal, 2012) and EXIOPOOL/EXIOBASE (Moll, Giljum, Lutter, & Acosta-Fernandez, 2008; Stadler et al., 2018) to name a few. As described before, EUREGIO is the first European-based regional MRIO model produced from regional statistical data on intra-EU economic transactions and extra-EU trade data (Thissen et al., 2018). Given that the level of detail of EUREGIO

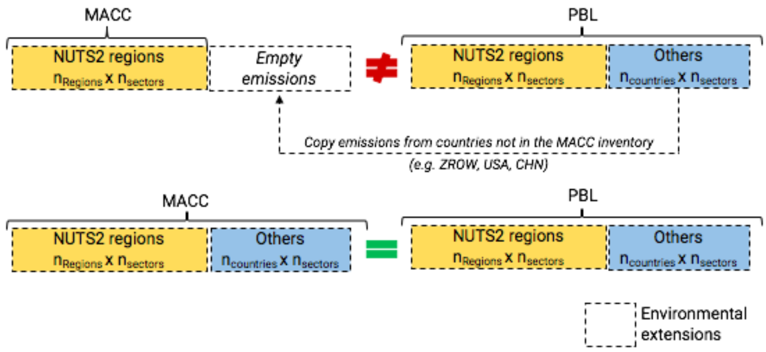


Figure 4: Emissions from countries not represented in the MACC inventory have been allocated from the PBL inventory. Boxes represent environmental extensions.

is per NUTS 2 regions of Europe, it follows that to couple environmental extensions to the MRIO model, the environmental extensions must be organized in the same way as the economic data of EUREGIO. In other words, the geographical and sectoral resolution of the environmental extensions to be coupled with EUREGIO must be the same as the economic transactions taking place between sectors within regions of the MRIO. In matrix notation, this implies a shape of the environmental extensions as $n_{pollutants} \times (n_{regions} \times n_{sectors})$. The territory and residence principle must also be taken into account since EUREGIO respects the accounting rule based on the residence principle. More on this topic will be discussed in the discussion section.

The transformation of the MACC inventory for full compatibility with the System of National Accounts (SNA) would require a multitude of pre-treatment steps that are not compatible with the tight deadline of performing a master thesis. Nevertheless, the MACC inventory can be used in a straightforward way provided that the following assumptions are kept in mind when comparing both bottom-up and top-down approaches of compiling the environmental extensions:

1. Latitude/longitude pairs of emissions will be clustered to regions based on which NUTS 2 region they belong to.

2. Bunkering emissions such as for maritime transport and air transport are taken into account in the following way:

    - Maritime transport: only emissions at port and of domestic shipping are included. The amount of dispersed emissions in the MACC inventory is not based on bunkering fuel consumption as declared in the UNFCCC memo but rather based on a complex Finnish distribution model of shipping routes for the whole world (Jalkanen, Johansson, & Kukkonen, 2016). Thus it would be impossible to "bring back" these emissions to the port of departure and then assign these emissions to the respective economic unit responsible for the purchase of the fuel.

    - Air transport: Given that the MACC inventory only compiles emissions related to taxe, take-off and landing, these are the ones included in the inventory. They are recorded at the location of where there are airports as point sources.

3. Road transport emissions cannot be fully allocated to the respective industries. More on this will be explained in the section dealing with allocation of road transport emissions.

The following paragraphs describe the step-wise procedure to go from the MACC emission inventory to an attempted version of regionalized environmental accounts.

2.2.1 Spatial transformations

In Python, there are powerful GIS modules such as `shapely` and `fiona` that read shapefiles and have useful built-in methods such as `contains` which returns a boolean as to whether or not a point belongs to a geometry. Such functionalities are extremely useful for the spatial transformations needed to manipulate the MACC inventory. After several iterations with the aim of optimizing the computational load of the Python script, the initial part of the script was divided into the following steps:

1. Function `get_mrioregions`: Narrows the search in the shapefile to $n_{Regions}$ of the MRIO to avoid processing regions that are not regionally characterized in the MRIO.
2. Function `get_bboxes`: Compilation of a large dictionary containing NUTS 2 regions as keys and a list with bounding box, shape geometries and names as items.
3. Functions `bbox_contains & insideshp`: The first function will check whether or not a point is inside any of the available bounding boxes. In case this is positive, the next function takes the region of the bounding box and checks if the point is inside the shape of that region.

Step 1 simplifies the shapes that are treated by the script. The euregio MRIO is composed of 266 regions of which 249 are NUTS 2 of Europe, 3 EU countries and 14 are countries outside EU. This means that the shapefile must contain 252 EU shapes to allow spatial integration of the points to the corresponding region. A detailed table with the information on the regions of EUREGIO is in appendix B (table 18) and the available regions in the shapefile in table 16.

Step 2 introduces a filtering step whereby the heavy computation behind the function `contains` is only performed for those points that at least are inside the bounding box of the region. A depiction is presented in figure 5. The light brown region corresponds to the shape of Algarve, Portugal (PT15), the red points represent the latitude/longitude entries in the macc inventory, the green box is the bounding box obtained by the pair of coordinates (x_{min}, y_{min});(x_{max}, y_{max}) that define the lowest/leftmost point of the region and the highest/rightmost point of the region. As said before, there might exist up to 223 entries of the same latitude/longitude pair representing the 223 sector types of the macc inventory.

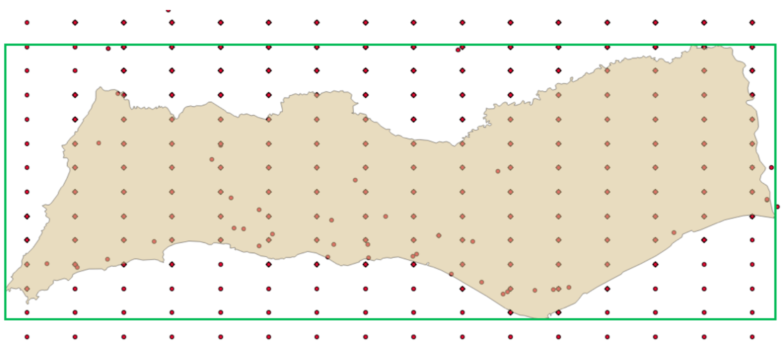


Figure 5: View of the region PT15 in southern Portugal with emissions points in red and the bounding box of the region in green. The points not following the grid array are point source emissions.

The aforementioned steps are repeated for all entries of the macc inventory until two `CSV` files are produced: `inside.csv & outside.csv`. The first, `inside.csv`, has a compilation of all point entries in the inventory that fall within the geographical boundary of euregio's NUTS 2 regions. The second, `outside.csv`, includes all other entries for which a matching euregio NUTS 2 region was not found. In figure 6 the same region PT15 is depicted where the results from `inside.csv & outside.csv` can be identified by the difference in the colors of the points: red points belong to `outside.csv` whereas green points belong to `inside.csv`. The figure also shows surrounding regions to show that the dataset `inside.csv` clearly includes only those points that fall within the shape.

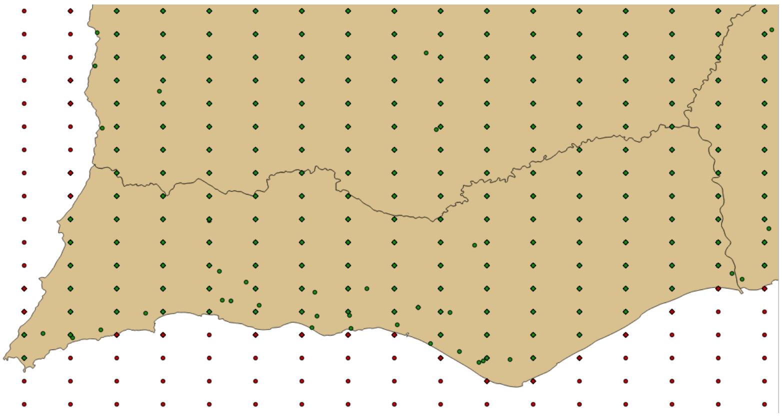


Figure 6: View of the region PT15 with emissions clustered by region and with adjacent regions. A clear demarcation exists between points inside and outside the shape where green points represents those inside and red the points those outside.

The two `csv` files close the necessary spatial transformations to populate NUTS 2 regions within euregio with MACC inventory entries.

2.3 Sector concordance

Sector concordance is a crucial part when compiling extensions due to the differences in sectoral resolution of different datasets. Furthermore, the more aggregated sectors are in the dataset, the more subjective choices have to be made when going from one classification to the other. On the other hand, datasets like the MACC inventory provide very detailed information on the emissions sources of 223 sectors, while the euregio has 18 sectors only. In this case, aggregation might mean loss of detail although simplifying the work behind the compilation of the IO system.

The challenge therefore is to create bridges between sectors by means of correspondence tables that allow to grasp as much detail as possible in a systematic way which can be reproduced in future work and is correctly documented with all underlying assumptions. In table 2 an overview of the sectors in the MACC inventory and the IO system is shown.

Table 2: Number of high-level sectors in the relevant sector classifications.

	Classification		
	MACC (SNAP)	EUREGIO	NACE rev. 1.1
Number of sectors	223	18	64

To narrow down from 223 MACC sectors to 18 EUREGIO sectors, the following logic is used: MACC (SNAP)→NACE rev. 2→NACE rev. 1.1→EUREGIO. This sequence is preferred due to the availability of a bridge matrix from TNO showing the correspondence between SNAP and NACE rev. 2. Without this table, with would be plain guesswork to workout the correspondent NACE sector to the SNAP one. In appendix B, the sectors in MACC are shown in table 21 and the concordance between WIOD/EUREGIO/NACE rev. 1.1 in table 20.

The aim of the sector concordance section is thus to provide a stepwise overview of the necessary steps to transform SNAP sectors into EUREGIO sectors. In the end, a concordance matrix cab be obtained that allows for quick sector code replacement in the `inside.csv` using the `map` method.

2.3.1 Concordance matrix

The concordance matrix was built following these sequential steps:

1. Correspondence between hybrid SNAP sector and NACE rev. 2 sector
2. Correspondence between NACE rev. 2 sector and NACE rev. 1.1
3. Handling the problem of multiple sectoral allocation of step 1
4. Concordance matrix between NACE rev. 1.1 and EUREGIO to import to Python.

Below a description is given on the details of each step with a generic example for petroleum refining (sector *1210 - oil & gas refining (comb)*) in the MACC inventory for further clarification.

2.3.1.1 Correspondence between snap and NACE rev. 2 sector

The MACC inventory has 226 sectors between parent and child sectors. Sometimes the parent sector has emissions and other times it is empty. In the case of sector *1210*, the parent sector is *1200 - Refining*. The SNAP nomenclature is used by the MACC inventory, but as mentioned in Kuenen et al. (2014), it has been hybridised and thus a direct correspondence between SNAP and NACE rev. 2 cannot be used. As seen in figure 7, and knowing that the sector to analyse is *1210 - oil & gas refining (comb)*, the ancillary table is thus filtered on the column "SNAP name" and the keyword "refining" is used as a search term. The filtered view in figure 7 points to the corresponding NACE rev. 2 sector being *19.2 - Manufacture of refined petroleum products*.

NACE Rev1.1 Eurostat	NACE Rev.2 SECTOR	NACE Rev.2 ACTIVITY	SNAP	SNAP name
			010300	**Petroleum refining plants**
23 and/or 40	19.2	35.3	010301	Petroleum refining - Combustion plants >= 300 MW (
23 and/or 40	19.2	35.3	010302	Petroleum refining - Combustion plants >= 50 and <
23 and/or 40	19.2	35.3	010303a	Petroleum refining - Combustion plants >= 20 and <
23 and/or 40	19.2	35.3	010303b	Petroleum refining - Combustion plants < 20 MW (bo
23 and/or 40	19.2	35.3	010304	Petroleum refining - Gas turbines
23 and/or 40	19.2	35.3	010305	Petroleum refining - Stationary engines
23 and/or 40	19.2	35.3	010306	Petroleum refining - Process furnaces

Figure 7: Example of one of the corresponding cases between sectors in the ancillary file. In this case the SNAP sector *010300 - Petroleum refining plants* which corresponds to NACE rev.2 *19.2 - Manufacture of refined petroleum products*.

2.3.1.2 Correspondence between NACE rev. 2 and NACE rev. 1.1

Once the NACE rev. 2 sector is known for the given MACC sector, a table obtained from the EUROSTAT [5] provides the equivalence between the two classifications. In this case, NACE rev.2 *19.2 - Manufacture of refined petroleum products* corresponds to *10.1-3* and *23.2* as reported in table 3. Given the scope of the sector, the previous relation in figure 7 and the parent SNAP sector is *1200 - Refining*, the allocation will be done to NACE rev. 1.1 *23.2 - Manufacture of refined petroleum products*.

[5] https://ec.europa.eu/eurostat/web/nace-rev2/correspondence_tables

Table 3: Correspondence between NACE rev.2 and NACE rev. 1.1

NACE rev. 2	Description	NACE rev 1.1	Description
19.2	Manufacture of refined petroleum products	10.1	Mining and agglomeration of hard coal
19.2	Manufacture of refined petroleum products	10.2	Mining and agglomeration of lignite
19.2	Manufacture of refined petroleum products	10.3	Extraction and agglomeration of peat
19.2	Manufacture of refined petroleum products	23.2	Manufacture of refined petroleum products

2.3.1.3 Handling the problem of multiple sectoral allocation of step 1

The aforementioned sector, is quite straightforward in terms of allocation. Other sectors require further refining to obtain one single correspondence whenever the NACE rev. 2 sectors belong to several EUREGIO sectors. This is the case for sectors where a high degree of ambiguity exists such as SNAP sector *2717 - Coating applications*. Here, the bridge table points to almost all NACE rev. 2 sectors where manufacturing takes place. To circumvent this, and because these NACE rev. 2 sectors spread over several EUREGIO sectors (3, 4, 5, 6, and 8), the parent sector is thus used as a proxy for the correct allocation which in this case is *2710 - Solvent use*. Solvent use is a less ambiguous sector according to the SNAP nomenclature even though different end-uses are described in the bridge file. Nevertheless, they all point to chemical applications and thus following the approach whereby the emissions are brought back to the parent sector, in this case they will be assigned to EUREGIO sector 5 - *Coke_refined_petroleum_nuclear_fuel_and_chemicals_etc* which includes all chemical manufacturing.

Other more complicated allocations such as the ones for transport, heating and agriculture are dealt in section 2.4.

2.3.1.4 Concordance matrix between NACE rev. 1.1 and EUREGIO

The concordance matrix will be of size $n_{SNAPSectors} \times n_{EUREGIOSectors}$ and is largely based on table 20 in appendix B. The table provides a straightforward integration in Python and is used to replace all SNAP sector codes in the files `inside.csv & outside.csv` by the corresponding euregio sector code. It is composed of 0 and 1 entries where the corresponding SNAP sector matches the EUREGIO entry.

2.4 Compilation of EUREGIO compatible environmental accounts

According to the SEEA framework several accounts can be compiled that are compatible with the SNA. These include energy accounts, material accounts, water accounts, emissions accounts, etc. All of these are compiled using supporting inventories/datasets that are not usually in the format required by the SEEA[6]. The allocation procedure explained in the following subsections is the result of detailed investigation on the nature of the sources of emissions recorded in the MACC inventory. This information has been obtained from experts at TNO following several meetings held during the thesis research period. The procedures detailed in the compilation of WIOD compatible accounts (Genty et al., 2012) and EXIOBASE compatible accounts (Kuenen,

[6] An exception is the National Accouting Matrix including Environmental Accounts (NAMEA) compiled by EUROSTAT providing accounts for air emissions.

Fernandez, Usubiaga, & Wittmer, 2013) were followed to the extent that data was available. Since Supply and use tables (SUT) for EUREGIO are not available, other proxies were used to compile accounts for certain sectors.

2.4.1 Allocation of transport emissions

Transport emissions in the MACC inventory are split between several SNAP codes although only the following hybrid SNAP codes have associated emissions in the `inside` file:

- Road transport:
  - *3100 - Passenger cars*
  - *3310 - Trucks (>3.5t)*
  - *3200 - Light duty vehicles*
  - *3320 - Buses*
  - *3410 - Motorcycles*
  - *3420 - Mopeds*
- *4710 - International transport, at sea*
- *4100 - Civil aviation - LTO*
- *4200 - Railways*

Road transport emissions in the MACC inventory are compiled using specific data sources such as each country's submission to the UNFCCC followed by a dispersion model based on several socio-economic proxies. More information on the used methodology can be found in the EMEP/EEA guidebook (EMEP/EEA, 2016).

Shipping emissions in the MACC inventory follow a dispersion model developed by the Finnish meteorological institute [7]. The emissions are not calculated by TNO but follow a worldwide emission registry. Given the nature of the `inside` and `outside` files, the emissions spread throughout shipping routes are recorded in the `outside` file. Hence only the emissions occurring within the port area or of domestic navigation nature are included. This obviously leads to severe underestimation of the amount of shipping emissions. The magnitude of the underestimation is in shown in table 22 in appendix B where it can be seen the difference between emissions in the MACC inventory and the EUROSTAT accounts where the latter are approximately 12x higher. Meaning that shipping emissions available in the MACC following a GIS approach will always be underestimated unless a different approach is followed.

Air transport emissions in the MACC inventory are only for take-off, taxi and landing (LTO NFR category *1.A.3.a.ii - civil aviation - LTO)* [8] and for domestic flights. Thus "cruise" emissions are not included as these are reported under bunker emissions in the UNFCCC submissions. This leads to a similar problem as with international shipping and the respective magnitude is reported in table 22 appendix B. Similar to shipping emissions, air transport emissions from LTO origin are substantially smaller than the ones provided by EUROSTAT accounts where the latter is approximately 3.5x higher.

As described in the sector concordance section, the transport sector in EUREGIO (*ss12*) gathers all emissions from transport sources where road, rail, air and water are all under the same category. This obviously leads to overestimation when clustering all sources of transport under the same emission intensity. More elaboration on this topic is provided in the discussion section.

[7] https://en.ilmatieteenlaitos.fi/surveying-maritime-emissions

[8] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation-2016

The subsequent subsections will detail the followed assumptions to allocate emissions from each source.

Truck (>3.5t) and light vehicle emissions

Inventoried truck and light vehicle emissions, henceforth called heavy vehicles, are composed of two contributors:

1. Emissions from the combustion of fuel by heavy vehicles belonging to the transport sector: $E_{r,heavy,transport}$
2. Emissions from the combustion of fuel by heavy vehicles belonging to all other sectors: $E_{r,heavy,others}$

where E represents the emissions and r the region. The breakdown of allocations between the transport sector and other sectors requires a proxy indicating the proportions of emissions by the transport sector and all other sectors. Initially, and following the methodology described in the compilation of environmental accounts for WIOD and EXIOBASE (Genty et al., 2012; Kuenen et al., 2013), it was thought to use the energy balances in EUROSTAT which collect the input of different energy commodities to NACE sectors[9]. By using energy consumption data, emission factors and combined with vehicle use statistics, the amount of air emissions by the different intermediate sources can be inferred. Obviously, the degree of emissions pertaining to activities abroad cannot be grasped in the MACC inventory due to the dispersion models used. These as mentioned above use the UNFCCC declarations which report under the territory principle.

Nevertheless, and according to the energy balances from the International Energy Agency (IEA) (which serves as basis for the EUROSTAT's energy balances), all energy consumption that relates to transport in public roads is to be recorded under the category *transport* regardless of the sector where the energy consumption takes place (IEA, 2004). This makes it impossible to use EUROSTAT's energy commodity balances to infer the consumption of fuel for heavy vehicle usage in each NACE sector. In other words, it would be impossible to estimate heavy vehicle emissions, both for the transport sector and all other sectors, based on the energy commodity balances provided by EUROSTAT. This is because without the data in the SUT of EUREGIO, it would be extremely hard to estimate intermediate fuel consumption by different sectors of activity. In light of this, an alternative for allocation was found using transport & logistic statistics available in eurostat. For this, two datasets are used in combination:

1. Table *road_go_na_tgtt* providing the distinction between own transport and hired transport for carriage of goods by road.
2. Table *road_go_na_rl3g* gives at a NUTS 3 level the breakdown for carriage of goods by road.

The first table, indicates at a national level the split between own transport and hired transport for the categories in carriage of goods by road. The second table provides a breakdown in terms of the carriage of goods by road at a NUTS 3 level. Combining both by means of aggregating NUTS 3 level to NUTS 2 level using a weighted average and the share of own/hired transport yields regional proxies for the allocation of the heavy vehicle emissions for the transport sector and all other sectors. Let α be the NUTS 3 share of carried goods displayed as a weighted average between carried goods for sector s and region r', β the share of own transport for carried goods, M is the transported mass per sector s and r' a NUTS 3 region belonging to a NUTS 2 region r, then the share of heavy vehicle emissions for sector s in region r is:

$$E_{r,heavy,s} = \alpha_{s,r} \times \beta_{s,C} \times E_{r,heavy} = \frac{M_{s,r'}}{\sum_{r'=1}^{r}\sum_{s=1}^{S} M_{s,r'}} \times \frac{own_{s,c}}{total_{s,c}} \times E_{r,heavy} \qquad (2)$$

[9] Table nrg_cb_oil as an example.

Conversely, the share of heavy vehicle emissions of sector s that result from the hiring of transport services $(1 - \beta_{s,c})$ from the transport sector and thus belonging to the transport sector is:

$$E_{r,heavy,s2transport} = \alpha_{s,r} \times (1 - \beta_{s,c}) \times E_{r,heavy} = \frac{M_{s,r'}}{\sum_{r'=1}^{r} \sum_{s=1}^{S} M_{s,r'}} \times (1 - \frac{own_{s,c}}{total_{s,c}}) \times E_{r,heavy} \quad (3)$$

Applying equations 2 and 3 to all NUTS 3 regions distributes heavy vehicle emissions on a regional basis to each corresponding NUTS 2 region to each sector s plus to the transport sector.

In terms of correspondence between the sectors defined in the carriage of goods by road and EUREGIO sectors, table 23 in appendix B shows the relation between sectors.

Passenger car, motorcycle and moped emissions

In line with was mentioned above for the allocation of emissions from heavy vehicles (namely the procedures for WIOD and EXIOBASE), passenger cars would require a similar proxy for allocation based on the consumption of energy products by HH. Again, given the lack of SUT from EUREGIO, it would be impossible to infer regional consumption of petroleum derived products like CPA23 and subtract that from the energy input to transport (WIOD method).

It was chosen to fully allocate all passenger car emissions to HH knowing that this is not accurate and will overestimate the direct emissions of HH. Table 24 in appendix B shows the overestimation problems where HH will see higher direct emissions allocated to that FD category when compared with TDA. The first column *Transport activities by households* shows the sum of passenger car, motorcycle and moped emissions in the case of the BUA whereas in the case of TDA it is notorious that *Transport activities by households* are on average 78% inferior than *Fuel combustion in cars*. This means that the difference between *Fuel combustion in cars* and *Transport activities by households* in the case of TDA are the amount of passenger car emissions to be allocated to intermediate consumption, i.e., other sectors of activity other than HH. As no proxy could be found for the allocation of passenger car emissions to intermediate consumption, these are all allocated to HH in the BUA.

Shipping emissions

Shipping emissions included in the are based on the Finnish model of global shipping emissions. Due to this, and the fact that the BUA are constructed based on GIS, it is not possible to report back these emissions to the port of departure or place of tanking. Nevertheless, and given that in the NAMEA there are the national maritime transport accounts, these values can be used in the construction of the BUA. Despite this possibility, it was chosen not to merge different data sources and thus the compilation of BUA resides solely in the MACC inventory. This leads to substantial underestimations of the shipping emissions for countries like Denmark, Malta, etc.

Allocation of air transport emissions

A similar approach as in shipping emissions was adopted for air transport emissions. Whereas the national air transport accounts are known from the NAMEA, from the MACC inventory only a fraction of the emissions related to air transport are recorded. As with shipping emissions, it was chosen to not use ancillary datasets and thus only data from the MACC inventory.

2.4.2 Allocation of heating emissions

Heating emissions arise from the combustion of energy products such as petroleum derived products for the purpose of space heating. As with other allocation exercices, proxies have to be used to correctly distribute these emissions within HH and sectors of activity. Heating emissions in terms of hybrid SNAP codes in the MACC inventory are:

- *2810 - Other manufacturing industry (comb)*
- *5100 - Commercial/institutional stationary combustion*
- *5200 - Residential stationary combustion*

The subsequent subsections will detail the followed assumptions to allocate emissions from each source.

Manufacturing (process) heating emissions

Under the reporting guidelines in the UNFCCC, industries report their energy use[10] in isolated categories. Several industries nevertheless are grouped under the umbrella term "other" in the MACC inventory. If one subtracts the existing unique codes for industries such as steel, cement, etc., the remaining industries that are left and thus grouped under *2810 - Other manufacturing industry (comb)* are:

- Machinery
- Mining
- Construction
- Textile and leather
- Non-specified

The allocation of emissions from SNAP code 2810 to the respective industries was done using proxies of energy use per NACE rev. 2 sector. This was performed using the consumption of oil products and gas from eurostat (tables nrg_cb_oil and nrg_cb_gas) as a way to infer a distribution factor amongst the above mentioned sectors based on their total use of gas and oil products. Let s be one of the sectors requiring allocation, O the consumption of oil products and gas, α a national weighted average between the consumption of oil products and gas of sector s over the whole consumption of oil products and gas across countries, the share of emissions from SNAP 2810 to be allocated to each sector is:

$$E_{r,2810,s} = \alpha_{s,c} \times E_{r,2810} = \frac{O_{s,c}}{\sum_{c=1}^{C}\sum_{s=1}^{S} O_{s,c}} \times E_{r,2810} \tag{4}$$

where s refers only to the sectors mentioned above (machinery, mining, construction, textile and leather and others). The correspondence between NACE rev. 2 sectors and EUREGIO sectors has already been reported earlier (cf. table 20).

Commercial heating emissions

After careful analysis with experts on emissions from TNO, it was concluded that hybrid SNAP code *5100 - Commercial/institutional stationary combustion* gathers emissions from all other "industrial" sectors other than industries. This is the case for NACE rev. 2 sectors from 50 to 99 which resonates with what the IEA compiles under *commercial and public services.*[11]. Given that no suitable proxy can be used in a straightforward way to disaggregate the category *commercial and public services* under which all energy consumption by such sectors is reported, a different proxy had to be found.

[10] https://www.iea.org/statistics/resources/balancedefinitions/

[11] Commercial and public services [ISIC Divisions 33, 36-39, 45-47, 52, 53, 55, 56, 58-66, 68-75, 77-82, 84 (excluding Class 8422), 85-88, 90-96 and 99]. https://www.iea.org/statistics/resources/balancedefinitions/

A report from the JRC on the heating and DHW needs in public and commercial buildings for the year 2009 was found (Pardo, Vatopoulos, Krook-Riekkola, Moya, & Perez, 2012). This report compiles disaggregated energy needs for the following types of commercial and public buildings with the matching EUREGIO in parenthesis:

- Hospital (*ss15*)
- Hotels and restaurants (*ss11*)
- Sport and recreation (*ss15*)
- Shop - large and small (*ss10*)
- Offices (*ss13-ss15*)

The different shares of energy consumption per type of building are shown in table 25 in appendix B. With the knowledge on the shares of energy consumption per type of building in the *commercial and public services* category, the emissions recorded under *5100 - Commercial/institutional stationary combustion* can be allocated between the responsible sectors. Let s be one of the sectors in *commercial and public services*, P the energy consumption for heating and Domestic Hot Water (DHW), α a national weighted average between the energy consumption of sector s over the whole energy consumption, the share of emissions from SNAP *5100* to be allocated to each sector in region r is:

$$E_{r,5100,s} = \alpha_{s,c} \times E_{r,5100} = \frac{P_{s,c}}{\sum_{c=1}^{C} \sum_{s=1}^{S} P_{s,C}} \times E_{r,5100} \tag{5}$$

For the offices category where 3 EUREGIO sectors are concerned, the disaggregation between EUREGIO sectors is done using a share of the economic output per country:

$$\alpha_{s,c} = \frac{X_{s,c}}{X_c}, \forall s \in S = \{ss13,\ ss14,\ ss15\} \tag{6}$$

Household heating emissions

HH are subject to a straightforward allocation where all emissions belonging to SNAP code *5200 - Residential stationary combustion* are entirely allocated to HH.

2.4.3 Allocation of mobile combustion emissions in agriculture/forestries/fishing

Similar to other sources of emissions arising from the combustion of energy products, sector *ss1 - Agriculture* should be subject to the allocation of emissions per each sub-sector of sector *ss1*:

- Crops (*ss1a*)
- Livestock with land (*ss1b*)
- Livestock without land (*ss1c*)
- Forestry (*ss1d*)
- Fisheries (*ss1e*)

Emissions from combustion for these sub-sectors are recorded under SNAP code *4400 Small combustion - Agriculture/Forestry/Fishing - Off-road vehicles and other machinery.* To make intermediate allocations to the sub-sectors, the EUROSTAT's table on the consumption of oil products is used[12] as a proxy for the consumption of oil-derived products per each sub-sector. In the table, a split between agriculture/forestries and fisheries is provided which allows the breakdown of SNAP code *4400* into 2 types of sources: fisheries and all other sub-sectors of agriculture combined. Let u be a sector of the set U, P the consumption of oil-derived products and $\alpha_{p,c}$ the share of consumption of P, the emissions to be allocated to fisheries $E_{c,4400,ss1e}$ and agriculture/forestries $E_{c,4400,U}$ in country c are:

$$E_{c,4400,U} = \alpha_{p,c} \times E_{c,4400} = \frac{P_{c,U}}{P_{c,U}+P_{c,ss1e}} \times E_{c,4400} \quad (7)$$

$$E_{c,4400,ss1e} = \alpha_{p,c} \times E_{c,4400} = \frac{P_{c,ss1e}}{P_{c,U}+P_{c,ss1e}} \times E_{c,4400} \quad (8)$$

$$where\, U = \{ss1a, ss1b, ss1c, ss1d\} \quad (9)$$

The above equations make explicit the share of SNAP code *4400* into each sub-type of agricultural sector. To breakdown those country aggregated values into regional equivalents two assumptions are made:

1. Regional emissions of agriculture/forestries (U) have the same share as in the national aggregation (equation 10)
2. Emissions of fisheries at a regional scale follow the share of regional economic output for sector $ss1e$

In the cases where it is not possible to make a breakdown between consumption of oil products because some countries do not report this distinction, the european average of $\alpha_{p,c}$ is used. This applies to for example Germany, Greece, Spain and others more. The overview of national $\alpha_{p,c}$ coefficients is in appendix B table 26 where the allocation of $\alpha_{p,c}$ to countries is shown.

Agriculture/forestries

Given the lack of an additional proxy to decompose sectors in U, and assuming that the economic output of sectors is not representative of the share of emissions (contrary to the procedure in the compilation of TDA), emissions will be distributed equally amongst all sectors in U according to the count of elements in U:

$$\beta_{u,r} = \beta_{u,c} \equiv \frac{E_{r,4400,u}}{E_{r,4400,U}} = \frac{E_{c,4400,u}}{E_{c,4400,U}}, \forall\, u \in U \quad (10)$$

$$E_{r,4400,u} = \frac{E_{r,4400,U}}{|U|} \quad (11)$$

Fisheries

To allocate combustion emissions arising by the activities of fishing boats at a regional scale, the regional share of economic output of fisheries compared to the national total is used. As seen in appendix A figure 31, regions by the sea side tend to have the highest economic output. This proxy is used as a means to distribute $E_{c,4400,ss1e}$ amongst the regions where fishing activities take place. Let $\phi_{r,c}$ be a regional share of the total economic output of country c, the regional emissions of fisheries $E_{r,4400,ss1e}$ in region r can be put as:

$$E_{r,4400,ss1e} = \phi_{r,c} \times E_{c,4400,ss1e} = \frac{X_{r,ss1e}}{X_{c,ss1e}} \times E_{c,4400,ss1e} \quad (12)$$

[12] Supply, transformation and consumption of oil and petroleum products [nrg_cb_oil]

Part 3

Analysis

The analysis chapter is divided into four sections: (1) a section analysing the PBA, (2) a section analysing the production intensity, (3) a section delving into the CBA and (4) a section dedicated to the comparison between the results using the bottom-up approach BUA and the only available to-date benchmark study from Ivanova et al. (2017). Across sections, insights into the results obtained using BUA are given and discussed to highlight future work. Given that both environmental account matrices are obtained following different methodologies (bottom-up VS top-down), it is interesting to point out where the discrepancies occur in terms of scale (national/regional) and report the magnitude of these discrepancies in terms of relative difference:

$$\Phi = \frac{BUA - TDA}{TDA}$$

Recall that the only CO_2 and CH_4 are comparable pollutants in both BUA and TDA and thus for the sake of simplicity, the pollutant compared across all sections is CO_2.

To make sure that the EEIO system is in balance, a few verifications are performed to assess mainly that the *input* emissions making up the PBA are the same as the emissions assigned to FD categories in the PBA. To verify this, the following steps are applied:

- Validation of the GIS code where the MACC inventory is translated into the files `inside` and `outside` with further plotting in QGIS for visual confirmation. The sum of rows in both files has to be equal to the raw MACC inventory.
- Visual inspection of the `inside` and `outside` files to be sure that they represent what they are meant. All points in `inside` should be inside regions and vice-versa for `outside`. Figures 29 and 30 in appendix A depict the GIS transformations.
- Checking the balance of the EEIO:
  - The consumption-driven emissions BLY equal the emission matrix R
  - The total output of the system is equal to the total input $X_{0ut} = X_{in}$:
    $Z + Y = Z + VA \equiv \sum_{j=1}^{n} z_{ij} + \sum_{j=1}^{n} y_{ij} = \sum_{i=1}^{m} z_{ij} + \sum_{i=1}^{m} va_{ij}$

where R denotes the emission matrix composed of $i \in I = \{1, ..., m\}$ pollutants and J is composed of $j \in J = \{1, ..., n\}$ regions x sectors, B denotes the emission intensity matrix which is obtained through $b_{ij} = \frac{r_{ij}}{x_j}$, L is the Leontief inverse matrix obtained by the formula $L = (I - A)^{-1}$ where I is the identity matrix and A is the direct requirement matrix where $a_{ij} = \frac{z_{ij}}{x_j}$, Y is the final demand matrix and VA refers to the value added matrix. These verifications, notably the ones pertaining to the EEIO system are extremely important. An unbalanced system will never yield accurate results thus any discrepancies must be corrected as they are detected.

Some terminology is needed to guarantee the correct understanding of the subsequent sections. Table 4 displays all the adopted terminology. As a reminder, the MRIO system has 266 regions of which 252 are in Europe (c.f. table 18).

3.1 Production-based accounts

In this section, BUA and TDA are compared which represent the R matrix in EEIOA language. Both accounts have been organized respecting the format of the EUREGIO MRIO. Recall that the accounts are being compared only for European countries. To compare both accounts, the relative

Table 4: Terminology adopted.

Item	Name	Size ($m \times n$)	Remarks
Z	Intermediate demand matrix	4788×4788	266 regions per 18 sectors (square size)
A	Direct requirement matrix	4788×4788	266 regions per 18 sectors (square size)
L	Leontief inverse matrix	4788×4788	266 regions per 18 sectors (square size)
Y	Final demand matrix	4788×1064	266 regions per 18 sectors per 266 regions per 4 final demand categories
x_{out}	Total output vector	4788×1	266 regions per 18 sectors per 1 total column
R	Emission matrix	9×4788	9 pollutants per 266 regions per 18 sectors
B	Emission intensity matrix	9×4788	9 pollutants per 266 regions per 18 sectors
M	Production intensity matrix	9×4788	9 pollutants per 266 regions per 18 sectors
HH	Household emissions or direct emissions matrix	9×1064	9 pollutants per 266 regions per 1 final demand category

difference Φ is used to investigate at the sector level where the divergences occur. Comparing at the sector level is more relevant since it will highlight variations that may stem from:

1. The difference between using a top-down approach and a bottom-up approach to compile environmental accounts where the bottom-up approach is expected to depict more accurately the reality
2. The allocation procedure adopted in the methodology section leading to allocation problems
3. Identify potential inventory issues in the MACC that require further analysis

3.1.1 National level

At the most aggregated level, an important figure to compare is the total emissions summed over regions and sectors for either of the account constructions. This number a priori will differ given the assumptions discussed in section 2.4 in terms of transport emissions[13]. Nevertheless, comparing total emissions gives a magnitude of that difference. Table 5 compiles both totals using equation 13 where i in this case relates to CO_2.

$$R_{CO_2} = \sum_{j=1}^{n} r_{ij} \tag{13}$$

Table 5: Total CO_2 emissions in the system (excluding non European regions).

Method	Sectoral emissions [Mt]	HH emissions [Mt]	Total [Mt]
BUA	3,152.02	1,213.23	4,365.25
TDA	3,227.75	938.48	4,166.23
Difference $BUA - TDA$	-75.74	274.75	199.01
Relative difference Φ in %	-2.3	29.3	4.8

A small relative difference of less than 5% exists when summing sectoral emissions and HH emissions. Also it is noticeable that in the BUA, the share of emissions allocated to HH is largely

[13] Recall that international shipping emissions, cruise altitude emissions and some passenger car emisisons have not been included in the BUA

greater than in TDA which has already been explained in the section 2.4 due to the different allocation assumptions (namely passenger cars). This implies that better allocation proxies for transport emissions are still needed in BUA construction since a large share of passenger vehicle emissions should be allocated to production sectors.

Looking now at the at the sector level, a considerable level of heterogeneity exists in terms of relative difference when looking at the variations existing at the sector level in figure 8. Some sectors such as *ss1e*, *ss2*, *ss3*, *ss5*, *ss6*, *ss10*, *ss12*, *ss14*, *ss15* and HH present small variations in terms Interquartile Range (IQR) variation which can be observed by the small size of the upper and lower quartiles. Whisker sizes in these sectors are also considerably smaller compared to other sectors indicating that the countries which are not outliers have similar results in terms of relative difference

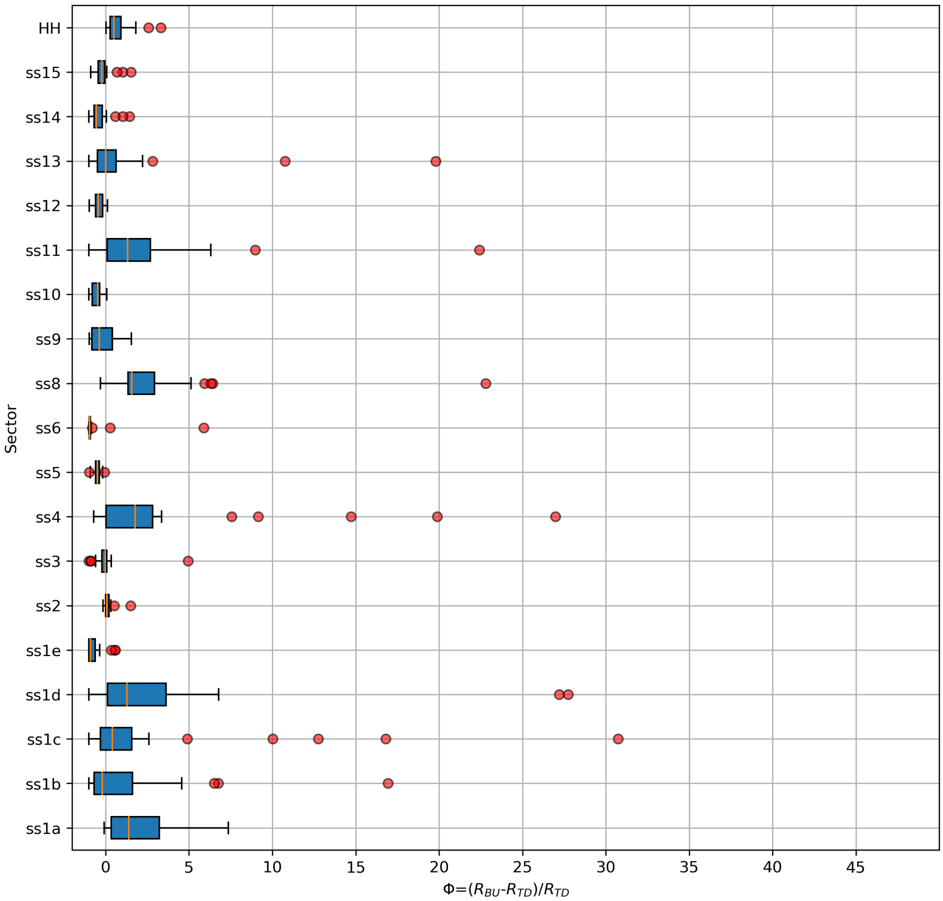


Figure 8: Boxplot depicting the distribution of the relative difference Φ of the origin of indirect emissions at a country level per sector. Red points represent outliers.

Nevertheless, some sectors have a large degree of variation in their distribution. To avoid going through all sectors, take sector *ss8* as an example which is a sector accounting for 21% of the total PBA in the bottom-up construction. Sector *ss8* includes all sorts of manufacturing as described in table 20 in appendix B. The outliers in this sector are Bulgaria, Cyprus, Greece and Portugal with relative differences of 5.94, 22.8, 6.31 and 6.42 respectively. In the lower end of the minimum whisker there is Malta with a relative difference of -0.3 and Lithuania at the top of the maximum whisker with 5.11. The values inside the IQR are mostly concentrated in the lower quartile since the median is towards the left side of the range showing a value of approximately 1.5. The country closest to zero relative difference is The Netherlands with 0.18 which already represents a upwards divergence of 14%. Country totals and their respective relative differences are reported in appendix

B tables 29 and 28. The values in table 28 are used to build the boxplot in figure 8.

Table 6: List of the outliers depicted in figure 8 and count of outliers at the regional level in figure 9.

Sector	Outliers (national level)	# Outliers (regional level)
ss1a	-	21
ss1b	Lithuania, Slovakia, Estonia	34
ss1c	Lithuania, Slovakia, Ireland, Slovenia, Estonia	25
ss1d	Italy, Ireland, Spain, United Kingdom, Greece	45
ss1e	Bulgaria, Estonia, Greece	28
ss2	Sweden, Austria	23
ss3	Malta, Germany, Estonia, Greece	12
ss4	Finland, Latvia, Austria, Greece, Cyprus	27
ss5	The Netherlands, Cyprus	41
ss6	Belgium, Finland, Greece	26
ss8	Bulgaria, Portugal, Greece, Cyprus	25
ss9	-	34
ss10	Slovenia	9
ss11	Slovakia, Finland	19
ss12	-	10
ss13	Slovakia, Latvia, United Kingdom	39
ss14	Italy, Slovakia, Ireland	20
ss15	Italy, Lithuania, Latvia	21
HH	Bulgaria, Estonia	22

It is also interesting to see that sector *ss1a* has no outliers although having a very wide IQR ranging from 0.34 to 3.22 with a median value of 1.4. The lower whisker has a value of approximately -0.09 for Malta while the maximum whisker has a value of 7.36 for Lithuania. In the upper 25% of the values (right whisker) values range from 3.22 to 7.36 while in the lower 25% of the population the relative difference ranges from -0.09 to 0.34. Other sectors, such as sector *ss4* or sector *ss1d* present extremely large differences between the IQR spanning almost across 500% difference between the lower and upper quartiles. Sectors with wide distributions are most likely those that will require further refinement in the allocation procedure. Sector *ss5* which accounts for approximately 5% of the emissions at the account level has all values of relative difference below 0 with the highest being The Netherlands with -0.06 and the lowest Cyprus with -0.99.

At the transport level, the fact that shipping emissions and air transport cruise emissions are not included translate into a sector that appears to be underestimated using the BUA. This can be seen from the fact that the IQR is below zero alongside with 75% of the values. Only a handful of countries push the top 25% of the distribution above zero. Countries that are typically problematic in the allocation of transport emissions such as Denmark, Luxembourg, Malta, etc., are the ones presenting the lowest values of relative difference very close to -1 (c.f. table 28). In TDA, Danish accounts associated with shipping are 35.2 Mt_{CO_2} while in BUA only 1.5 Mt_{CO_2} can be attributed to Danish shipping supporting the overall low relative difference of -31% for Denmark (c.f. table 29). In the case of Luxembourg, the high discrepancy can be identified again at the level of the allocations to the transport sector where at the country level, the TDA records 10x more emissions. This problem is strongly correlated with the refinements that are still needed in the BUA to cope with the territorial/residence principle. Table *Air emissions accounts totals bridging to emission inventory totals* from EUROSTAT sheds light on the countries that will need further adjustment in terms of the transport sector in the BUA by looking at the transport columns in that dataset. In the case of Luxembourg, the *Land transport operated on the territory by non-residents* column is 20x larger than the associated accounts. In the MACC inventory this means that the purchases of fuel in Luxembourg are recorded in neighbouring regions and not in Luxembourg or ideally brought back to the country of residence of the non-residents purchasing fuel in Luxembourg. Using the TDA values for sector *ss12* in BUA would reduce the relative difference to -5 %.

Malta is a problematic country since at the inventory level it records no CO_2 emissions in many sectors. These can be associated with reporting issues at the level of the UNFCCC submissions since that's one of the main sources of information for the compilation of the MACC inventory. The only relevant SNAP sectors where emissions are recorded are *1100 - Public electricity and heat production* and *3100 - Passenger cars*. Again by applying the TDA values for sector *ss12* in BUA, the relative difference would drop to -1.2 % instead of the current -58 % since sector *ss2* in Malta has a relative difference of 0.5%.

Looking at table 6, some countries are recurrently present across sectors where for example Greece is present 6 times. Looking more closely at Greece two observations can be drawn: (1) at the sector level there exists a high-level of relative difference between the BUA and TDA while (2) at the country totals (c.f. table 29), Greece presents deviations of -4% and 5% for the sector totals and HH emissions respectively far below the deviations observed at the sector level (c.f. table 28). This could be partly explained by abnormal sector characterization in the point-source data used in the MACC. In general, if Greece or any other country featured as an outlier in this section is thoroughly checked for inventory inconsistencies and if the latter has no reporting problems, then the observed relative differences are purely function of the linear allocation of emissions based on equation 1.

In terms of the utilities sector *ss2* accounting for 46% of the total emissions, Sweden and Austria present upwards deviations of 1.5 and 0.5 respectively which deviate considerably from the median value of 0.06. These will be further detailed in the regional analysis.

Information on country-by-country sector variation is given in table 28 in appendix B. Table 30 compiles all the data in the boxplot.

3.1.2 Regional level

At the regional level, relative differences are expected to be further amplified since some sectors have zero values in the TDA due to the fact that simply there are no recorded emissions for some sectors. Conversely, TDA are mostly above zero since they follow a linear distribution. Figure 9 synthesises the relative difference Φ across sectors at the regional level.

At a first glance, more outliers are present at a regional level compared to the national level. In the agricultural sectors, the median values have moved closer to 0. In general two things can be observed: (1) the distributions have become wider since the IQR is larger for almost all sectors and (2) the level of outliers grew substantially from 51 to 500 (not controlling for double counts). This means that has the scope shifts from the national to the regional level, the relative difference grows substantially across sectors.

Looking again at sector *ss8*, from the national level to the regional level, the two former statements are true. On the one hand, the IQR grew closer to 0 meaning that more emission values in the BUA equal the TDA while at the same time the median decreased from 1.5 to 1 and now the distribution is left-skewed indicating more predominance of values towards the first quartile. On the other hand, the number of outliers increased from 4 to 25 with some points have divergences of up to 31.2 in GR24 followed by 22.8 in Cyprus and 20.9 in GR14. On the other extreme, the minimum whisker extends down to -1 which represents regions where the BUA has no values. This is the case only for FI20 which is a rather small region in Finland. Closely followed by BE10 with -0.9 which is a capital region.

As mentioned in the beginning of section 3.1, the observed relative differences were expected to stem either from the methodology followed to allocate inventory emissions to sectors or simply because the inventory presents some inconsistencies. Taking the largest sector into account (*ss2*), Austria and Sweden were the countries presented as outliers at a country level. At the regional level Austria regions present a mix ranging from -0.62 to 1.8 which indicates a strong heterogeneity supporting the fact that while at the national level the upwards deviation was close to 0.5, when

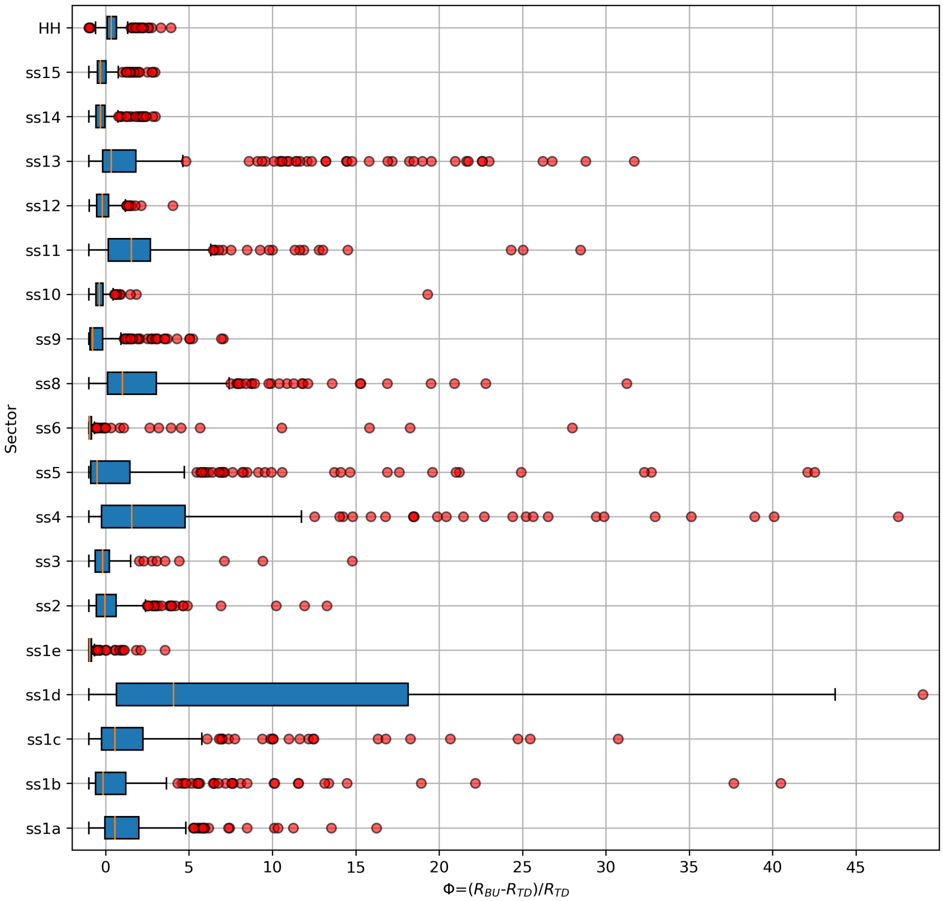


Figure 9: Boxplot depicting the distribution of the relative difference Φ of regional totals per sector of activity. Red points represent outliers.

decreasing the scale to the regional level, the advantages of having a bottom-up approach become more evident. Sweden on the other hand ranges from -0.11 to 11.9. In Sweden, 3 out of 8 regions (SE12, SE22 and SE23) and in Greece, 3 out of 13 (GR11, GR13 and GR25) are outliers at the regional level. The largest outliers in terms of deviation being GR25 with 13.28 followed by SE23 and UKE2 with 11.9 and 10.2 respectively.

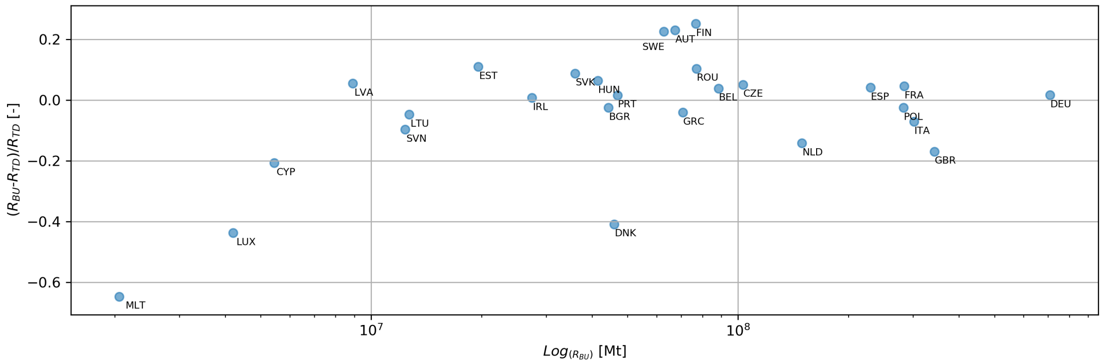
In Greece, a look at the inventory highlights the need to further understand the nature of the large entries in SNAP code *1100 -Public electricity and heat production* pertaining to point-sources. The fact that at a national level, the relative difference for sector *ss2* in Greece is -15% indicates that using the bottom-up construction of the accounts yields better estimates because of the accrued level of divergence at the regional level - provided that the MACC inventory has accurate data. Conversely, in the case of Sweden, the relative difference at the national level for sector *ss2* is 150%. This excludes the hypothesis that the bottom-up construction yields better estimates of the regional accounts for Sweden since there seems to be a problem at the country level that is further amplified at the regional scale underlying the need to identify the source of the upwards discrepancy.

An overview of the regional relative differences per sector can be found in appendix A figure 39. Table 31 compiles all the data in the boxplot.

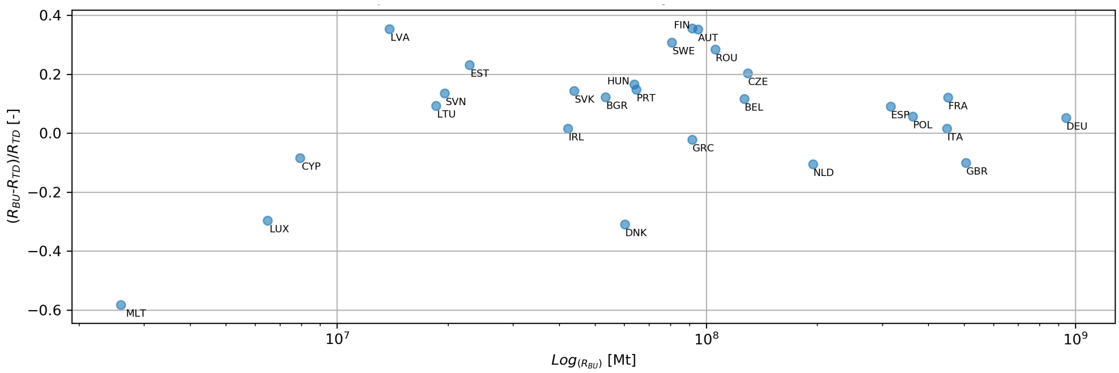
Before going to the *production intensity* section it is important to highlight as a closing remark for this section that the large variation in the relative difference across sectors in regions will contribute massively for the discrepancies that will arise downstream of the first part of the EEIO system. In other words, prior to the multiplication of the emission intensities B by the Leontief inverse L, discrepancies already exist at the account level which will only be amplified further down in the system all the way down to the consumption-driven emissions by FD categories.

3.1.3 Bottom-up approach (BUA) descriptive results

In appendix B, table 27 compiles at the national level on a sector basis the BUA values and in table 28 the relative difference values are displayed. Table 29 summarizes the total account values per country for PBA and direct (HH) emissions. Figure 10 depicts the variations across countries for both compilation methods including and excluding HH emissions. In the X-axis, countries are ranked according to their total national account values and in the Y-axis the relative difference Φ towards the TDA is plotted.



(a) Excluding HH emissions.



(b) Including HH emissions.

Figure 10: Comparison of R matrices at a country level. The Y axis represents the relative difference Φ and the X axis the sum of emissions on a country level in BUA.

It is interesting to notice that the addition of HH emissions induces opposing effects in countries, i.e., in some cases it approaches countries to the 0 reference while in other cases it does the opposite effect. The approaching effect can be seen in The Netherlands or United Kingdom while the opposite effect occurs for example in the Finland/Austria/Sweden cluster. This is in indication that when adding HH emissions, all points shift upwards.

Taking The Netherlands as an example, figure 11 illustrates the sector breakdown at the national level in terms of BUA and TDA values with the relative difference plotted on the right. Sectors are ranked according to their absolute value in terms of TDA.

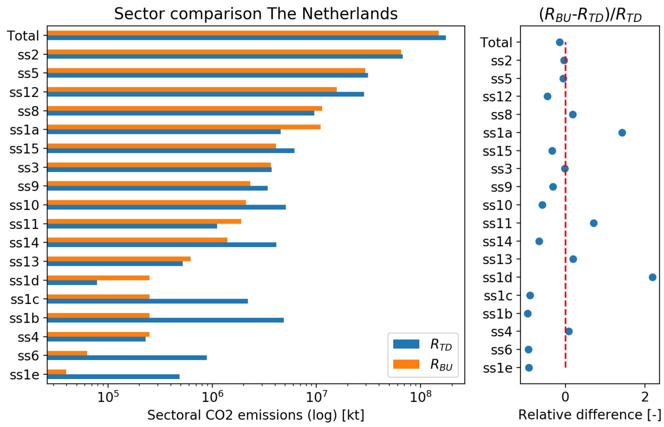
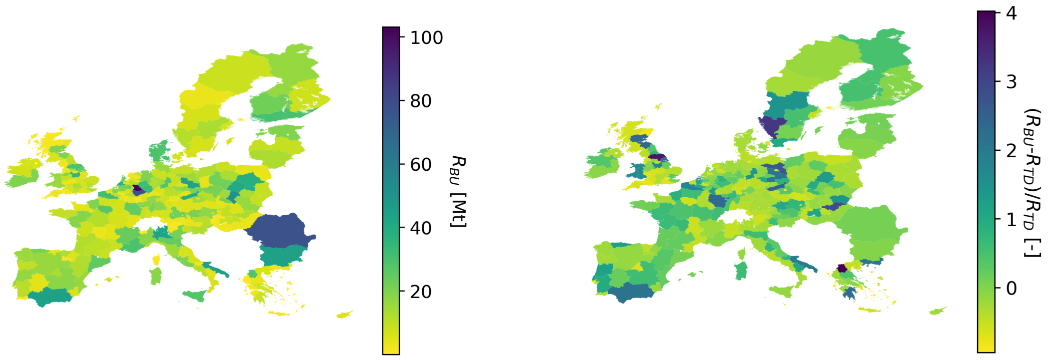


Figure 11: Sectoral comparison for both account methods in The Netherlands. The graph on the left shows a breakdown per sector while the right one depicts the relative difference Φ.

At the regional level, and given the amount of regions to be treated, data will be shown using geographic plots. Figure 12 depicts both the absolute values of the BUA and the relative difference towards TDA[14]. In the left figure, absolute values in BUA are shown where the regional variation of the accounts per region is plotted. As it is obvious, some regions will have much larger associated emissions compared to others coupled with the fact that some regions represent a full country like Romania, Cyprus, Bulgaria and others (c.f. 18).



(a) Regional accounts.

(b) Relative difference.

Figure 12: Comparison of CO_2 regional accounts.

In table 7, the top-10 regions with the highest values are shown for both accounting methodologies. In terms of scale, 5 regions are common $DEA1, DEA2, PL22, PL12$ and $ITC4$ although ranked in different orders. The relative differences are also shown for both accounts and it can be seen that the relative differences are mostly positive in the BUA side and conversely, mostly negative at the TDA side as it can be expected since the relative difference shows the offset compared to the baseline accounts TDA.

[14]Larger versions of both figures can be found in appendix A figures 33 and 34

Table 7: Ranked regional accounts for BUA and TDA.

	BUA			TDA		
Rank	NUTS2	Emissions [Mt]	Φ [-]	NUTS2	Emissions [Mt]	Φ [-]
1	DEA1	103.1	0.84	FR10	65.7	-0.58
2	DEA2	78.1	0.61	ITC4	64.1	-0.33
3	PL22	51.0	0.10	PL12	56.5	-0.32
4	ITF4	45.1	1.97	DEA1	56.2	0.84
5	ES61	44.4	2.13	DEA2	48.5	0.61
6	DE42	43.7	2.08	NL33	47.0	-0.24
7	ITC4	42.8	-0.33	PL22	46.4	0.10
8	PL11	41.0	1.31	DE30	44.3	-0.72
9	CZ04	39.8	2.45	DE60	41.3	-0.79
10	PL12	38.5	-0.32	DE71	40.8	-0.58

Taking these 10 sectors as a reference, figure 13 plots these regions in respect to the sectors. Across the 10 regions, if sectors *ss2*, *ss8* and *ss12* are summed, these are the ones that represent the highest share in emissions with 325 Mt, 102 Mt and 30.3 Mt respectively. In appendix A figure 35 shows the same sector ranking but for TDA.

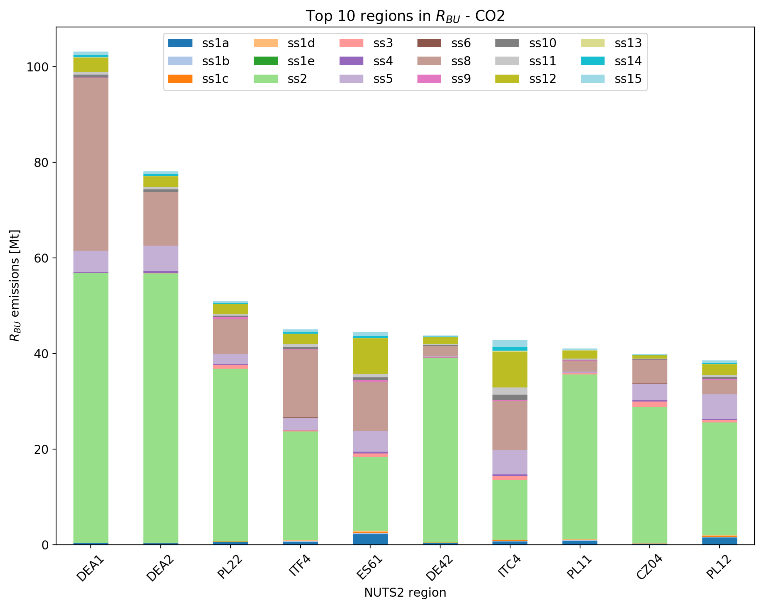


Figure 13: Regional accounts for BUA per sector.

3.2 Production intensity

The production intensity matrix M reports the relation between emissions and economic output. In a nutshell, it shows for each region and sector, what are the associated emissions when increasing one unit of economic output. Mathematically, the production intensity matrix is obtained by:

$$M = B'L \tag{14}$$

where B is the emission intensity matrix, L is the Leontief inverse matrix and expressed in $[\frac{kg}{€}]$. The production intensity matrix M will have a size equal to $1 \times n$ or $m \times n$ depending on whether the row vector b' is used or the diagonal of b' is used. The emission intensity matrix B is composed of coefficients b_{ij} that relate for each region and sector of the system the amount of emissions with the size of the economic output. To obtain matrix B, all elements of R are divided by X:

$$b_{ij} = \frac{r_{ij}}{x_j}, \forall i \in I \, and \, \forall j \in J \tag{15}$$

where I is composed of $I = \{1, ..., m\}$ pollutants and J is composed of $J = \{1, ..., n\}$ regions x sectors (recall that R is the emission matrix and X is the total output).

Two different interpretations can be drawn from the production intensity matrix M depending on the shape of b':

1. b'_i: The resulting row vector m_i of size $1 \times n$ will have for each m_j a value representing the total intensity to produce one unit of additional output of j. For each i of B', a row vector can be obtained (figure 14).
2. $diag(b'_i)$: The resulting matrix M_i of size $m \times n$ will have for each m_{ij} a value representing the contribution of i to produce one unit of additional output of j where $\sum_{i=1}^{m} m_{ij} = m_j$. For each i of B', a matrix can be calculated.

Given the dependence of B from R, and that R can either be constructed using both the BUA or TDA methods, the variations in the density of the coefficients in the M matrix will represent the differences in production intensities using either of the methods.

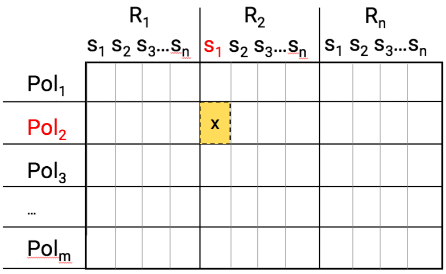


Figure 14: Production intensity matrix M obtained using b'_i showing all elements of I.

Due to the fact that M is a matrix with multipliers, i.e., to be later multiplied by values in the FD matrix, it is of little meaning to sum coefficients over regions or sectors to produce national partial totals given that FD is expressed in terms of regions and sectors. It is more interesting to compare the structure of the M matrix using either of the PBA to assess how the intensities vary and the origin of the upstream impact towards the multiplier. Instead of looking at relative differences, the absolute values of intensity will be compared. To this extent, the production intensity will be analysed only at a regional level and taking The Netherlands and Greece as two example countries.

3.2.1 Regional level

At the regional level, the regions that present the highest share in the total production intensity of The Netherlands are shown in table 8. Values are obtained using equation 16 where i is for the row representing CO_2 in B:

$$m_j = b'_i L \tag{16}$$

In both account constructions there is a strong presence of *ss1d* across regions although when using BUA, sectors *ss2* and *ss5* are also present. In terms of regions, similar regions appear in the results. The biggest difference lies in the values of the production intensities where the BUA presents substantially higher values compared to values obtained with TDA. It is worthwhile to notice the effects of the linear allocation of emissions in the compilation of TDA which can be seen by the fact that intensities are closely related in terms of magnitude. A graphical depiction of both matrices in the form of a heat map is presented in appendix A figures 41 and 42 where the values in table 8 are the top 10 rows of each figure.

The difference in the composition of the top-rows of the M matrices is the noticeable effect at the production intensity level of the divergence documented at the level of the accounts. It can be observed that there is a considerable amount of intensity around sector *ss2*, i.e., sector *ss2* in several regions is a large contributor (row-by-row or m_i) for the overall production intensity of Dutch regions (column-by-column). Nevertheless, the peaks (darker rectangles) observed for example in the first 10 rows of figure 41 are associated with large contributions of sector *ss1d* and are in part responsible for the high production intensities of the sector *ss1d* as reported in table 8.

A similar effect occurs in the M matrix using TDA where the top rows are mostly related to *ss2* but at a contribution level, sector *ss1d* appears to be the largest responsible.

Table 8: Top 10 region/sector ranked by production intensity m_j in The Netherlands.

	BUA			TDA		
Rank	Region	Sector	$[\frac{t}{€}]$	Region	Sector	$[\frac{t}{€}]$
1	NL11	*ss1d*	47,262	NL33	*ss1d*	2,035
2	NL42	*ss5*	46,583	NL12	*ss1d*	2,030
3	NL34	*ss1d*	31,759	NL22	*ss1d*	2,023
4	NL12	*ss1d*	23,640	NL13	*ss1d*	2,022
5	NL32	*ss1d*	13,207	NL34	*ss1d*	2,021
6	NL23	*ss1d*	11,667	NL42	*ss1d*	2,021
7	NL13	*ss1d*	7,651	NL23	*ss1d*	2,018
8	NL22	*ss5*	7,094	NL31	*ss1d*	2,014
9	NL21	*ss1d*	5,996	NL32	*ss1d*	2,012
10	NL23	*ss2*	5,720	NL11	*ss1d*	2,011

To understand the origin of the high intensities reported in table 8, the first rows can be isolated and using equation 17 to carry out a column-based analysis:

$$M_i = diag(b'_i)L \tag{17}$$

A matrix M can be obtained and thus the contributors to NL11 *ss1d* and NL33 *ss1d* can be ranked in descending order to identify top contributors. These are presented in appendix B table 34. The main contributors for either of the matrices are from the same region and the same sector followed by *ss2* although proportionately, to a much smaller extent. This indicates the a high production intensity associated with sector *ss1d* in The Netherlands. At the level of the MACC inventory, the only allocated source of emissions to *ss1d* comes from the allocation of mobile combustion emissions whereas in the TDA, the allocations are done on a linear basis.

Greece is a country presenting extremely large divergences at the summed level of production intensities. From the previous analysis at the account level, sectors where source emission values are based on the point-source database such as sectors *ss2* and *ss5* have been reported as potentially problematic. To investigate this behaviour, a heat map of production intensities for Greece calculated with BUA is shown in appendix A figure 43. The first row shows the largest contributor for Greece's production intensity which is *ss5* in region GR23 and GR21. These pairs show peaks at the own contribution column meaning that the high intensity in these regional pairs stems from own consumption. Table 9 summarizes the regions with highest production intensity while table 10 shows the contribution to the pair region/sector with highest production intensity.

Table 9: Top 10 region/sector ranked by production intensity m_j.

	BUA			TDA		
Rank	Region	Sector	$[\frac{t}{€}]$	Region	Sector	$[\frac{t}{€}]$
1	GR23	*ss5*	2,896,715	GR11	*ss2*	81,966
2	GR21	*ss5*	1,079,520	GR25	*ss2*	39,106
3	GR25	*ss2*	556,973	GR21	*ss2*	6,514
4	GR11	*ss2*	312,287	GR23	*ss2*	6,267
5	GR24	*ss5*	28,810	GR14	*ss2*	6,131
6	GR13	*ss2*	28,243	GR12	*ss2*	6,051
7	GR25	*ss4*	16,443	GR43	*ss2*	5,862
8	GR11	*ss5*	14,404	GR30	*ss2*	5,861
9	GR25	*ss9*	14,282	GR22	*ss2*	5,763
10	GR23	*ss1d*	13,432	GR24	*ss2*	5,750

It can be observed that the peak in the production intensity obtained with BUA is associated with GR 23 sector *ss5* as explained before. This can be explained by extremely large source points in the MACC inventory recorded for those regions and for SNAPs *1210 - Oil refining and gas (combustion)* and *1100 - Public electricity and heat production*. These conspicuous divergences point to the fact that Greece might require a more refined look at the level of the point-source database reporting.

Table 10: Main contributors for largest region/sector in table 9

	BUA - GR23 *ss5*			TDA - GR11 *ss2*		
Rank	Region	Sector	$[\frac{t}{€}]$	Region	Sector	$[\frac{t}{€}]$
1	GR23	*ss5*	2,894,436.1	GR11	*ss2*	81,864.1
2	GR25	*ss2*	1,985.8	GR13	*ss2*	11.6
3	ITD2	*ss2*	71.2	GR14	*ss2*	10.2
4	GR23	*ss8*	42.6	ITD2	*ss2*	8.5
5	GR24	*ss5*	23.3	ITD1	*ss2*	7.2
6	GR23	*ss2*	9.9	FI20	*ss2*	5.3
7	ITD5	*ss2*	8.2	GR11	*ss5*	5.0
8	ITD1	*ss2*	6.7	GR30	*ss5*	4.9
9	ITG1	*ss2*	6.7	GR12	*ss2*	3.8
10	ITG2	*ss2*	5.4	GR11	*ss12*	2.7

3.3 Consumption-driven emissions

Consumption-driven emissions are the emissions that are associated with the consumption of goods provided by industries. In a nutshell, the consumption of a certain good by FD will trigger emissions for the production of the good plus emissions at all the upstream activities required to deliver the good. Or, using the production intensity from last section, it is the multiplication of the euros spent by FD times the production intensity. Graphically, figure 15 illustrates the upstream relationships that may exist to produce one unit of economic output of a single sector to be purchased by FD. In this case, and as an example, to produce one economic unit of insurance, paper is needed which comes from wood that is cut down using machinery that is built using steel and so on. This structural path is only one of the n_{th} paths that may exists to produce the 1 unit of economic output of insurance.

Mathematically, the consumption-driven emissions can be calculated in its more simplistic way

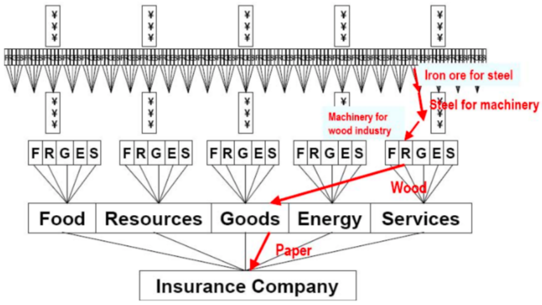


Figure 15: Depiction of the upstream relationships in the production phase. From (Wood, 2010).

with:

$$R = b'LY + h \tag{18}$$

where Y is the FD with size $m \times n$ composed of y_{ij} coefficients where $I = \{1, ..., m\}$ for m regions x sectors and $J = \{1, ..., n\}$ for n regions x FD categories. The FD direct emissions, i.e, emissions arising directly from activities of FD[15] are represented by h composed of h_j where $J = \{1, ..., n\}$ for n regions x FD categories. In the case of equation 18, the resulting matrix R[16] of size $m \times n$ which has 1 row vector per pollutant i, gives for each r_j the total amount of emissions that are associated with the consumption by y_j FD category. The first part of equation 18 yields the indirect emissions while h are the direct emissions.

Two different decomposition strategies of R can be followed to either (1) look at which FD category contributes the most for the total emissions associated with a given sector or (2) to understand which sector contributed the most for the total emissions associated with one FD category. The first strategy is called a *contribution* analysis where the results are interpreted on a column-by-column basis. The second one is called a *hotspot* analysis where the results are interpreted on a row-by-row basis. Both of them will output different matrices with different meanings depending on the *diag* chosen:

$$\text{Contribution: } R_c = B'Ldiag(y_j) \tag{19}$$

$$\text{Hotspot: } R_h = diag(b'_i)LY \tag{20}$$

In equation 19 only a single FD category y_j can be used since the aim is to see the contribution of that final demand category for the total emission output of sector i. Whereas in 20, a single row of B is diagonalized to produce matrix R_h where in each column the top contributors to the overall consumption-driven emissions of y_j can be identified thus highlighting *hotspots* of emissions.

Equations 19 and 20 can be combined in a single equation where a larger matrix is obtained which allows a thorough understanding of the relation between each row of B (pollutant) and a column of Y:

$$R = diag(b'_i)Ldiag(y_j) \tag{21}$$

3.3.1 National level

In order to compare consumption-driven emissions across countries, indirect emissions will be aggregated per sector to investigate how the origin of emissions changes when calculating the EEIO system with two difference PBA. To obtain figure 16 with sectors in the Y-axis and distributions in the X-axis the following procedure is performed for each European country C in scope:

[15] Driving a car, burning natural gas at home,etc.

[16] Here R has the same denomination as in table 4 since the sum of emissions before and after the IO calculations are the same just assigned to different categories. In the first, emissions are in the account format, but after as the production and consumption take place, emissions are shifted from sectors to FD categories.

1. Obtain a r_C column vector with equation 20 where for country C, Y will be the sum of FD categories across regions and i is for CO_2
2. Sum over regions in r_C to isolate sectors

The procedure is followed for BUA and TDA and in the end the relative difference Φ is calculated looking at the sector coefficients in each vector r_C.

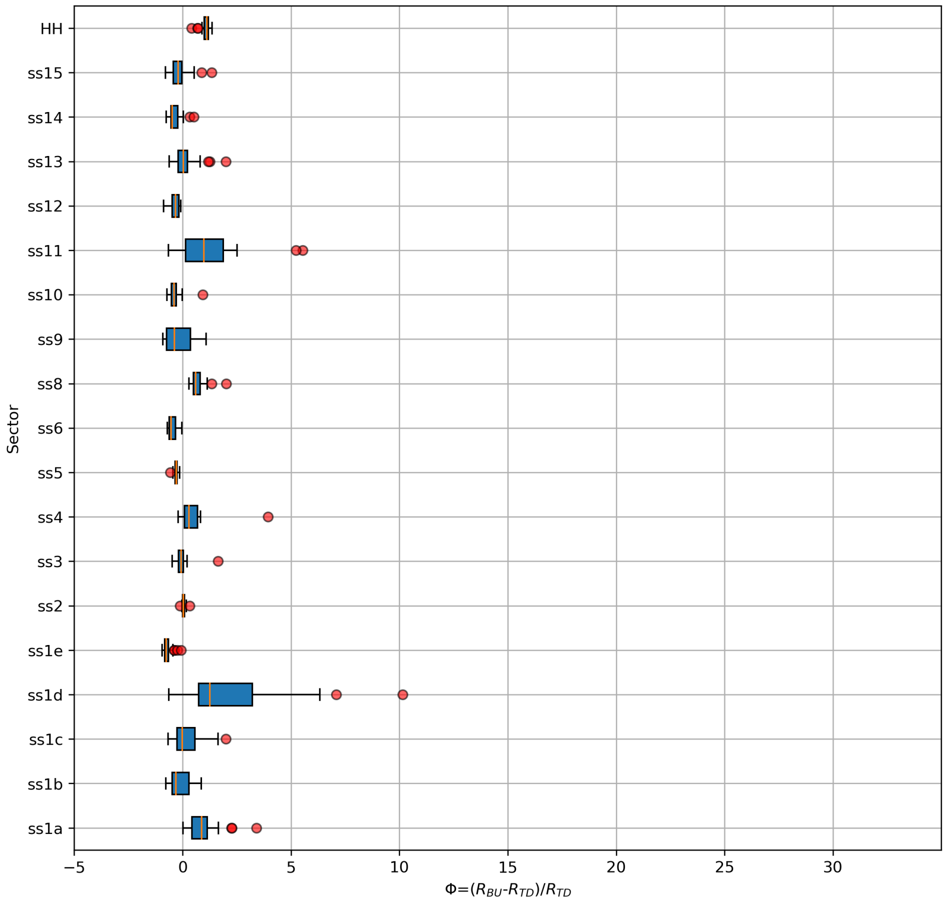
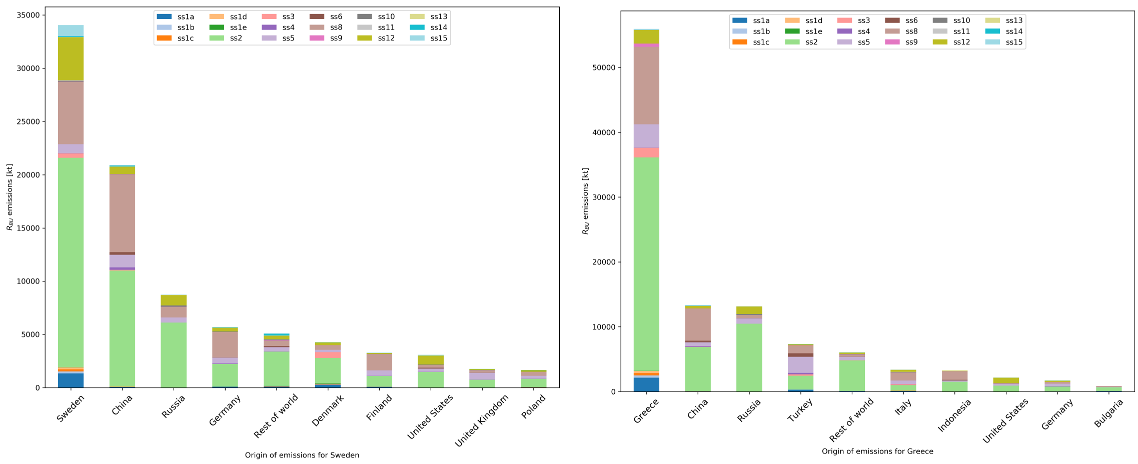


Figure 16: Boxplot depicting the distribution of the relative difference Φ of country totals per sector of activity. Red points represent outliers. The x-axis is purposely set to x_{max}=35 to have the same scale as figure 19.

Data in figure 16 should be interpreted by looking at a given sector and from there looking at the distribution (composition) of the boxplot. Take sector *ss2* which the largest sector in terms of emissions. It shows a quite an exact match between the attributed indirect emissions to each country originating in sector *ss2* since both the median and the IQR are very close to zero. The same problematic countries at the account level are again the outliers: Sweden and Greece with relative difference of 0.33 and -0.11 respectively. The two extreme ends were already noticed in the regional comparison of the accounts. In order to understand the origin of the divergence, a step back is taken to characterize the main contributors to the upwards deviation in Sweden and conversely in Greece. To this extent, figure 17 depicts the 10 largest contributors in terms of region/sector to the indirect emissions of both Sweden and Greece. The fact that the largest contributor is the domestic sector *ss2* confirms the need to double-check inventory data in the MACC.

The distribution of sector *ss2* portrays a sector where a small divergence exists between CBA. This can be understood by the small size of the IQR and that the first and third quartiles are mostly concentrated around zero. What this means in terms of emissions, is that (1) sector



(a) Sweden (b) Greece

Figure 17: Top 10 contributing regions and sectors for the total indirect CO_2 emissions in Sweden and Greece for all FD categories.

ss2 presents low variation at the account level as justified in the accounts' section and (2) a large share of the indirect emissions attributable to *ss2* are "imported", i.e., not originating in Europe[17]. This affirmation can be verified by figure 18 where the main contributors for the overall indirect emissions in Europe are sector *ss2* in Russia, China and ROW. Being these emissions the same in both CBA masks the divergence that could occur function of the differences at the PBA level (cf. 8). In total, the attributable "imported" indirect emissions to sector *ss2* in Europe amount to 39% of the total indirect emissions while *ss2* amounts to 53% of the total indirect emissions in Europe.

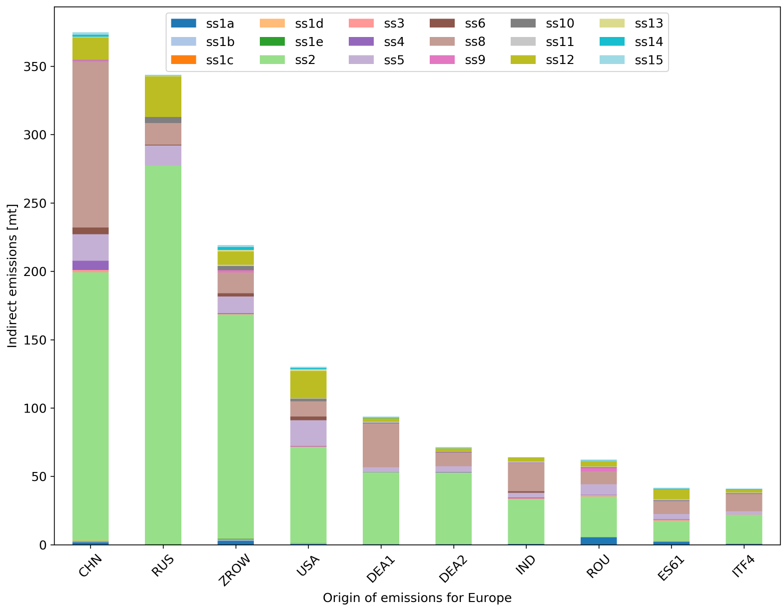


Figure 18: Top 10 contributing regions and sectors for the total indirect CO_2 emissions in Europe for all FD categories.

The second largest contributor for the total indirect emissions in Europe is sector *ss8* with 18% of the emissions. The outliers in figure 16 are Spain and Portugal with relative differences of 2 and

[17]Recall that for the regions outside of Europe the TDA and BUA use the same emissions

1.3 respectively. The IQR is placed between 0.3 and 0.8 with a median of 0.6. The lower whisker has a minimum value of 0.29 (Estonia) while the maximum whisker reaches 1.13 (Cyprus). The majority of the values are concentrated within the first quartile since the median is towards the first half of the IQR indicating a left skewed distribution for 50% of the values.

The list of outliers in figure 16 can be found in table 11. Table 32 compiles all the data in the boxplot.

Table 11: List of the outliers depicted in figure 16 and count of outliers at the regional level in figure 19.

Sector	Outliers (national level)	# Outliers (regional level)
ss1a	Latvia, Romania, Estonia	11
ss1b	-	10
ss1c	Slovenia	16
ss1d	Italy, Greece	22
ss1e	Denmark, Bulgaria, Latvia, Estonia	20
ss2	Sweden, Greece	17
ss3	Greece	18
ss4	Latvia	34
ss5	Portugal	16
ss6	-	23
ss8	Spain, Portugal	27
ss9	-	17
ss10	Slovenia	6
ss11	Slovakia, Hungary	10
ss12	-	2
ss13	Slovakia, Latvia, United Kingdom	5
ss14	Italy, Slovakia	18
ss15	Italy, Latvia	21
HH	Malta, Denmark, Luxembourg	22

3.3.2 Regional level

To analyse sectors at the regional level, a similar procedure is followed as for the national level where regions are not summed (excluding step 2). This is followed for BUA and TDA and in the end the relative difference Φ is calculated looking at the sector coefficients in each vector r_C. Figure 19 summarizes the relative difference distributions on a sector basis at the regional level.

Looking at the more relevant sectors in terms of magnitude of indirect emissions, sectors *ss2* and *ss12* present a lower median value at the regional level whereas sector *ss8* has a higher value. The IQR values show a wider distribution for these sectors while the skewness is barely changing.

For sector *ss2*, the minimum whisker has a value of -0.39 and maximum whisker a value of 0.49 for DE60 and DEA4 respectively. The outliers at the negative side are GR25 and GR11 with -8.27 and -2.28 respectively and on the positive side 17 regions ranging from 0.5 up until 2.27 for FR41 and UKE2 respectively.

In sector *ss8*, the minimum value for the lower 24.675% of the distribution is 0.16 for AT34 and at the upper 24.675% of the distribution is 1.58 for ES51. There are 34 outliers in total all on the positive side of the distribution ranging from 1.62 to 4.14 for GR12 to ES64.

In general, all agricultural sectors present positive values of relative difference with the exception of sector *ss1e*. This distribution of values across agricultural sectors was already observed in the accounts section and is function for some sectors of the chosen allocation methodology. For

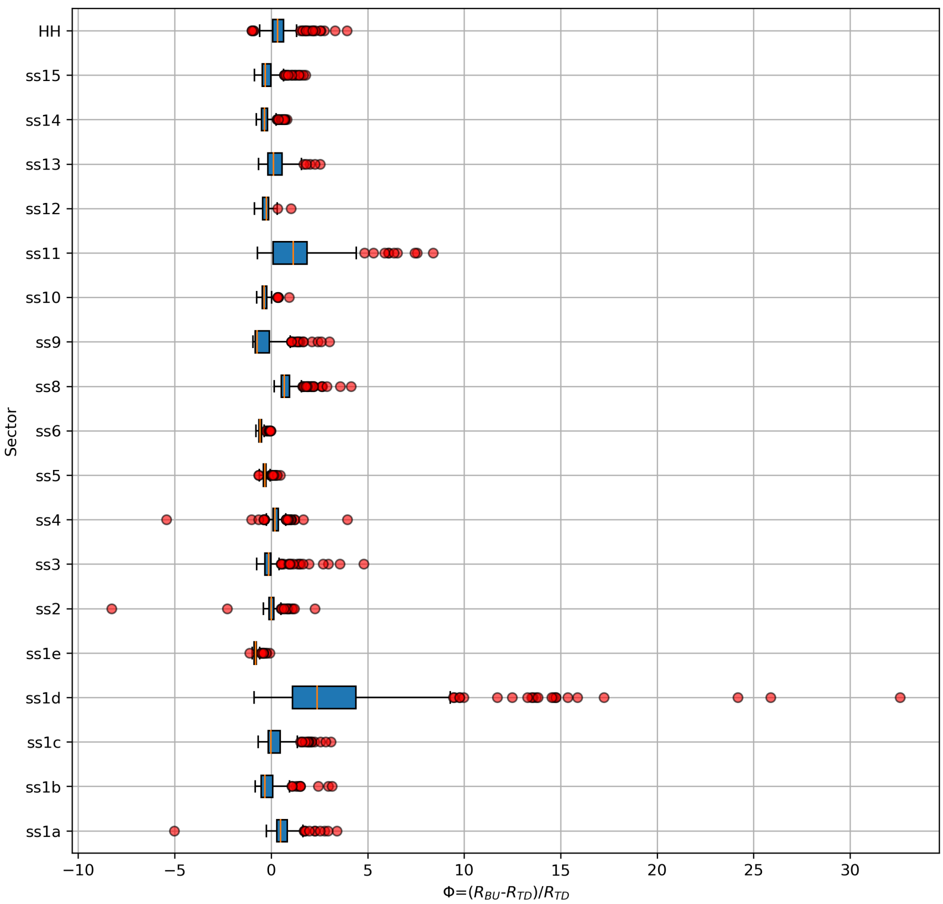


Figure 19: Boxplot depicting the distribution of the relative difference Φ of the origin of indirect emissions at a regional level per sector. Red points represent outliers.

instance, emissions attributed to sector *ss1e* may be subject ot further refinement in the future alongside with sector *ss1d* since these are all based on ubiquitous sources described as *"others"*. Table 33 compiles all the data in the boxplot.

3.3.3 Correlation between changes in production-based accounts (PBA) and consumption-based accounts (CBA)

Here an additional effort is presented to infer if there is correlation between the variations both at the account level and consumption-driven indirect emissions. To test this, sectoral emissions at the account level are aggregated and the relative difference is calculated. At the level of indirect emissions (CBA), FD is summed over European countries and equation 20 is used to isolate the contributing regions/sectors. To obtain column vector r_C, emissions are aggregated at the sector level excluding emissions originating outside of Europe. The result is displayed in table 12. PBA are the values in the R matrix summer over European regions while isolating for sectors.

To check for correlation, the Pearson test is used to investigate if there is a linear relationship between the divergence reported in PBA and the downstream effect at the CBA. Using the values in 12 yields a correlation coefficient of $r = 0.997$ which indicates a strong positive correlation with a P-value of almost 0. Figure 20 depicts the relationship between relative difference values values for both PBA and CBA.

Table 12: Relative difference Φ at the PBA and CBA level for sector-aggregated emissions.

Sector	PBA (Φ)	CBA (Φ)
ss1a	0.570	0.581
ss1b	-0.292	-0.280
ss1c	0.075	0.095
ss1d	2.033	2.262
ss1e	-0.894	-0.899
ss2	0.047	0.048
ss3	-0.139	-0.141
ss4	0.584	0.408
ss5	-0.456	-0.437
ss6	-0.947	-0.948
ss8	1.550	1.586
ss9	-0.611	-0.615
ss10	-0.426	-0.420
ss11	1.239	1.248
ss12	-0.397	-0.376
ss13	0.191	0.163
ss14	-0.411	-0.407
ss15	-0.290	-0.289

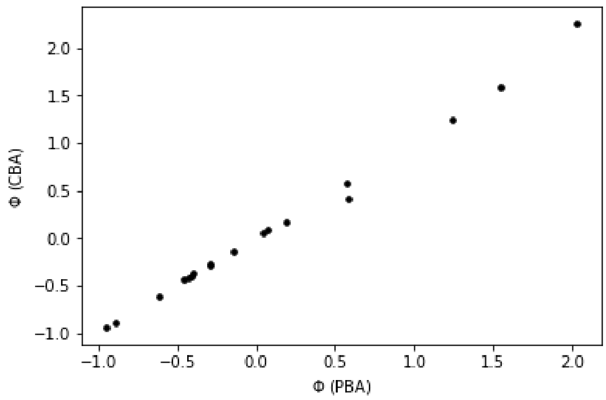


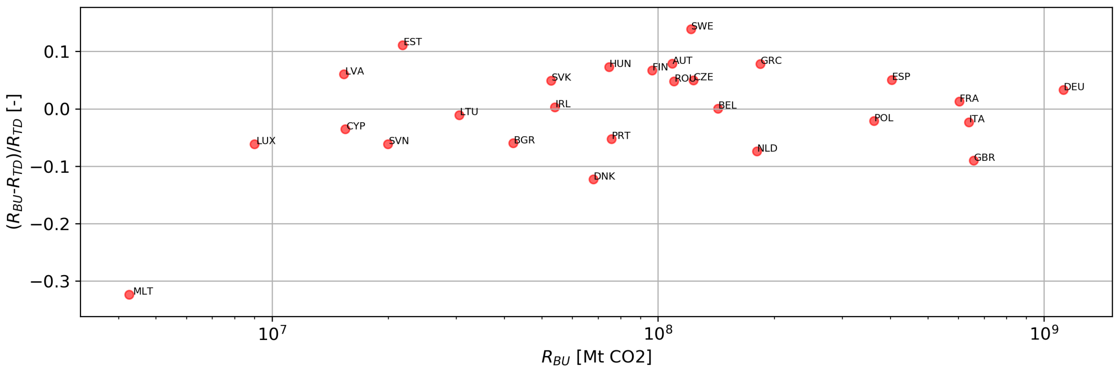
Figure 20: The almost linear relationship between the relative difference Φ for PBA and CBA

3.3.4 Bottom-up approach (BUA) descriptive results

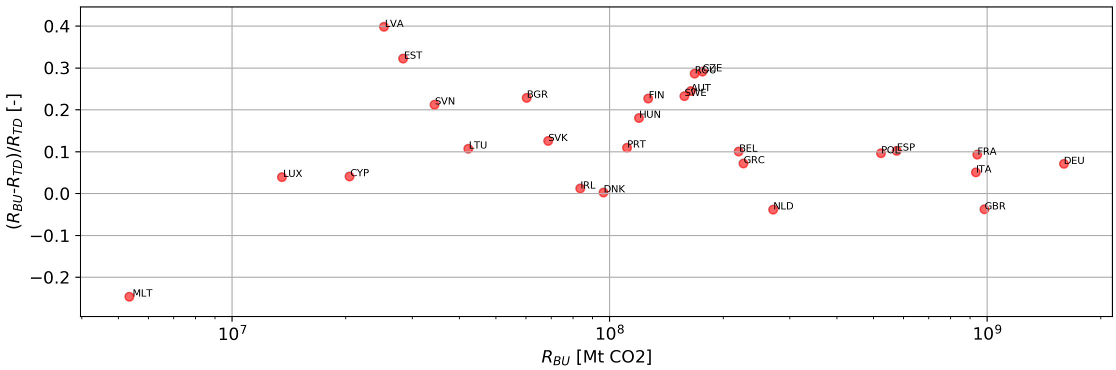
At the national level, consumption-driven emissions can be summed over FD categories and regions to obtain country totals. These are depicted in figure 21 where in the top figure direct emissions are excluded and in the bottom figure direct emissions are included. Similar to what was observed in the accounts section, when adding direct emissions the relative differences increase. This again indicates the need in next iterations to address the direct emissions in more detail.

In appendix B table 35 country totals are shown per FD category combined with the totals (indirect+direct). It appears that indirect emissions are constantly underestimated while total emissions are overestimated. Once again, correctly allocating direct emissions proves important to avoid overestimations. The numbers are consistent with what was interpreted from table 29 where sectoral accounts were underestimated compared to the baseline scenario. As the emissions are distributed downstream from the account level to consumers, the underestimations are felt at the level of indirect consumption-driven emissions.

Using The Netherlands as an example, one of the decompositions mentioned above can be per-



(a) Excluding direct (HH) emissions.



(b) Including direct (HH) emissions.

Figure 21: Comparison of consumption-driven CO_2 emission totals at a country level. The Y axis represents the relative difference Φ and the X axis the sum of emissions attributed to the sum of FD categories.

formed for FD category *ss16* which is composed of HH and non-profit. By applying equation 20 and summing over regions, figure 22 can be generated where the top contributing countries are depicted in descending order of contribution. The Netherlands itself is the largest contributor with around 33 Mt of CO_2 accounting for 18% of emissions followed by Germany with 10 Mt (6%) and China 9 Mt (5%).

In terms of sectors, sector *ss2* is the largest contributor with over 48 Mt of CO_2 which accounts for 54% of the emissions followed by sector *ss8* with over 12 Mt accounting for 14% of the emissions and sector *ss12* with 10 Mt accounting for 11% of the total emissions. Slight differences exist compared to the baseline accounts for the 3 top sectors: sector *ss2* with -1% followed by sector *ss8* with divergence of 40% and sector *ss12* -35%. It is important to notice here the fact that a very low relative difference in sector *ss2* indicates a good match between both accounts which was already observed at the account level in table 28 where the relative difference for sector *ss2* was 5% overall. A complete overview of the contribution of all countries calculated with both accounts and respective relative difference can be found in appendix B table 36 and on a sector basis table 37.

In terms of total indirect emissions driven by European regions, table 13 summarizes the share of domestic emissions compared to those originating outside of Europe. Sectors *ss2*, *ss8* and *ss12* are the largest sectors. The predominance of emissions arising in sector *ss2* outside of Europe can be identified by the 40% share in emissions amounting to 823 Mt.

Similar to the national level, indirect and direct emissions can be analysed at the regional level by summing emissions between sectors of the same region to produce regional totals. In figure 23, consumption-driven emissions are compared at a regional level. In the left plot, indirect emissions

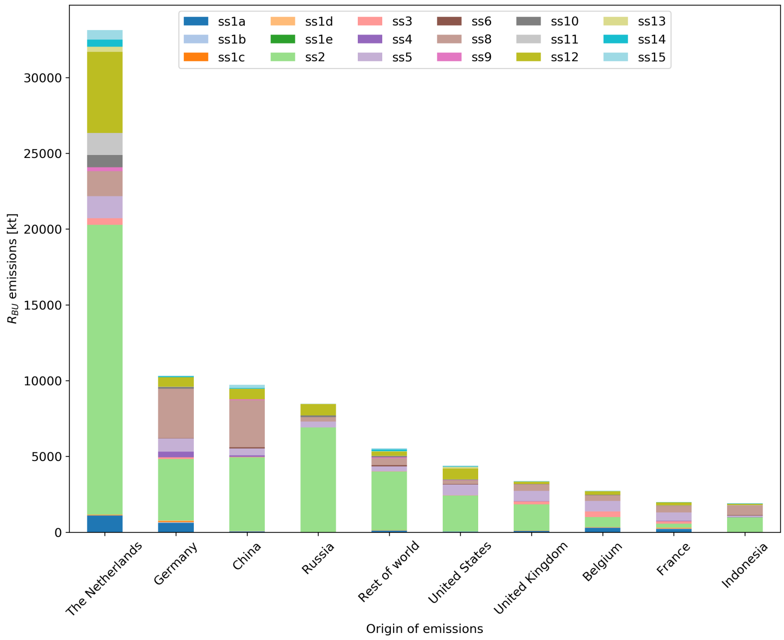


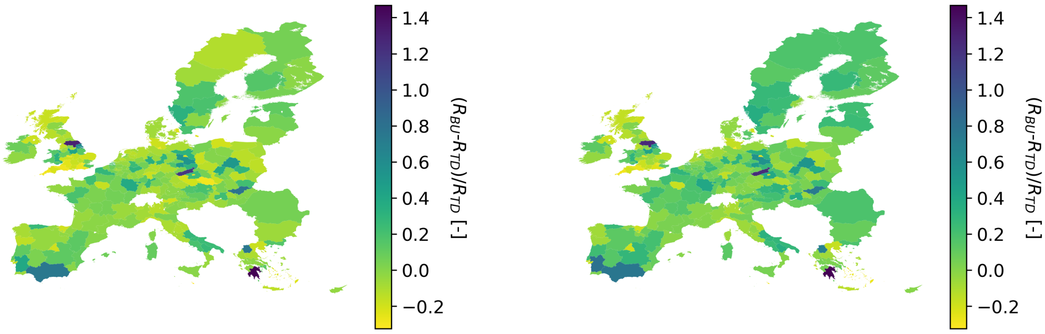
Figure 22: Top 10 contributing countries and sectors for the total indirect CO_2 emissions in The Netherlands for FD category *ss16*.

Table 13: Overview of indirect emissions aggregated per sector.

Sector	BUA indirect emissions [Mt]	Intra-EU share [%]
ss1a	105.44	0.93
ss1b	12.63	0.85
ss1c	12.20	0.88
ss1d	11.45	0.93
ss1e	1.04	0.67
ss2	2057.24	0.60
ss3	52.22	0.93
ss4	18.96	0.45
ss5	317.50	0.71
ss6	15.99	0.07
ss8	714.44	0.71
ss9	25.09	0.82
ss10	53.81	0.77
ss11	45.32	0.92
ss12	338.44	0.73
ss13	11.44	0.67
ss14	32.08	0.82
ss15	77.17	0.93

are compared while in the right plot direct emissions are included. Overall, an increase in relative difference is seen when direct emissions are included which was already observed in the accounts' section. Direct emissions has discussed previously, introduce a higher degree of relative difference between calculations done with either of the accounts. The absolute values of indirect emissions are compared in appendix A figure 46 and direct emissions are compared in figure 47. The right plot in figure 47 illustrates what has been recurrently discussed in terms of direct (HH) emissions and the refinement required in the allocation procedure.

In terms of regions with the highest indirect consumption-driven emissions, table 14 illustrates



(a) Excluding direct (HH) emissions. (b) Including direct (HH) emissions.

Figure 23: Comparison of relative difference in consumption-driven CO_2 emissions at a regional level.

the highest consumers of indirect emissions combined with per capita footprints.

Table 14: Top 15 regions ranked in descending order in terms of indirect emissions. Emissions per capita are also shown.

		Indirect emissions			Total emissions		
NUTS2	Name	[Mt CO_2]	Φ [-]	[tCO_2/cap]	[Mt CO_2]	Φ [-]	[tCO_2/cap]
ITC4	Lombardia	113.9	(0.13)	11.9	139.0	(0.09)	14.5
FR10	Ile de France	110.1	(0.17)	9.3	128.0	(0.17)	10.9
DEA1	Dusseldorf	99.9	0.25	19.3	112.1	0.21	21.7
DEA2	Koln	91.1	0.30	20.8	101.9	0.26	23.2
GR30	Attiki	80.7	0.13	20.2	85.7	0.09	21.4
ES61	Andalucia	75.9	0.7	9.2	95.0	0.75	11.5
ITC1	Piemonte	75.6	(0.08)	17.3	88.8	(0.03)	20.3
ITE4	Lazio	63.7	(0.09)	11.7	76.3	(0.05)	14.0
FR71	Rhone-Alpes	57.7	(0.06)	9.3	75.4	0.01	12.1
ES30	Madrid	57.6	(0.19)	9.0	67.6	(0.19)	10.6
PL12	Mazowieckie	57.4	(0.14)	11.0	67.6	(0.11)	13.0
ITD3	Veneto	55.6	0.00	11.5	69.4	0.04	14.3
ITD5	Emilia-Romagna	55.3	0.03	12.8	67.8	0.06	15.7
DE21	Oberbayern	55.0	(0.01)	12.7	67.3	0.01	15.5
DEA5	Arnsberg	55.0	0.06	15.0	64.4	0.06	17.5

A large majority of regions in table 14 are regions where country capitals or very large cities are located. The level of divergence from the baseline scenario is quite heterogeneous ranging from -19% to in Madrid to 70% in Andalucia. The region with the highest consumption-driven emissions across all FD categories is Lombardia with almost 114 Mt CO_2 which accounts for around 25% of the total indirect emissions of Italy although Lombardia has a rather small per capita footprint with only 14.5 tCO_2/cap. The second largest consumer of indirect emissions is the region of Paris with 110 Mt CO_2 accounting for around 25% of the total indirect emissions of France. The per capita carbon footprint is one of the lowest in Europe representing around 11 tCO_2/cap.

Indirect emissions have their origin in the upstream production matrix when the latter is stimulated by consumption. Again by applying equation 20, the origin of the indirect emissions can be identified. As an example, figure 24 illustrates the region of origin of the emissions combined with the sector.

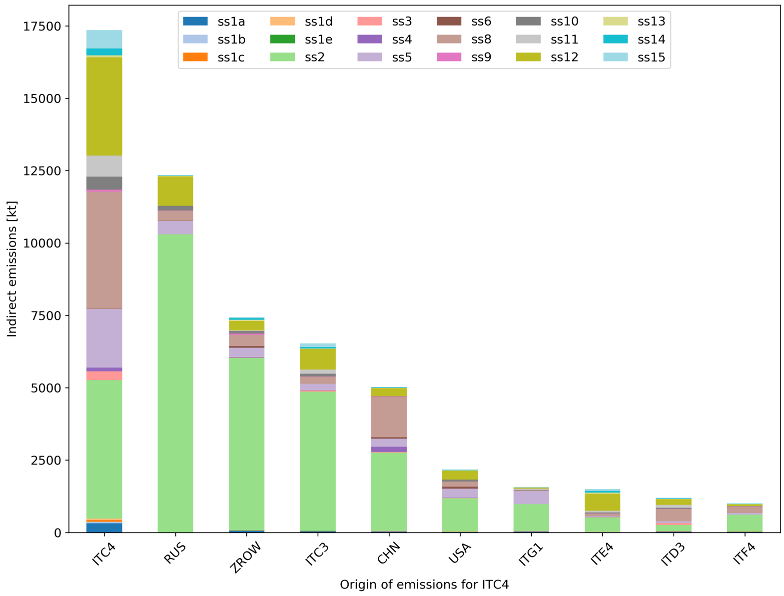


Figure 24: Top 10 contributing regions and sectors for the total indirect CO_2 emissions in Lombardia for all FD categories.

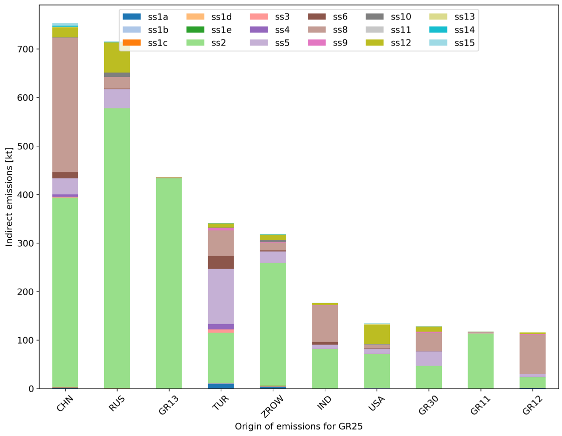
The main origin of the emissions is in Lombardia itself with a diverse level of responsible sectors. These are mainly sectors *ss2, ss8* and *ss12* which is similar to what was already described for the origin of the upstream emissions in The Netherlands. Other contributors include mostly sector *ss2* from abroad specially Russia with 10 Mt CO_2 which is the largest pair region/sector contributing the most for the indirect emissions of Lombardia. A similar observation can be made for Paris, Piemonte, Lazio, Rhone-Alpes, Veneto and Emilia-Romagna where the single largest contributor for the magnitude of indirect emissions is sector *ss2* from Russia. At the European level, the same is observed where sector *ss2* from Russia is again the single largest contributor for the magnitude of European indirect emissions. European indirect emissions amount to 1,442.3 Mt where sector *ss2* from Russia is responsible for 19.2% of the emissions followed by sector *ss2* from China with 13.6% and rest-of-the-world sector *ss2* with 11.4%. The emissions from sector *ss2* amount to 63.2% of the indirect emissions in Europe. Figure 18 illustrates the above.

Regions with the largest upwards deviation are summarize in table 15 where the same problematic regions in terms of production intensity appear once again. In global terms, the sum of indirect emissions calculated using BUA presents a deviation of 5% towards the baseline whereas when including direct emissions the value decreases to 4.4%.

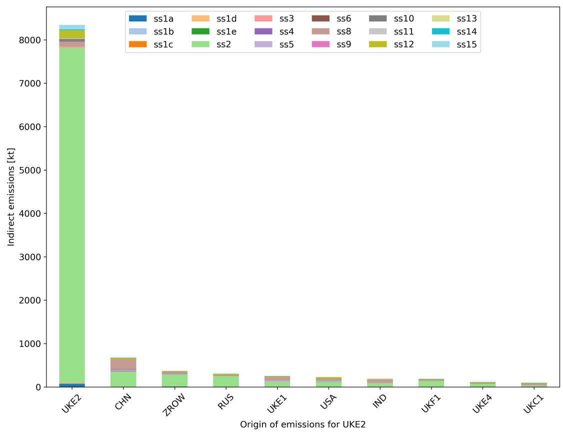
The indirect emissions of the top 3 regions in table 15 can be further decomposed with equation 20 to understand the origin of the emissions. By knowing the origin of the emissions, the problematic pair region/country can be dissected. This allows to potentially understand where at the inventory/production intensity level is the source of deviation. The 3 resulting decompositions are reported in figure 25. From the 3 plots in the figure, the source of the divergence can only belong to European regions since the accounts for the regions outside of Europe have the same values in both TDA and BUA (c.f. 4). This means that for GR25 the divergence will come from the upstream emissions of *ss2* in GR13, in UKE2 the source of divergence is within the region in sector *ss2* while for CZ04 the same is observed where the largest share of indirect emissions is the domestic sector *ss2*.

Table 15: Top 10 regions presenting largest upwards deviation in terms of relative difference Φ.

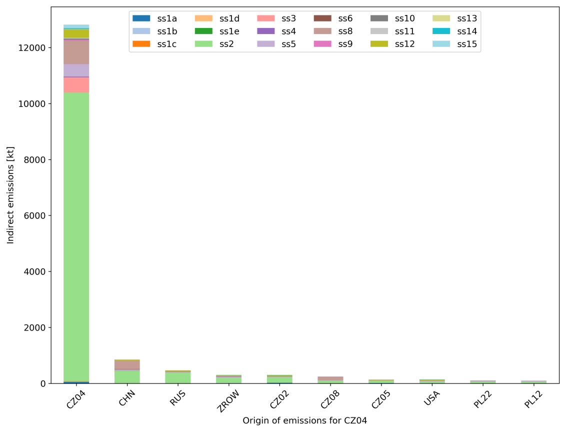
	Indirect			Total		
Rank	NUTS2	Φ [-]	[Mt]	NUTS2	Φ[-]	[Mt]
1	GR25	1.47	17.7	GR25	1.44	17.7
2	UKE2	1.31	21.0	UKE2	1.24	21.0
3	CZ04	1.18	28.8	CZ04	1.22	28.8
4	HU31	0.78	13.6	PT18	0.79	7.3
5	GR13	0.76	7.7	ES61	0.75	75.6
6	ES61	0.75	75.6	HU31	0.73	13.6
7	UKE1	0.62	16.6	GR13	0.68	7.7
8	DE42	0.54	26.6	DE42	0.55	26.6
9	PL11	0.51	38.3	PL11	0.53	38.3
10	DED3	0.50	18.4	UKE1	0.52	16.6



(a) GR25.



(b) UKE2.



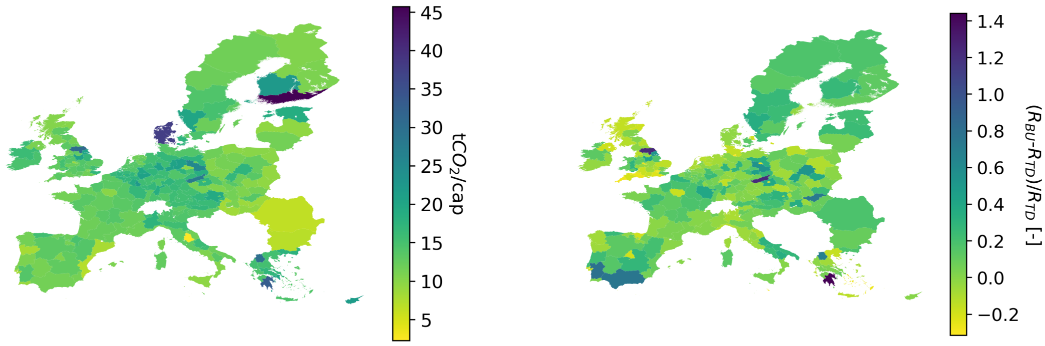
(c) CZ04.

Figure 25: Origin of the indirect emissions for all FD categories for the top 3 regions in table 15

3.4 Comparison with the benchmark - Ivanova et al.

As mentioned in the *research gap* section in the *introduction*, to date, only one comparable study has been done on the CBA at the regional level in Europe. Although in Ivanova et al., the production matrix comes from Exiobase thus being discriminated at the national level and the FD is the only regionalised part of the EEIO system.

The per capita carbon footprint varies considerably across European regions with the lowest value of 2.3 tCO_2/cap in ITE2 (Umbria) up to 45.7 in FI18 (Southern Finland) and a mean value of 14.24 tCO_2/cap. Figure 26 illustrates the carbon footprint across European regions calculated either using BUA or TDA. In appendix A an overview of all carbon footprints can be in figure 48.



(a) BUA (b) Relative difference Φ

Figure 26: Comparison of per capita CO_2 emissions at a regional level.

The values obtained here can be compared with the carbon footprints calculated by Ivanova et al. Figure 27 depicts the variation between carbon footprints obtained with BUA and the ones obtained by Ivanova et al. (2017) using the same approach as Φ where the variation is mapped towards the baseline scenario where in this case the baseline are the footprints of Ivanova et al. (2017). It can be observed in figure 27 that several regions have footprints largely above those calculated with by Ivanova et al. (2017).

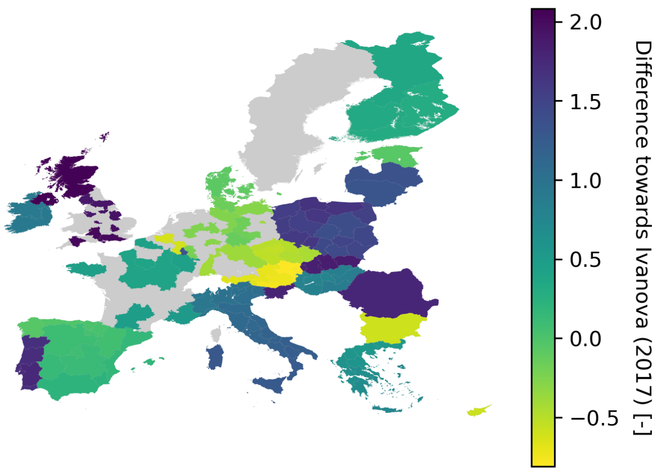


Figure 27: Comparison between footprints obtained with BUA and the ones obtained by Ivanova et al. (2017). Grey values indicate regions where there is no data for the benchmark footprint. Values are expressed in relative difference between BUA and the benchmark.

In the boxplot, the outliers in the negative side is ITE2 (Umbria) which is the region with the lowest carbon footprints in the TDA. The outliers at the positive side are in decreasing order:

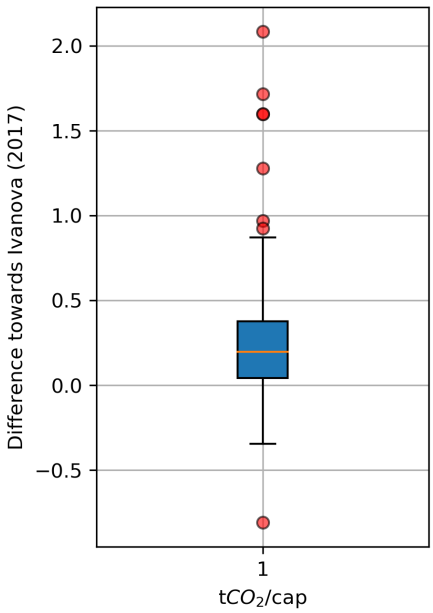


Figure 28: Distribution of the data-points used in figure 27.

FI18, CZ04, DK03, GR25, HU31, PL11 and PL52. The media value is 0.195 which is very close to the middle of the IQR indicating no skewness in the central part of the distribution. The whiskers have extremes of -0.34 and 0.87. It can be concluded that almost 74% of the data points are above zero indicating larger footprints calculated with BUA.

Part 4

Discussion

In this thesis, a comparison between two environmental stressors compatible with EUREGIO obtained from different inventories was performed. The divergences observed in the analysis chapter arise exclusively from the underlying differences between the two stressors which stem from using different inventories and allocation methodologies. To this extent, the produced CBA are purely function of the used environmental stressors and independent from the transaction matrix Z and Y since in this study the same IO system is used. Therefore, the relative difference observed when going from PBA to CBA are independent from the IO system and are purely function of the emissions matrix R: $\Phi = f(B)$ (Moran & Wood, 2014; Rodrigues, Moran, Wood, & Behrens, 2018).

Even though the MACC inventory and the EUROSTAT accounts aim at replicating the same source emissions, the fact that there are considerable divergences at the account level hints at the need to look at the results of this thesis with a critical approach. To harmonize both accounts, the data used to compile the EUROSTAT accounts should have been brought one step back to the inventory level and subsequently subject to the allocation procedure described in the methodology section. If this had been possible, the detected divergence between PBA and CBA in using both the BUA and TDA could have been identified and controlled for. This procedure has been employed by Moran and Wood (2014) when comparing differences in CBA controlling for the IO system and allocation procedure leaving only the used emission inventory as the variable. They report considerable variations in terms of CBA at a country level even if the construction of the accounts is done using the same methodology. This highlights the fact that if using reliable and harmonized inventory data, such divergences should not occur. Differences at the inventory level for emission reporting are known (Marland, 2008) and reliability of emission data is strongly correlated with country's GDP (Edens et al., 2015; Moran & Wood, 2014) as this indicates the capacity of a country to accurately report emission data.

The MACC inventory uses a multitude of input data to generate grid-based emissions. In theory, using a grid-based inventory should provide more accurate information on both the PBA and CBA. Although a grid-based inventory poses additional challenges in terms of allocation, it should provide a more accurate picture of the localized emissions compared to the usage of equation 1 (linear allocation). Provided that there is no comparative basis to assert the accuracy of the MACC inventory, one is left to assume that is has no mistakes in its compilation since the data used is in theory the same as the one used for the NAMEA. According to TNO experts, data on emissions for a given year may fluctuate depending on the year of compilation thus year-on-year deviations will always be expected as pointed out in Moran and Wood (2014).

The compilation of environmental accounts must follow guidelines laid out in the SEEA handbook (United Nations et al., 2012) or in the NAMEA compilation manual (European Union, 2015). In practice, EEIO practitioners have documented their steps in the compilation of environmental accounts for EXIOBASE (Kuenen et al., 2013) and for WIOD (Genty et al., 2012). In both methodologies, the usage of energy SUT is paramount for the compilation of the accounts combined with different emission factors and population proxies. At the national level, the territory-residence principle underpinning the accuracy of the SNA can be respected given that extensive data exists on the consumption of residents abroad and on domestic consumption undertaken by foreign consumers. In the compilation of EXIOBASE and WIOD environmental extensions, this accounting principle was respected thus yielding environmental extensions that are aligned with the economic flows.

Neither the compilation of extensions for EUREGIO using the MACC inventory (BUA) nor the linearly-transformed EUROSTAT accounts (TDA) respect the former accounting principle. Although in the case of transport emissions, the TDA depicts more accurately the amount of regional emissions for the PBA. The challenges documented in the methodology chapter of this thesis have been described in greater detail by Usubiaga and Acosta-Fernández (2015) where the known challenges in the allocation of transport emissions are described. Employing a similar methodology to obtain SNA compatible transport accounts is not possible with the MACC since it uses a dispersion model for transport emissions based on an *energy-first* approach (EMEP/EEA, 2016). As this thesis describes the first ever attempt to compile European-wide PBA for a regionalised IO system, solving the allocation challenges should be done in future work. The lack of regionalised PBA for comparison obtained respecting the SNA and SEEA, poses an additional challenge in the interpretation of the results described in the analysis section. This can be seen as a barrier towards asserting the quality of the BUA. Assuming that the MACC inventory provides a more accurate picture of the localized emissions, the BUA will inform better on the nature of the CBA in terms of its magnitude and origin.

The present study focused on the CO_2 based results while the pollutants in the BUA matrix R were not analysed. One of the main strengths of using the MACC inventory is the multitude of air pollutants which are included and can also be subject to a spatially-explicit CBA type of analysis. In the future, such type of analysis may shed light into the health impacts of consumption as recently was pointed out by Tessum et al. (2019) or based on international trade Zhang et al. (2017). To date in Europe, no study has been done on the linkages between indirect consumption-driven emissions and local health impacts as most of the studies focused on carbon or GHG emissions (Ivanova et al., 2017; Kanemoto et al., 2016; Moran, Kanemoto, et al., 2018).

Part 5

Conclusion

In the previous pages of this work, an attempt is made to answer the RQs through the described methodology and analysis chapters. The main RQ is:

> There are many factors affecting carbon footprints at the regional level, how do these compare using a bottom-up versus a top-down approach in the construction of emission accounts?

In the analysis chapter, extensive description of the regional variation that exists across Europe is provided combined with the variations per capita. To construct the EEIO model that allows to calculate CBA across Europe, the following sub-RQs are also used:

1. How to convert a grid-based inventory into compatible regional environmental extensions?
2. What are the differences in production-based accounts and consumption-based accounts when using a bottom-up approach versus a top-down approach to assemble environmental extensions?
3. What are the differences in consumption-based accounts per capita compared to the benchmark results described in Ivanova et al. (2017)?

To answer the first sub-RQ, all the detailed procedures explained in the methodology chapter are followed in order to build a Python-based model that allows to perform GIS manipulations. Auxiliary Excel spreadsheets were used to make the concordance between the hybrid SNAP sectors in the MACC inventory and the industry sectors in EUREGIO. The allocation of emissions required several bridge tables compiled in Excel that are subsequently imported to Python to allow the manipulation of emissions from the MACC inventory in a systematic way. If the methodology chapter is followed rigorously then the conversion of a grid-based emission inventory into compatible regional environmental extensions is possible.

The second sub-RQ is answered throughout the analysis chapter. The analysis chapter is divided between (1) a statistical analysis of the relative difference Φ between bottom-up BUA and top-down TDA approaches where the differences between PBA and CBA obtained with either of the approaches is fully analysed and (2) a descriptive analysis of the absolute values obtained using BUA for PBA, production intensity and CBA. The differences in PBA and CBA are found to be more prominent at the regional level compared to the national level. This indicates that using BUA yields more accurate estimations of the CBA provided that the inventory is deprived of reporting errors. Some problematic regions and sectors are also highlighted for further research to assess whether the reported emissions are accurate or not. Examples include *ss2* in Greece and Sweden, sector *ss5* in Greece, etc. A strong linear correlation is documented between the variations at the PBA level and the way these variations are translated into CBA which is in line with the findings reported by Moran and Wood (2014).

Direct (HH) emissions are overestimated in the BUA. This in turn leads to underestimation of the PBA which directly affects the magnitude of the CBA as explained by the linear relationship between the changes at the account level and the effects at the level of consumption. In other words, improved allocations at the account level will directly impact the magnitude of the CBA. Nevertheless, most of the observed divergences took place in sectors where passenger car emissions will not play a role such as sectors *ss2* and *ss8* although having more refined accounts would lead to preciser CBA.

The challenge underlined at many occasions throughout the report concerning the residence/territory principle and the way allocations should be performed, manifests itself heavily in the emissions in sector *12* - transport sector. In the tables in the appendix, very large relative differences occur between countries at the level of sector *12* showing the need to correctly tackle the allocations for the resident/territory principle (c.f. table 28). Apart from Austria, Belgium and France, all other countries have relative differences lower than 0 highlighting the fact that the bottom-up approach did not fully grasp the necessary allocations at the regional level to cope with the residence/territory principle's requirements. To solve this, emissions pertaining to shipping and aviation will be easier to approach by relying on transport statistics and/or bunkering declarations. In the case of road transport, it might be impossible to rely on the MACC inventory since the latter attributes emissions geographically based on dispersion, population and transport models. Hence to use the MACC as a single source for transport emissions compatible with the residence/territory principle is demonstrated in this thesis not to be the right choice. The solution lies in using the ancillary models used to compile the MACC inventory as a source of emissions at the country level to then used a combination of proxies to correctly allocate emissions to industries and HH.

The third subRQ is answered using regional carbon footprints as a means of comparing the relative difference between the bottom-up approach and the values obtained by Ivanova et al. (2017). The values reported by Ivanova et al. are strongly underestimated compared to the footprints obtained with BUA given that almost 75% of the footprints are at least 4% larger than the ones obtained by Ivanova et al. (2017). This difference highlights the added-value in terms of accuracy of using a regionalised production matrix to obtain production intensities. A similar conclusion is reached by Fry et al. (2018) in the need of more refined MRIO models to carry out detailed regional analysis.

Overall, (1) at the PBA level the divergence is increasing equally with detail, i.e., the smaller the geographical scope the higher the level of divergence between the bottom-up and the top-down approach and (2) a linear correlation exists between the PBA and the CBA level meaning that the conclusions reached by Moran and Wood (2014) are also echoed in this analysis.

Outlook and future research

As a means to develop a more refined methodology to construct environmental extensions at the regional level, the following propositions are made:

1. Improve the residence/territory principle approach for the allocation of transport emissions for shipping, air transport and passenger cars by using other sources than the MACC inventory. For shipping and air transport different emission source datasets should be used whereas for road transport the MACC inventory should be brought back one level, i.e., at the level before the application of the dispersion models.

2. Investigate at the inventory level in the MACC dataset the large regional variations for some sectors as pointed out in the regional analysis of the relative difference such as sector *ss2* in Sweden and in Greece and sector ss5. These peaks in relative difference may underline problems in data collection at the inventory level which may be ubiquitous (occuring at all collection points) or just isolated as in the case of some point-source data points in Greece.

3. Investigate the regional health impacts driven by exposure to air pollutants resulting from consumption-driven indirect emissions. This can be done by using the full extent of the calculated environmental extensions using the bottom-up approach combined with LCA-type data such as characterization factors.

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A Figures

Figure 29: MACC inventory datapoints plotted over the EU NUTS 2 shapefile.

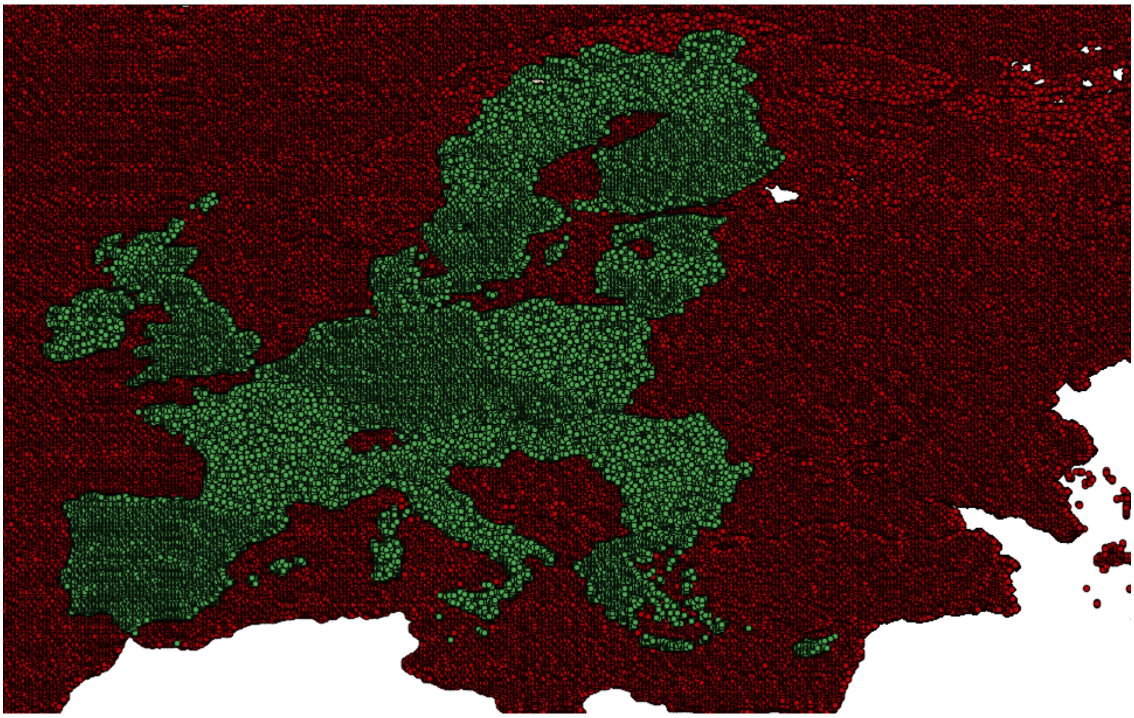


Figure 30: Results from *inside* and *outside* files. In red the points outside geometries and in green the points inside geometries.

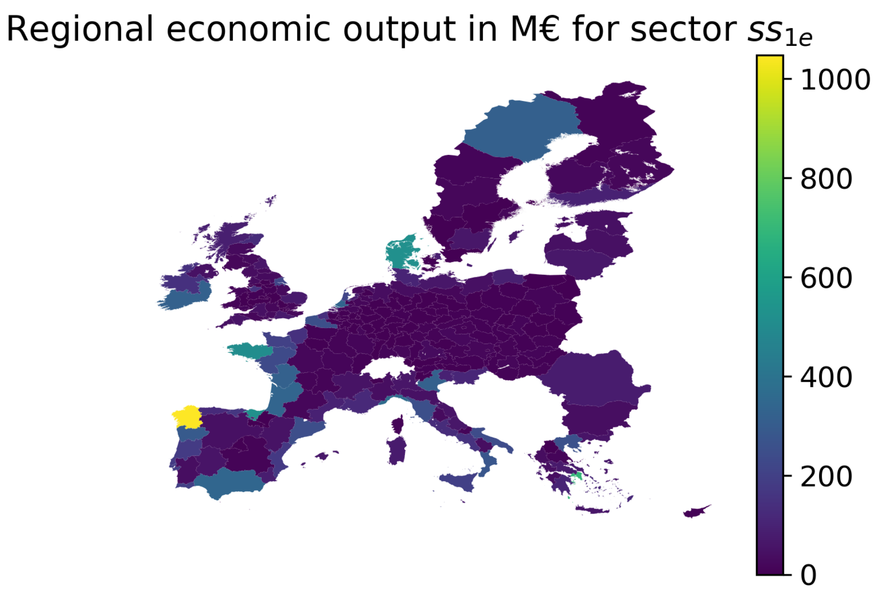


Figure 31: Overview of the regional absolute economic output of fisheries (*ss1e*). Regions located by the sea side naturally have higher economic output.

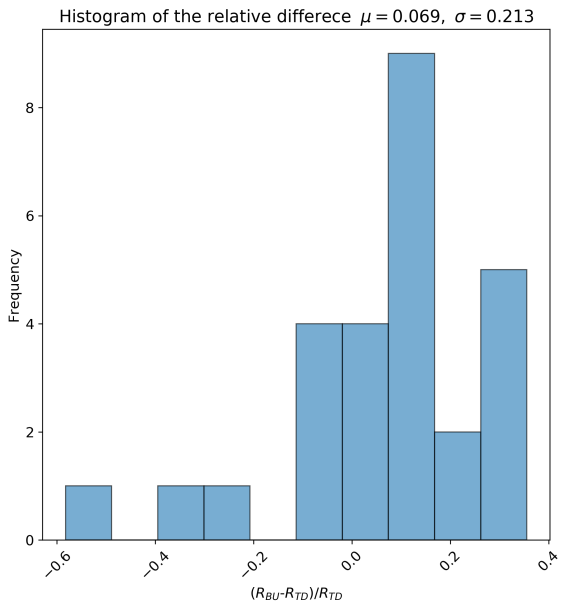


Figure 32: Histogram of the relative difference Φ at a national level in accounts including HH emissions.

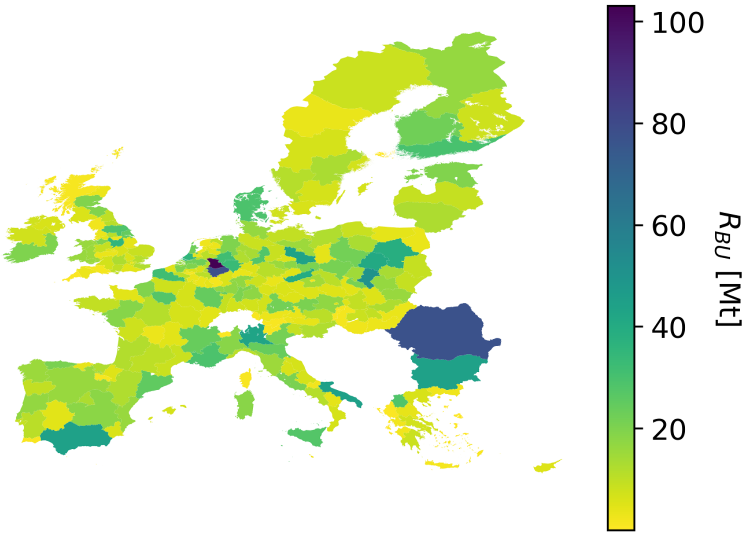


Figure 33: Comparison of CO_2 regional accounts.

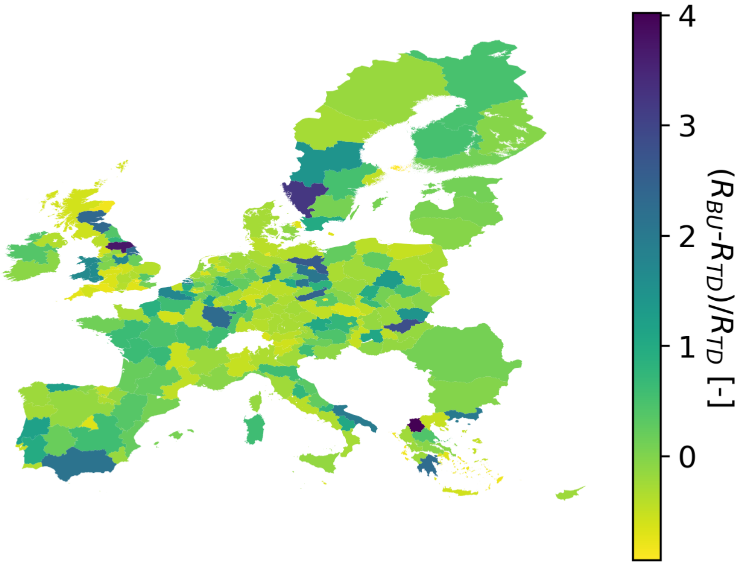


Figure 34: Comparison of the relative difference Φ in regional accounts for CO_2.

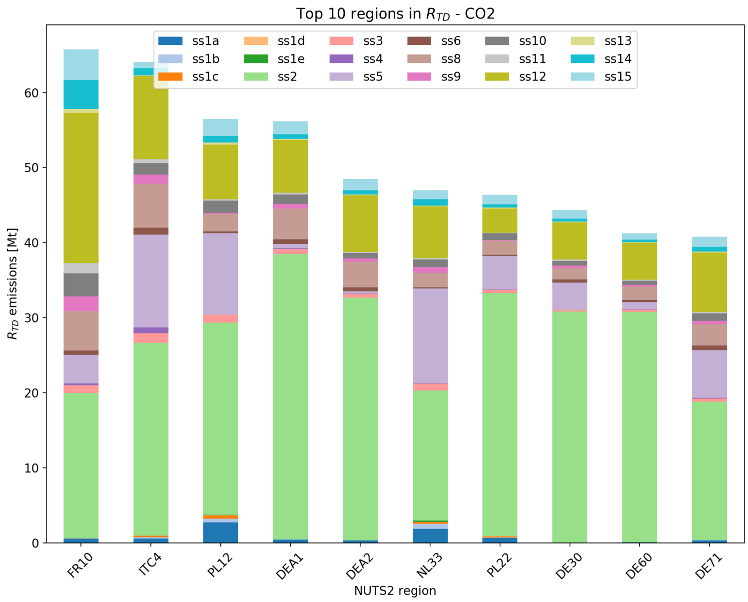


Figure 35: Regional accounts for TDA per sector.

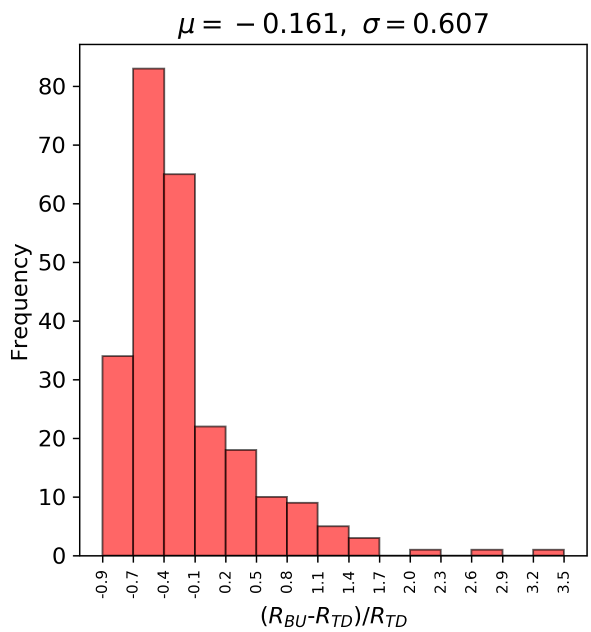


Figure 36: Histogram of the relative difference Φ at a regional level in accounts including HH emissions.

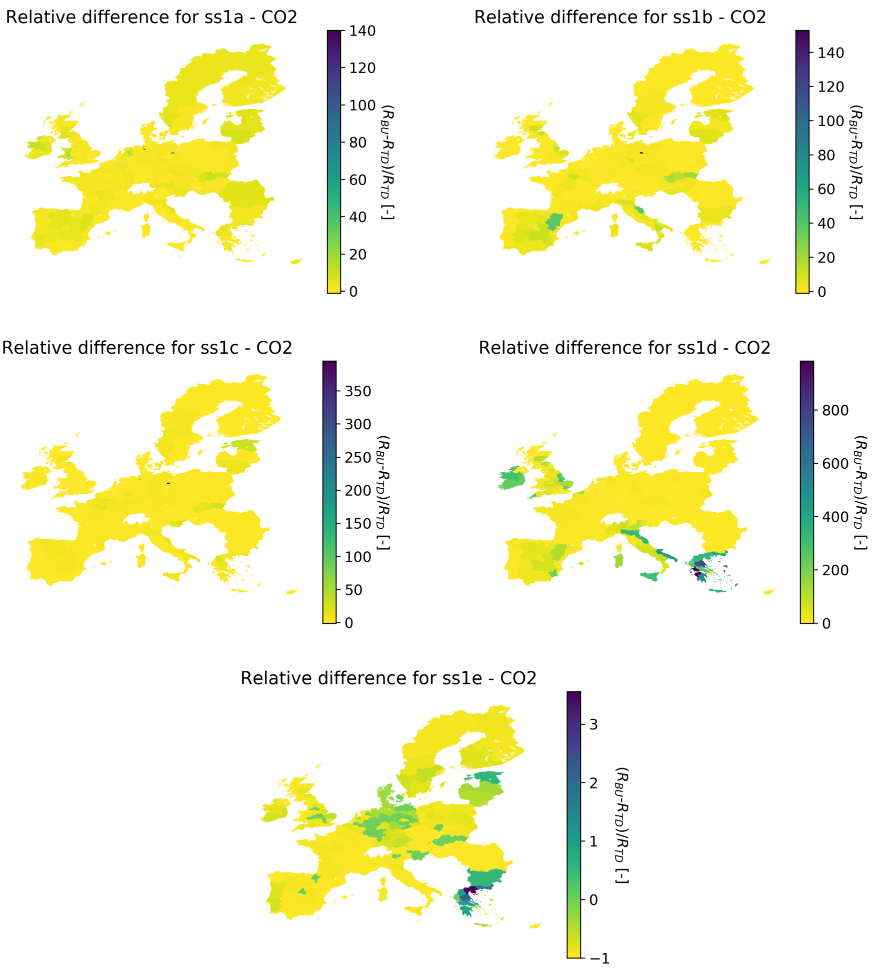


Figure 37: Relative difference Φ in regions per sector (*ss1a*, *ss1b*, *ss1c*, *ss1d*, *ss1e*).

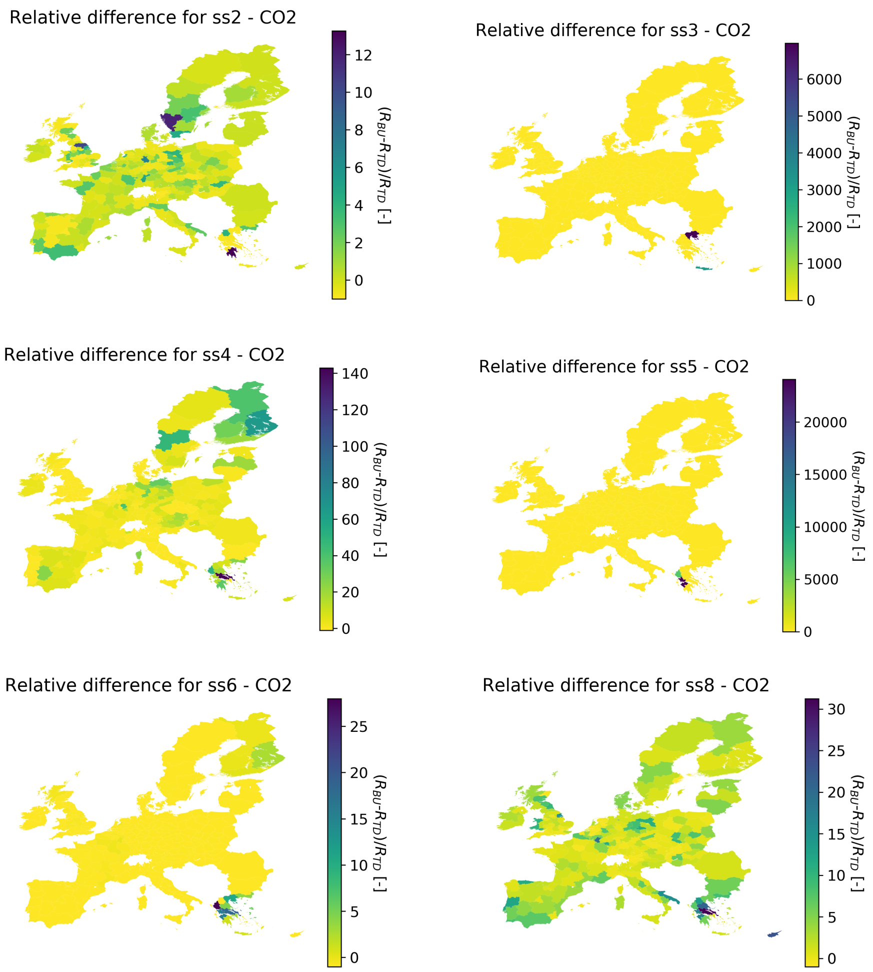


Figure 38: Relative difference Φ in regions per sector (*ss2*, *ss3*, *ss4*, *ss5*, *ss6*, *ss8*).

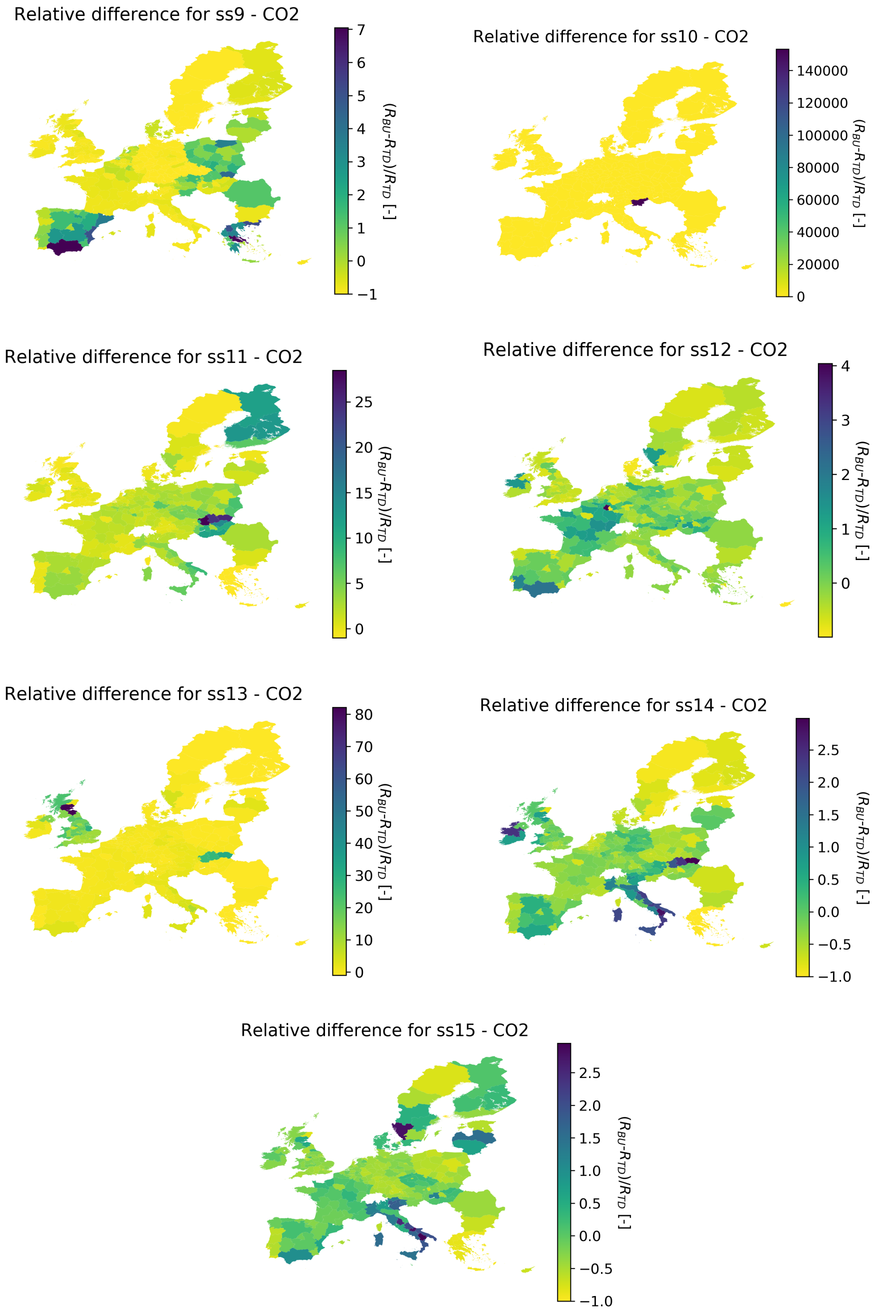


Figure 39: Relative difference Φ in regions per sector (*ss9*, *ss10*, *ss11*, *ss12*, *ss13*, *ss14*, *ss15*).

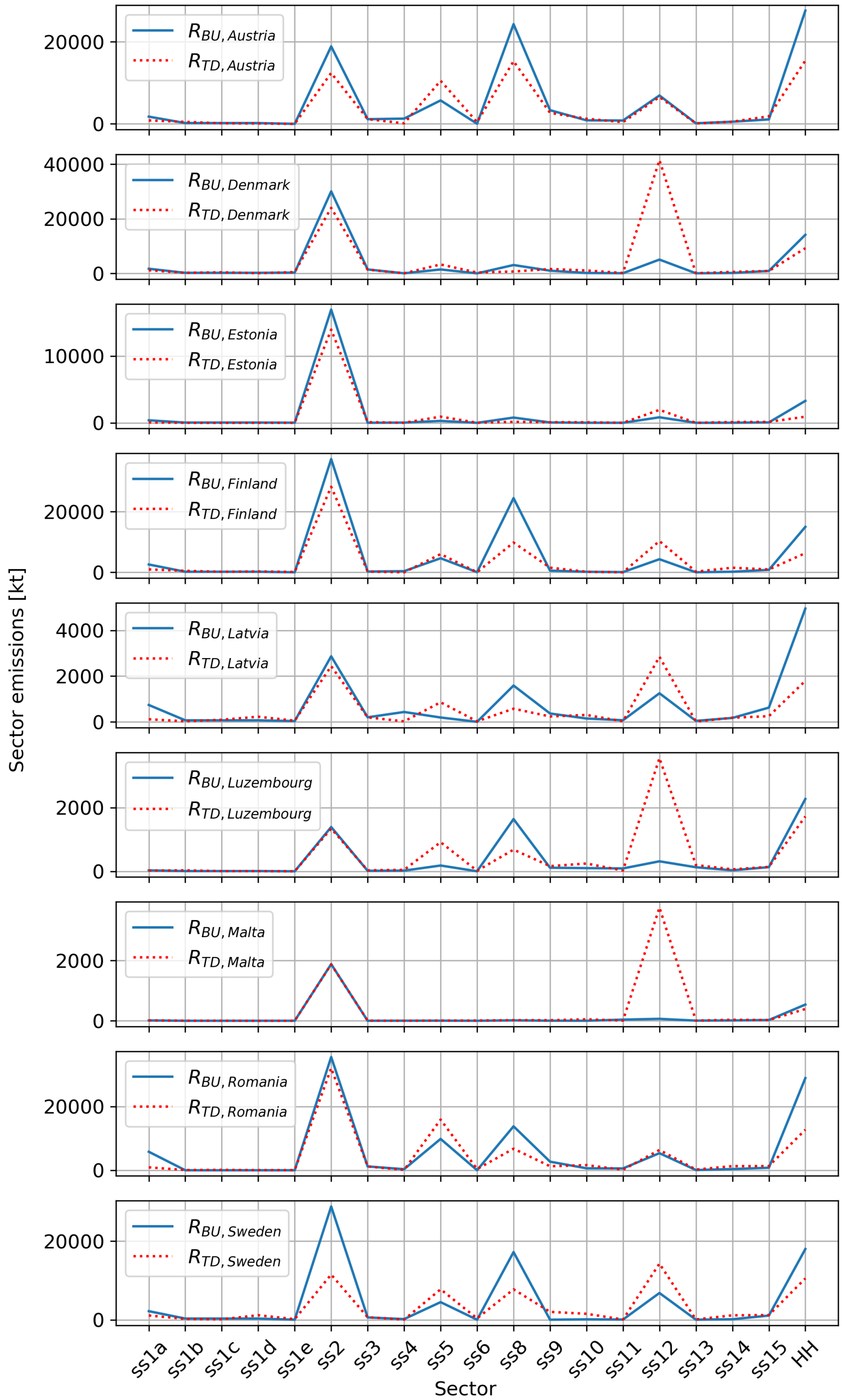


Figure 40: Sector variation across problematic countries.

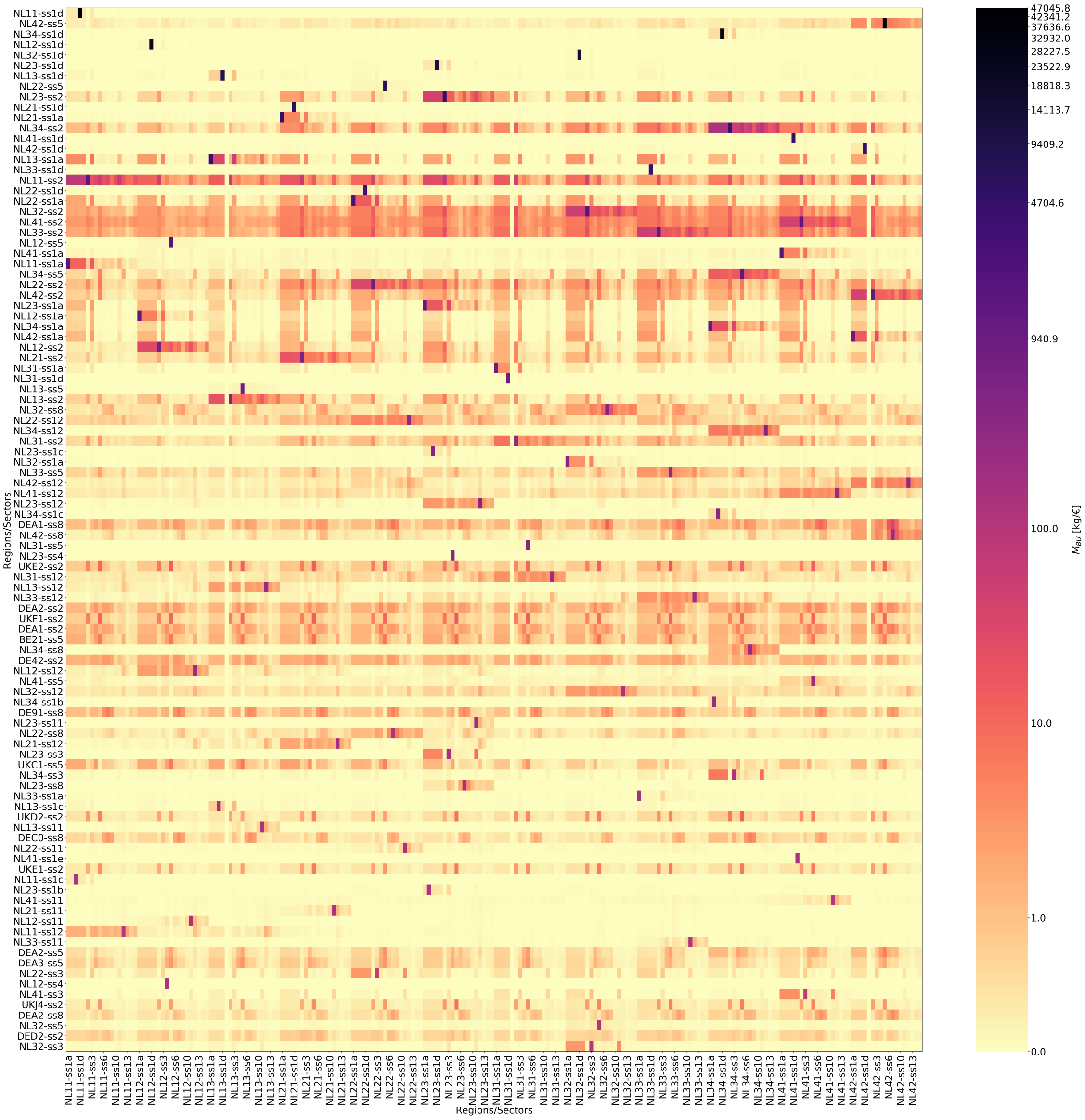


Figure 41: View of a portion of the M matrix representing the top 100 contributors for the production intensity of Dutch regions using BUA. Top 100 contributing regions/sectors are in the Y-axis and Dutch regions/sectors in the X-axis. Values represent the production intensity m_{ij} normalised using log_{10}. Rows have been ranked in descending order based on row totals $\sum_{j=1}^{n} m_{ij}$

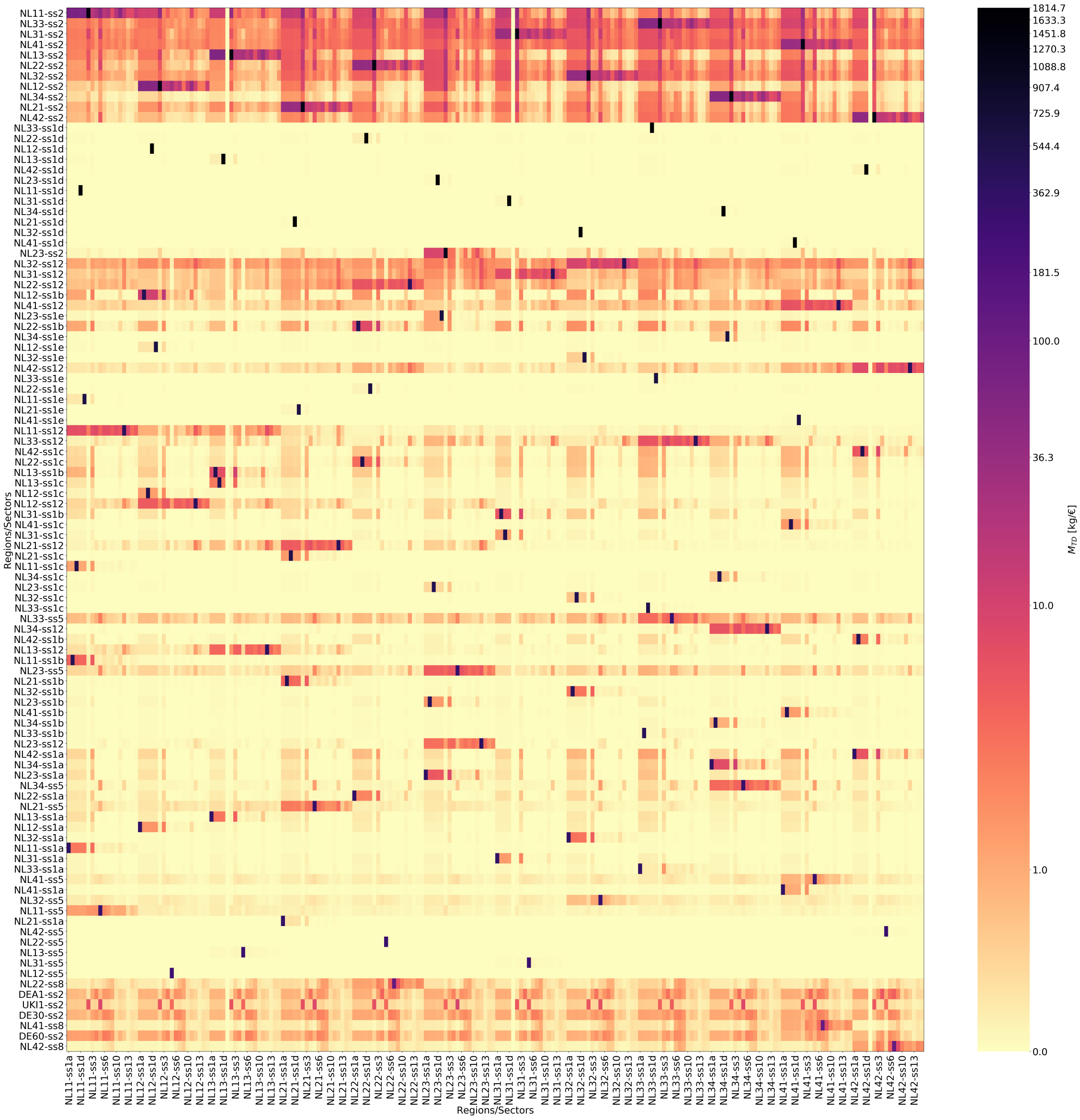


Figure 42: View of a portion of the M matrix representing the top 100 contributors for the production intensity of Dutch regions using TDA. Top 100 contributing regions/sectors are in the Y-axis and Dutch regions/sectors in the X-axis. Values represent the production intensity m_{ij} normalised using log_{10}. Rows have been ranked in descending order based on row totals $\sum_{j=1}^{n} m_{ij}$

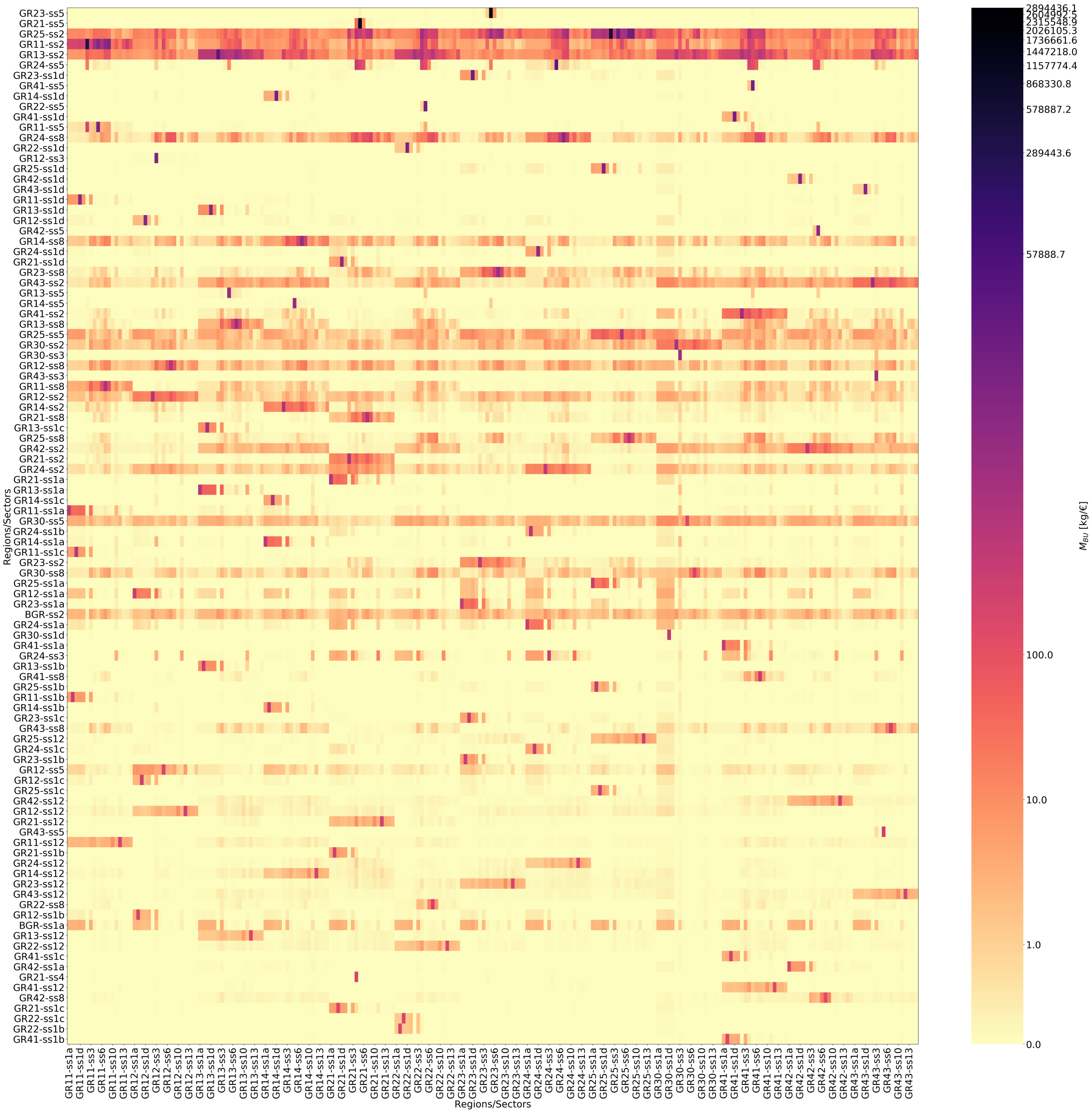


Figure 43: View of a portion of the M matrix representing the top 100 contributors for the production intensity of Greek regions using BUA. Top 100 contributing regions/sectors are in the Y-axis and Greek regions/sectors in the X-axis. Values represent the production intensity m_{ij} normalised using log_{10}. Rows have been ranked in descending order based on row totals $\sum_{j=1}^{n} m_{ij}$

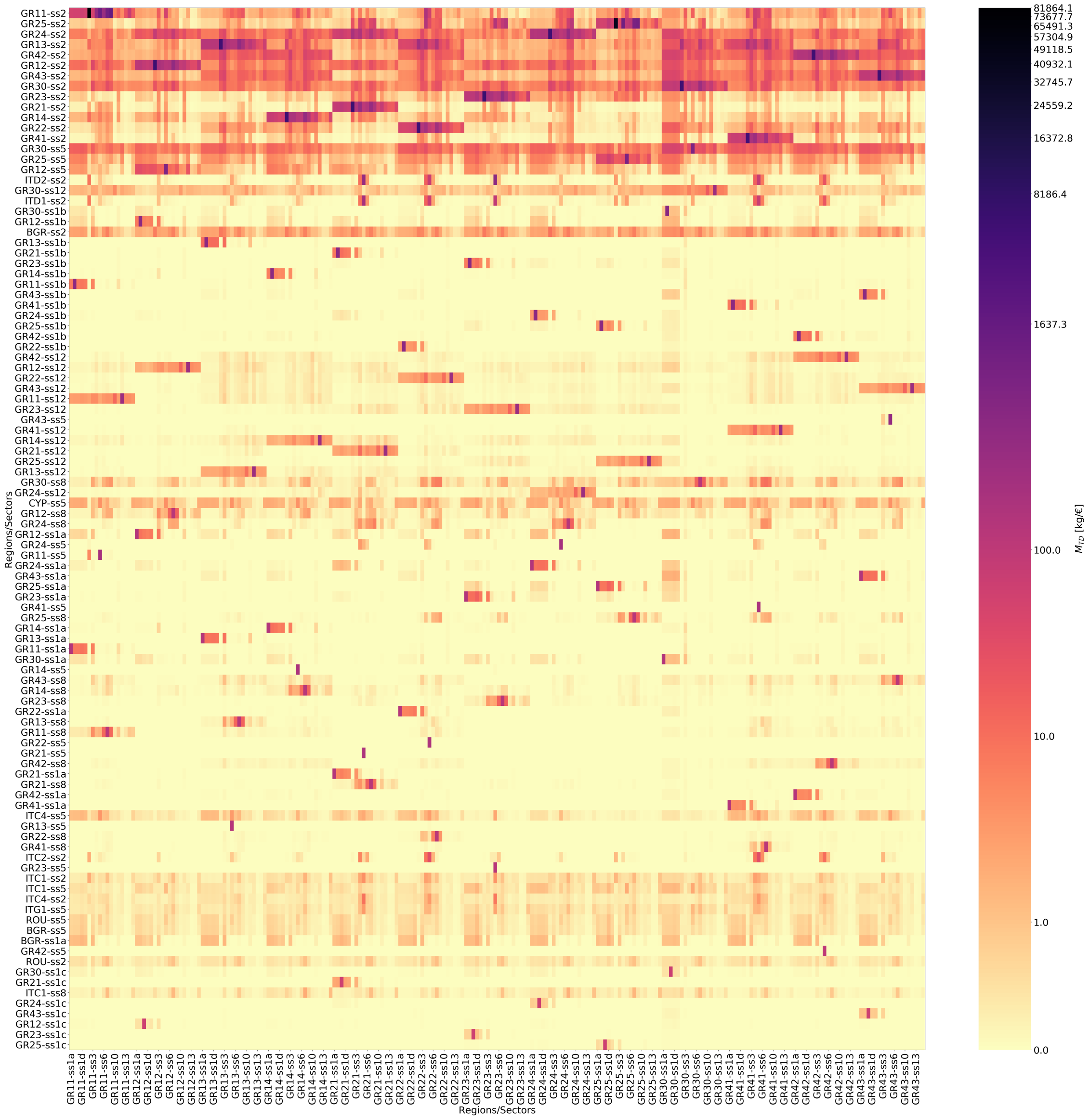
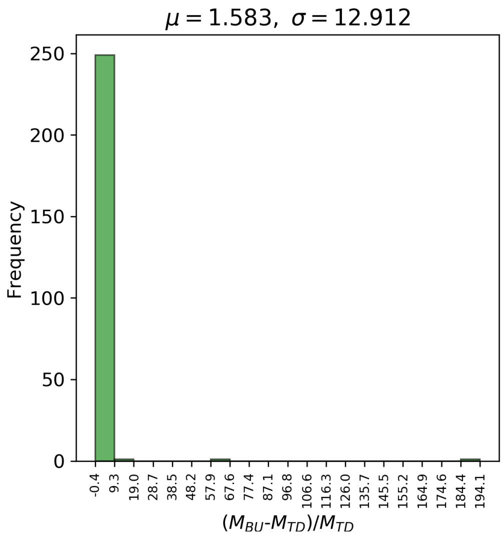
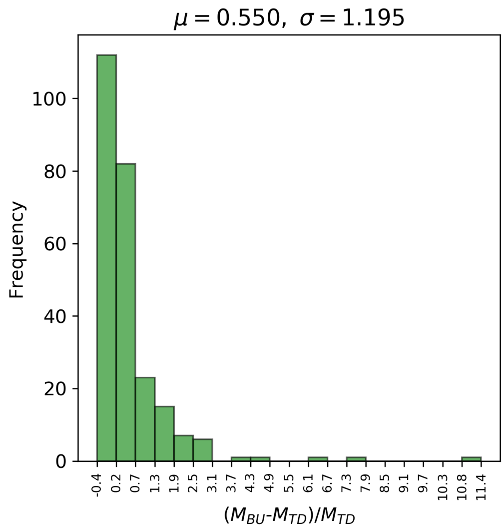


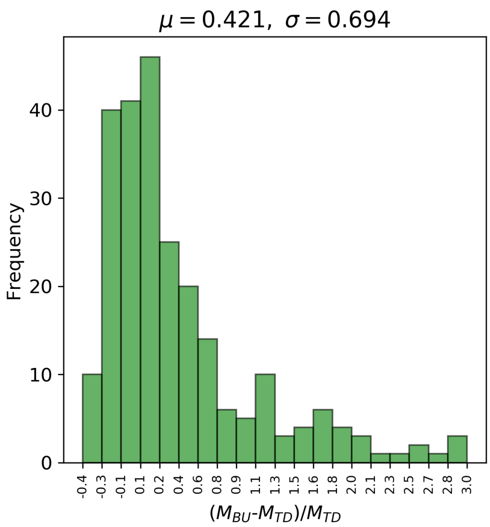
Figure 44: View of a portion of the M matrix representing the top 100 contributors for the production intensity of Greek regions using TDA. Top 100 contributing regions/sectors are in the Y-axis and Greek regions/sectors in the X-axis. Values represent the production intensity m_{ij} normalised using log_{10}. Rows have been ranked in descending order based on row totals $\sum_{j=1}^{n} m_{ij}$



(a) All regions.

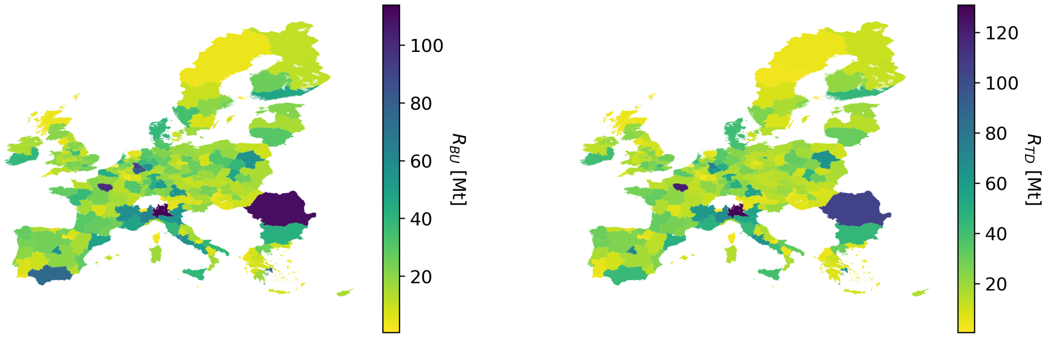


(b) Excluding BE23 and DE14.



(c) Excluding BE23, DE14, BE22, UKH2, GR22, PT16, PL31.

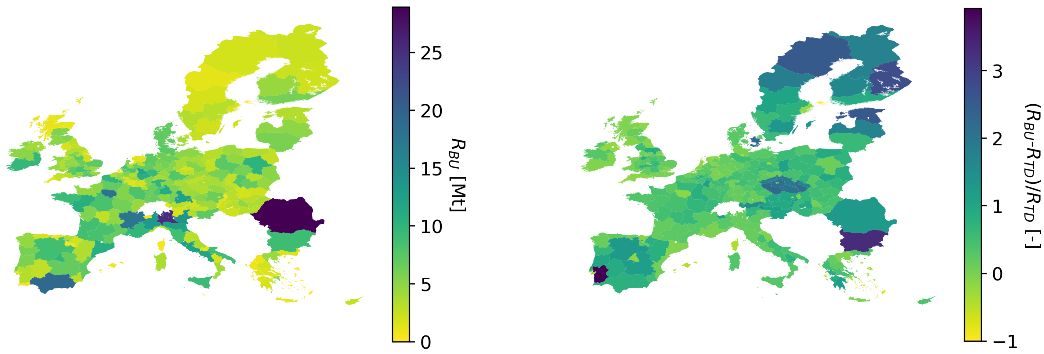
Figure 45: Histogram of the relative difference Φ between production intensities calculated with both accounts. Regional totals are used to compare the differences.



(a) Indirect emissions in BUA.

(b) Indirect emissions in TDA.

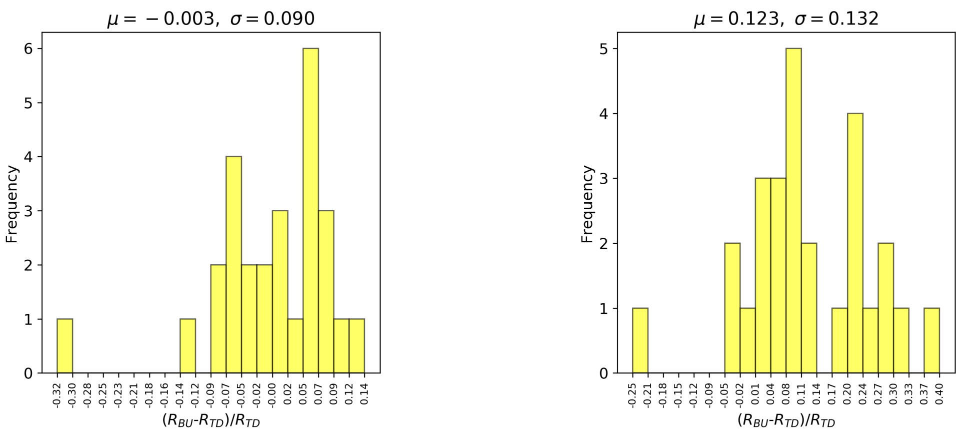
Figure 46: Regional overview of the absolute indirect emissions in BUA and TDA.



(a) Direct emissions in BUA.

(b) Relative difference Φ in direct emissions.

Figure 47: Regional overview of the absolute direct emissions in BUA and the relative difference towards the baseline accounts.



(a) Excluding direct (HH) emissions.

(b) Including direct (HH) emissions.

Figure 49: Histogram of the relative difference Φ in consumption-driven emissions at the national level for all FD categories.

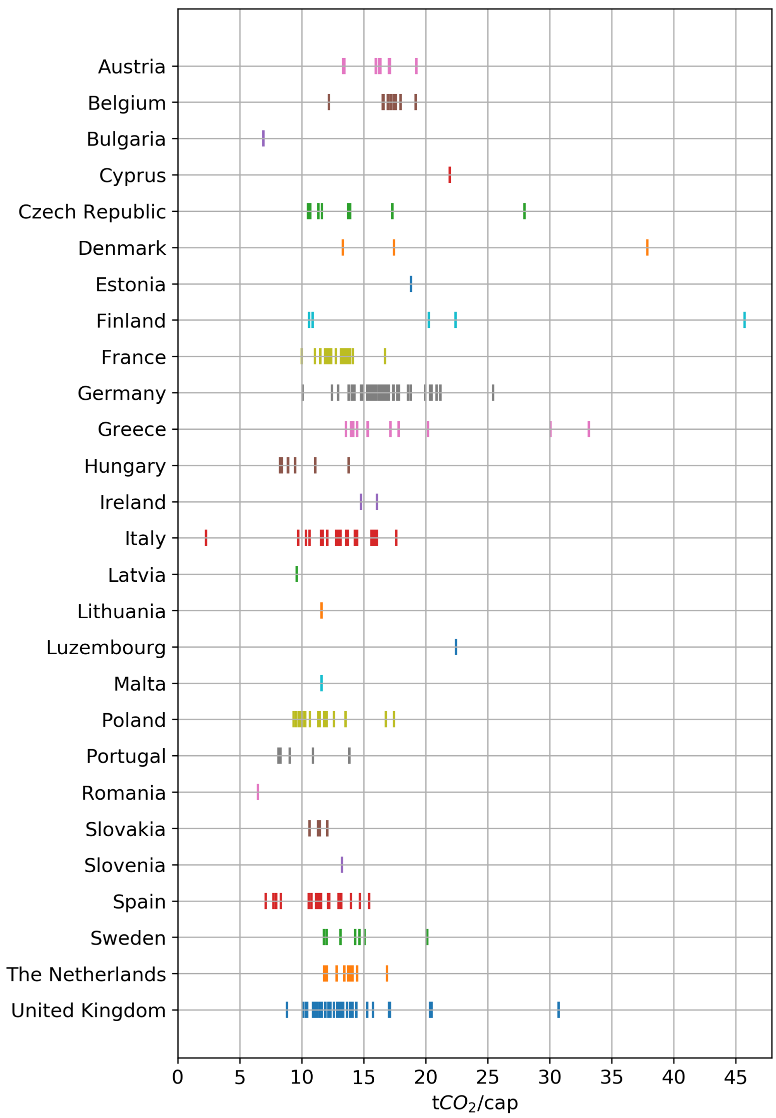


Figure 48: Distribution of the per capita carbon footprints for total emissions.

B Tables

Table 16: NUTS2 regions available in the 2003 and 2006 level 2 EU shapefiles.

2003		2006	
NUTS ID	NUTS Name	NUTS ID	NUTS Name
AT11	Burgenland	AT11	Burgenland (A)
AT12	Niederosterreich	AT12	Niederosterreich
AT13	Wien	AT13	Wien
AT21	Karnten	AT21	Karnten
AT22	Steiermark	AT22	Steiermark
AT31	Oberosterreich	AT31	Oberosterreich
AT32	Salzburg	AT32	Salzburg
AT33	Tirol	AT33	Tirol
AT34	Vorarlberg	AT34	Vorarlberg
BE10	Region de Bruxelles-Capitale	BE10	Region de Bruxelles-Capitale
BE21	Prov. Antwerpen	BE21	Prov. Antwerpen
BE22	Prov. Limburg (B)	BE22	Prov. Limburg (B)
BE23	Prov. Oost-Vlaanderen	BE23	Prov. Oost-Vlaanderen
BE24	Prov. Vlaams-Brabant	BE24	Prov. Vlaams-Brabant

Continued on next page

Table 16 – continued from previous page

2003		2006	
NUTS ID	NUTS Name	NUTS ID	NUTS Name
BE25	Prov. West-Vlaanderen	BE25	Prov. West-Vlaanderen
BE31	Prov. Brabant Wallon	BE31	Prov. Brabant Wallon
BE32	Prov. Hainaut	BE32	Prov. Hainaut
BE33	Prov. Liege	BE33	Prov. Liege
BE34	Prov. Luxembourg (B)	BE34	Prov. Luxembourg (B)
BE35	Prov. Namur	BE35	Prov. Namur
BG31	Severozapaden	BG31	Severozapaden
BG32	Severen tsentralen	BG32	Severen tsentralen
BG33	Severoiztochen	BG33	Severoiztochen
BG34	Yugoiztochen	BG34	Yugoiztochen
BG41	Yugozapaden	BG41	Yugozapaden
BG42	Yuzhen tsentralen	BG42	Yuzhen tsentralen
CH01	Region Lemanique	CH01	Region Lemanique
CH02	Espace Mittelland	CH02	Espace Mittelland
CH03	Nordwestschweiz	CH03	Nordwestschweiz
CH04	Zurich	CH04	Zurich
CH05	Ostschweiz	CH05	Ostschweiz
CH06	Zentralschweiz	CH06	Zentralschweiz
CH07	Ticino	CH07	Ticino
CY00	Kypros	CY00	Kypros
CZ01	Praha	CZ01	Praha
CZ02	Stredni Cechy	CZ02	Stredni Cechy
CZ03	Jihozapad	CZ03	Jihozapad
CZ04	Severozapad	CZ04	Severozapad
CZ05	Severovychod	CZ05	Severovychod
CZ06	Jihovychod	CZ06	Jihovychod
CZ07	Stredni Morava	CZ07	Stredni Morava
CZ08	Moravskoslezsko	CZ08	Moravskoslezsko
DE11	Stuttgart	DE11	Stuttgart
DE12	Karlsruhe	DE12	Karlsruhe
DE13	Freiburg	DE13	Freiburg
DE14	Tubingen	DE14	Tubingen
DE21	Oberbayern	DE21	Oberbayern
DE22	Niederbayern	DE22	Niederbayern
DE23	Oberpfalz	DE23	Oberpfalz
DE24	Oberfranken	DE24	Oberfranken
DE25	Mittelfranken	DE25	Mittelfranken
DE26	Unterfranken	DE26	Unterfranken
DE27	Schwaben	DE27	Schwaben
DE30	Berlin	DE30	Berlin
DE41	Brandenburg - Nordost	DE41	Brandenburg - Nordost
DE42	Brandenburg - Sudwest	DE42	Brandenburg - Sudwest
DE50	Bremen	DE50	Bremen
DE60	Hamburg	DE60	Hamburg
DE71	Darmstadt	DE71	Darmstadt
DE72	Giessen	DE72	Giessen
DE73	Kassel	DE73	Kassel
DE80	Mecklenburg-Vorpommern	DE80	Mecklenburg-Vorpommern
DE91	Braunschweig	DE91	Braunschweig
DE92	Hannover	DE92	Hannover
DE93	Luneburg	DE93	Luneburg
DE94	Weser-Ems	DE94	Weser-Ems
DEA1	Dusseldorf	DEA1	Dusseldorf
DEA2	Koln	DEA2	Koln
DEA3	Munster	DEA3	Munster
DEA4	Detmold	DEA4	Detmold
DEA5	Arnsberg	DEA5	Arnsberg
DEB1	Koblenz	DEB1	Koblenz
DEB2	Trier	DEB2	Trier
DEB3	Rheinhessen-Pfalz	DEB3	Rheinhessen-Pfalz
DEC0	Saarland	DEC0	Saarland
DED1	Chemnitz	DED1	Chemnitz
DED2	Dresden	DED2	Dresden
DED3	Leipzig	DED3	Leipzig
DEE1	Dessau	DEE0	Sachsen-Anhalt
DEE2	Halle	DEF0	Schleswig-Holstein
DEE3	Magdeburg	DEG0	Thuringen
DEF0	Schleswig-Holstein	DK01	Hovedstaden
DEG0	Thuringen	DK02	Sjaelland
DK00	Danmark	DK03	Syddanmark
EE00	Eesti	DK04	Midtjylland
ES11	Galicia	DK05	Nordjylland
ES12	Principado de Asturias	EE00	Eesti
ES13	Cantabria	ES11	Galicia
ES21	Pais Vasco	ES12	Principado de Asturias
ES22	Comunidad Foral de Navarra	ES13	Cantabria
ES23	La Rioja	ES21	Pais Vasco
ES24	Aragon	ES22	Comunidad Foral de Navarra

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Table 16 – continued from previous page

2003		2006	
NUTS ID	NUTS Name	NUTS ID	NUTS Name
ES30	Comunidad de Madrid	ES23	La Rioja
ES41	Castilla y Leon	ES24	Aragon
ES42	Castilla-La Mancha	ES30	Comunidad de Madrid
ES43	Extremadura	ES41	Castilla y Leon
ES51	Catalunia	ES42	Castilla-La Mancha
ES52	Comunidad Valenciana	ES43	Extremadura
ES53	Illes Balears	ES51	Catalunia
ES61	Andalucia	ES52	Comunidad Valenciana
ES62	Region de Murcia	ES53	Illes Balears
ES63	Ciudad Autonoma de Ceuta	ES61	Andalucia
ES64	Ciudad Autonoma de Melilla	ES62	Region de Murcia
ES70	Canarias	ES63	Ciudad Autonoma de Ceuta
FI13	Ita-Suomi	ES64	Ciudad Autonoma de Melilla
FI18	Etela-Suomi	ES70	Canarias
FI19	Lansi-Suomi	FI13	Ita-Suomi
FI1A	Pohjois-Suomi	FI18	Etela-Suomi
FI20	Aland	FI19	Lansi-Suomi
FR10	Ile de France	FI1A	Pohjois-Suomi
FR21	Champagne-Ardenne	FI20	Aland
FR22	Picardie	FR10	Ile de France
FR23	Haute-Normandie	FR21	Champagne-Ardenne
FR24	Centre	FR22	Picardie
FR25	Basse-Normandie	FR23	Haute-Normandie
FR26	Bourgogne	FR24	Centre
FR30	Nord - Pas-de-Calais	FR25	Basse-Normandie
FR41	Lorraine	FR26	Bourgogne
FR42	Alsace	FR30	Nord - Pas-de-Calais
FR43	Franche-Comte	FR41	Lorraine
FR51	Pays de la Loire	FR42	Alsace
FR52	Bretagne	FR43	Franche-Comte
FR53	Poitou-Charentes	FR51	Pays de la Loire
FR61	Aquitaine	FR52	Bretagne
FR62	Midi-Pyrenees	FR53	Poitou-Charentes
FR63	Limousin	FR61	Aquitaine
FR71	Rhone-Alpes	FR62	Midi-Pyrenees
FR72	Auvergne	FR63	Limousin
FR81	Languedoc-Roussillon	FR71	Rhone-Alpes
FR82	Provence-Alpes-Cote d'Azur	FR72	Auvergne
FR83	Corse	FR81	Languedoc-Roussillon
FR91	Guadeloupe	FR82	Provence-Alpes-Cote d'Azur
FR92	Martinique	FR83	Corse
FR93	Guyane	FR91	Guadeloupe
FR94	Reunion	FR92	Martinique
GR11	Anatoliki Makedonia, Thraki	FR93	Guyane
GR12	Kentriki Makedonia	FR94	Reunion
GR13	Dytiki Makedonia	GR11	Anatoliki Makedonia, Thraki
GR14	Thessalia	GR12	Kentriki Makedonia
GR21	Ipeiros	GR13	Dytiki Makedonia
GR22	Ionia Nisia	GR14	Thessalia
GR23	Dytiki Ellada	GR21	Ipeiros
GR24	Sterea Ellada	GR22	Ionia Nisia
GR25	Peloponnisos	GR23	Dytiki Ellada
GR30	Attiki	GR24	Sterea Ellada
GR41	Voreio Aigaio	GR25	Peloponnisos
GR42	Notio Aigaio	GR30	Attiki
GR43	Kriti	GR41	Voreio Aigaio
HR01	Sjeverozapadna Hrvatska	GR42	Notio Aigaio
HR02	Sredisnja i Istocna (Panonska) Hrvatska	GR43	Kriti
HR03	Jadranska Hrvatska	HR01	Sjeverozapadna Hrvatska
HU10	Kozep-Magyarorszag	HR02	Sredisnja i Istocna (Panonska) Hrvatska
HU21	Kozep-Dunantul	HR03	Jadranska Hrvatska
HU22	Nyugat-Dunantul	HU10	Kozep-Magyarorszag
HU23	Del-Dunantul	HU21	Kozep-Dunantul
HU31	Eszak-Magyarorszag	HU22	Nyugat-Dunantul
HU32	Eszak-Alfold	HU23	Del-Dunantul
HU33	Del-AlfÃold	HU31	Eszak-Magyarorszag
IE01	Border, Midland and Western	HU32	Eszak-Alfold
IE02	Southern and Eastern	HU33	Del-AlfÃold
IS00	Island	IE01	Border, Midland and Western
ITC1	Piemonte	IE02	Southern and Eastern
ITC2	Valle d'Aosta	IS00	Island
ITC3	Liguria	ITC1	Piemonte
ITC4	Lombardia	ITC2	Valle d'Aosta
ITD1	Provincia Autonoma Bolzano/Bozen	ITC3	Liguria
ITD2	Provincia Autonoma Trento	ITC4	Lombardia
ITD3	Veneto	ITD1	Provincia Autonoma Bolzano/Bozen

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Table 16 – continued from previous page

2003		2006	
NUTS ID	NUTS Name	NUTS ID	NUTS Name
ITD4	Friuli-Venezia Giulia	ITD2	Provincia Autonoma Trento
ITD5	Emilia-Romagna	ITD3	Veneto
ITE1	Toscana	ITD4	Friuli-Venezia Giulia
ITE2	Umbria	ITD5	Emilia-Romagna
ITE3	Marche	ITE1	Toscana
ITE4	Lazio	ITE2	Umbria
ITF1	Abruzzo	ITE3	Marche
ITF2	Molise	ITE4	Lazio
ITF3	Campania	ITF1	Abruzzo
ITF4	Puglia	ITF2	Molise
ITF5	Basilicata	ITF3	Campania
ITF6	Calabria	ITF4	Puglia
ITG1	Sicilia	ITF5	Basilicata
ITG2	Sardegna	ITF6	Calabria
LI00	Liechtenstein	ITG1	Sicilia
LT00	Lietuva	ITG2	Sardegna
LU00	Luxembourg (Grand-Duchee)	LI00	Liechtenstein
LV00	Latvija	LT00	Lietuva
MT00	Malta	LU00	Luxembourg (Grand-Duchee)
NL11	Groningen	LV00	Latvija
NL12	Friesland	ME00	Montenegro
NL13	Drenthe	MK00	Macedonia
NL21	Overijssel	MT00	Malta
NL22	Gelderland	NL11	Groningen
NL23	Flevoland	NL12	Friesland (NL)
NL31	Utrecht	NL13	Drenthe
NL32	Noord-Holland	NL21	Overijssel
NL33	Zuid-Holland	NL22	Gelderland
NL34	Zeeland	NL23	Flevoland
NL41	Noord-Brabant	NL31	Utrecht
NL42	Limburg (NL)	NL32	Noord-Holland
NO01	Oslo og Akershus	NL33	Zuid-Holland
NO02	Hedmark og Oppland	NL34	Zeeland
NO03	Sor-Ostlandet	NL41	Noord-Brabant
NO04	Agder og Rogaland	NL42	Limburg (NL)
NO05	Vestlandet	NO01	Oslo og Akershus
NO06	Trondelag	NO02	Hedmark og Oppland
NO07	Nord-Norge	NO03	Sor-Ostlandet
PL11	Lodzkie	NO04	Agder og Rogaland
PL12	Mazowieckie	NO05	Vestlandet
PL21	Malopolskie	NO06	Trondelag
PL22	Slaskie	NO07	Nord-Norge
PL31	Lubelskie	PL11	Lodzkie
PL32	Podkarpackie	PL12	Mazowieckie
PL33	Swietokrzyskie	PL21	Malopolskie
PL34	Podlaskie	PL22	Slaskie
PL41	Wielkopolskie	PL31	Lubelskie
PL42	Zachodniopomorskie	PL32	Podkarpackie
PL43	Lubuskie	PL33	Swietokrzyskie
PL51	Dolnoslaskie	PL34	Podlaskie
PL52	Opolskie	PL41	Wielkopolskie
PL61	Kujawsko-Pomorskie	PL42	Zachodniopomorskie
PL62	Warminsko-Mazurskie	PL43	Lubuskie
PL63	Pomorskie	PL51	Dolnoslaskie
PT11	Norte	PL52	Opolskie
PT15	Algarve	PL61	Kujawsko-Pomorskie
PT16	Centro (P)	PL62	Warminsko-Mazurskie
PT17	Lisboa	PL63	Pomorskie
PT18	Alentejo	PT11	Norte
PT20	Regiao Autonoma dos Acores	PT15	Algarve
PT30	Regiao Autonoma da Madeira	PT16	Centro (P)
RO11	Nord-Vest	PT17	Lisboa
RO12	Centru	PT18	Alentejo
RO21	Nord-Est	PT20	Regiao Autonoma dos Acores
RO22	Sud-Est	PT30	Regiao Autonoma da Madeira
RO31	Sud - Muntenia	RO11	Nord-Vest
RO32	Bucuresti - Ilfov	RO12	Centru
RO41	Sud-Vest Oltenia	RO21	Nord-Est
RO42	Vest	RO22	Sud-Est
SE01	Stockholm	RO31	Sud - Muntenia
SE02	Ostra Mellansverige	RO32	Bucuresti - Ilfov
SE04	Sydsverige	RO41	Sud-Vest Oltenia
SE06	Norra Mellansverige	RO42	Vest
SE07	Mellersta Norrland	SE11	Stockholm
SE08	Ovre Norrland	SE12	Ostra Mellansverige
SE09	Smaland med oarna	SE21	Smaland med oarna
SE0A	Vastsverige	SE22	Sydsverige
SI00	Slovenija	SE23	Vastsverige

Continued on next page

Table 16 – continued from previous page

2003		2006	
NUTS ID	NUTS Name	NUTS ID	NUTS Name
SK01	Bratislavsky kraj	SE31	Norra Mellansverige
SK02	Zapadne Slovensko	SE32	Mellersta Norrland
SK03	Stredne Slovensko	SE33	Ovre Norrland
SK04	Vychodne Slovensko	SI01	Vzhodna Slovenija
TR10	Istanbul	SI02	Zahodna Slovenija
TR21	Tekirdag	SK01	Bratislavsky kraj
TR22	Balikesir	SK02	Zapadne Slovensko
TR31	Ozmir	SK03	Stredne Slovensko
TR32	Aydin	SK04	Vychodne Slovensko
TR33	Manisa	TR10	Istanbul
TR41	Bursa	TR21	Tekirdag
TR42	Kocaeli	TR22	Balikesir
TR51	Ankara	TR31	Ozmir
TR52	Konya	TR32	Aydin
TR61	Antalya	TR33	Manisa
TR62	Adana	TR41	Bursa
TR63	Hatay	TR42	Kocaeli
TR71	Kirikkale	TR51	Ankara
TR72	Kayseri	TR52	Konya
TR81	Zonguldak	TR61	Antalya
TR82	Kastamonu	TR62	Adana
TR83	Samsun	TR63	Hatay
TR90	Dogu Karadeniz	TR71	Kirikkale
TRA1	Erzurum	TR72	Kayseri
TRA2	Agri	TR81	Zonguldak
TRB1	Malatya	TR82	Kastamonu
TRB2	Van	TR83	Samsun
TRC1	Gaziantep	TR90	Dogu Karadeniz
TRC2	Sanliurfa	TRA1	Erzurum
TRC3	Mardin	TRA2	Agri
UKC1	Tees Valley and Durham	TRB1	Malatya
UKC2	Northumberland and Tyne and Wear	TRB2	Van
UKD1	Cumbria	TRC1	Gaziantep
UKD2	Cheshire	TRC2	Sanliurfa
UKD3	Greater Manchester	TRC3	Mardin
UKD4	Lancashire	UKC1	Tees Valley and Durham
UKD5	Merseyside	UKC2	Northumberland and Tyne and Wear
UKE1	East Riding and North Lincolnshire	UKD1	Cumbria
UKE2	North Yorkshire	UKD2	Cheshire
UKE3	South Yorkshire	UKD3	Greater Manchester
UKE4	West Yorkshire	UKD4	Lancashire
UKF1	Derbyshire and Nottinghamshire	UKD5	Merseyside
UKF2	Leicestershire, Rutland and Northamptonshire	UKE1	East Yorkshire and Northern Lincolnshire
UKF3	Lincolnshire	UKE2	North Yorkshire
UKG1	Herefordshire, Worcestershire and Warwickshire	UKE3	South Yorkshire
UKG2	Shropshire and Staffordshire	UKE4	West Yorkshire
UKG3	West Midlands	UKF1	Derbyshire and Nottinghamshire
UKH1	East Anglia	UKF2	Leicestershire, Rutland and Northamptonshire
UKH2	Bedfordshire and Hertfordshire	UKF3	Lincolnshire
UKH3	Essex	UKG1	Herefordshire, Worcestershire and Warwickshire
UKI1	Inner London	UKG2	Shropshire and Staffordshire
UKI2	Outer London	UKG3	West Midlands
UKJ1	Berkshire, Buckinghamshire and Oxfordshire	UKH1	East Anglia
UKJ2	Surrey, East and West Sussex	UKH2	Bedfordshire and Hertfordshire
UKJ3	Hampshire and Isle of Wight	UKH3	Essex
UKJ4	Kent	UKI1	Inner London
UKK1	Gloucestershire, Wiltshire and North Somerset	UKI2	Outer London
UKK2	Dorset and Somerset	UKJ1	Berkshire, Buckinghamshire and Oxfordshire
UKK3	Cornwall and Isles of Scilly	UKJ2	Surrey, East and West Sussex
UKK4	Devon	UKJ3	Hampshire and Isle of Wight
UKL1	West Wales and The Valleys	UKJ4	Kent
UKL2	East Wales	UKK1	Gloucestershire, Wiltshire and Bristol/Bath area
UKM1	North Eastern Scotland	UKK2	Dorset and Somerset
UKM2	Eastern Scotland	UKK3	Cornwall and Isles of Scilly
UKM3	South Western Scotland	UKK4	Devon
UKM4	Highlands and Islands	UKL1	West Wales and The Valleys
UKN0	Northern Ireland	UKL2	East Wales

Table 17: EUREGIO sectors

EUREGIO sector	Description
ss1a	Crops
ss1b	Livestock with land
ss1c	Livestock without land
ss1d	Forestry
ss1e	Fisheries
ss2	Mining_quarrying_and_energy_supply
ss3	Food_beverages_and_tobacco
ss4	Textiles_and_leather_etc
ss5	Coke_refined_petroleum_nuclear_fuel_and_chemicals_etc
ss6	Electrical_and_optical_equipment_and_Transport_equipment
ss8	Other_manufacturing
ss9	Construction
ss10	Distribution
ss11	Hotels_and_restaurant
ss12	Transport_storage_and_communication
ss13	Financial_intermediation
ss14	Real_estate_renting_and_busine_activitie
ss15	Non-Market_Service

Table 21: Hybrid SNAP nomenclature used for sectors of the MACC inventory

Sector ID	Combustion	Description	GNFR Category	GNFR Name	Category
1100	TRUE	Public electricity and heat production	A	A_PublicPower	
1200	FALSE	Refining	B	B_Industry	
1210	TRUE	Oil and gas refining (comb)	B	B_Industry	
1220	FALSE	Oil and gas refining	B	B_Industry	
1300	TRUE	Manufacture of solid fuels and other energy industries	B	B_Industry	
1310	TRUE	Coal mining (comb)	B	B_Industry	
1320	TRUE	Oil production (comb)	D	D_Fugitives	
1330	TRUE	Gas exploration (comb)	D	D_Fugitives	
1340	TRUE	Coke ovens (comb)	B	B_Industry	
1400	FALSE	Fugitive emissions from solid fuels	B	B_Industry	
1410	FALSE	Coal mining and handling	B	B_Industry	
1420	FALSE	Solid fuel transformation	B	B_Industry	
1430	FALSE	Other	B	B_Industry	
1500	FALSE	Fugitive emissions from liquid fuels	D	D_Fugitives	
1510	FALSE	Exploration, production, transport	D	D_Fugitives	
1520	FALSE	Distribution of oil products	D	D_Fugitives	
1600	FALSE	Fugitive emissions from gaseous fuels	D	D_Fugitives	
1610	FALSE	Natural gas - production	D	D_Fugitives	
1620	FALSE	Natural gas - high pressure distribution	D	D_Fugitives	
1630	FALSE	Natural gas - low pressure distribution	D	D_Fugitives	
1700	FALSE	Venting and flaring (oil, gas, combined oil and gas)	D	D_Fugitives	
1800	FALSE	Other fugitive emissions	D	D_Fugitives	
1810	FALSE	Other fugitive emissions from energy production	D	D_Fugitives	
1820	FALSE	Transport of CO2	D	D_Fugitives	
1830	FALSE	Injection and storage	D	D_Fugitives	
2100	FALSE	Iron and steel industry	B	B_Industry	
2110	TRUE	Iron and steel industry (comb)	B	B_Industry	
2120	FALSE	Iron and steel production	B	B_Industry	
2121	FALSE	Iron and steel industry, coke ovens	B	B_Industry	
2122	FALSE	Iron and steel industry, sinter production	B	B_Industry	
2123	FALSE	Iron and steel industry, pellet production	B	B_Industry	
2124	FALSE	Iron and steel industry, pig iron	B	B_Industry	
2125	FALSE	Iron and steel industry, cast iron	B	B_Industry	
2126	FALSE	Iron and steel industry, basic oxygen furnace	B	B_Industry	
2127	FALSE	Iron and steel industry, open hearth furnace	B	B_Industry	
2128	FALSE	Iron and steel industry, electric arc furnace	B	B_Industry	
2129	FALSE	Ferroalloys production	B	B_Industry	
2200	FALSE	Non-ferrous metal industry	B	B_Industry	
2210	TRUE	Non-ferrous metals (comb)	B	B_Industry	
2220	FALSE	Aluminium production	B	B_Industry	
2230	FALSE	Other non-ferrous metal production	B	B_Industry	

Continued on next page

Table 21 – continued from previous page

Sector ID	Combustion	Description	GNFR Category	GNFR Name	Category
2231	FALSE	Magnesium production	B	B_Industry	
2232	FALSE	Lead production	B	B_Industry	
2233	FALSE	Zinc production	B	B_Industry	
2234	FALSE	Storage and handling	B	B_Industry	
2235	FALSE	Other metal production	B	B_Industry	
2300	FALSE	Chemical industry	B	B_Industry	
2310	TRUE	Chemical industry (comb)	B	B_Industry	
2320	FALSE	Chemical industry	B	B_Industry	
2321	FALSE	Ammonia production	B	B_Industry	
2322	FALSE	Nitric acid production	B	B_Industry	
2323	FALSE	Adipic acid production	B	B_Industry	
2324	FALSE	Carbide production	B	B_Industry	
2325	FALSE	Titanium dioxide production	B	B_Industry	
2326	FALSE	Soda ash production	B	B_Industry	
2327	FALSE	Chemical industry - Storage and handling	B	B_Industry	
2328	FALSE	Other chemical industry	B	B_Industry	
2400	FALSE	Pulp and paper industry	B	B_Industry	
2410	TRUE	Pulp and paper industry (comb)	B	B_Industry	
2420	FALSE	Pulp and paper industry	B	B_Industry	
2500	FALSE	Food and beverages industry	B	B_Industry	
2510	TRUE	Food processing, beverages and tobacco (comb)	B	B_Industry	
2520	FALSE	Food and beverages industry	B	B_Industry	
2600	FALSE	Non-metallic mineral industry	B	B_Industry	
2610	TRUE	Non-metallic minerals (comb)	B	B_Industry	
2620	FALSE	Cement production	B	B_Industry	
2630	FALSE	Other non-metallic mineral production	B	B_Industry	
2631	FALSE	Lime production	B	B_Industry	
2632	FALSE	Glass production	B	B_Industry	
2633	FALSE	Other process uses of carbonates	B	B_Industry	
2634	FALSE	Quarrying and mining of minerals other than coal	B	B_Industry	
2635	FALSE	Construction and demolition	B	B_Industry	
2636	FALSE	Mineral industry - Storage and handling	B	B_Industry	
2637	FALSE	Other mineral industry	B	B_Industry	
2710	FALSE	Solvent use	E	E_Solvents	
2711	FALSE	Domestic solvent use including fungicides	E	E_Solvents	
2712	FALSE	Coating applications	E	E_Solvents	
2713	FALSE	Degreasing	E	E_Solvents	
2714	FALSE	Dry cleaning	E	E_Solvents	
2715	FALSE	Chemical products	E	E_Solvents	
2716	FALSE	Printing	E	E_Solvents	
2717	FALSE	Other solvent use	E	E_Solvents	
2721	FALSE	Paraffin wax use	E	E_Solvents	
2722	FALSE	Road paving with asphalt	B	B_Industry	
2723	FALSE	Asphalt roofing	B	B_Industry	
2724	FALSE	Other product use	E	E_Solvents	
2800	FALSE	Other industry	B	B_Industry	
2810	TRUE	Other manufacturing industry (comb)	B	B_Industry	
2820	FALSE	Other industrial processes	B	B_Industry	
3100	TRUE	Passenger cars	F	F_RoadTransport	
3110	TRUE	Passenger cars - main road	F	F_RoadTransport	
3120	TRUE	Passenger cars - first class road	F	F_RoadTransport	
3130	TRUE	Passenger cars - second class road	F	F_RoadTransport	
3140	TRUE	Passenger cars - third class road	F	F_RoadTransport	
3150	TRUE	Passenger cars - fourth class road	F	F_RoadTransport	
3200	TRUE	Light duty vehicles	F	F_RoadTransport	
3210	TRUE	Light duty vehicles - main road	F	F_RoadTransport	
3220	TRUE	Light duty vehicles - first class road	F	F_RoadTransport	
3230	TRUE	Light duty vehicles - second class road	F	F_RoadTransport	
3240	TRUE	Light duty vehicles - third class road	F	F_RoadTransport	
3250	TRUE	Light duty vehicles - fourth class road	F	F_RoadTransport	
3300	TRUE	Heavy duty vehicles	F	F_RoadTransport	
3310	TRUE	Trucks (¿3.5t)	F	F_RoadTransport	
3311	TRUE	Trucks (¿3.5t) - main road	F	F_RoadTransport	
3312	TRUE	Trucks (¿3.5t) - first class road	F	F_RoadTransport	
3313	TRUE	Trucks (¿3.5t) - second class road	F	F_RoadTransport	
3314	TRUE	Trucks (¿3.5t) - third class road	F	F_RoadTransport	
3315	TRUE	Trucks (¿3.5t) - fourth class road	F	F_RoadTransport	
3320	TRUE	Buses	F	F_RoadTransport	
3321	TRUE	Buses - main road	F	F_RoadTransport	
3322	TRUE	Buses - first class road	F	F_RoadTransport	
3323	TRUE	Buses - second class road	F	F_RoadTransport	
3324	TRUE	Buses - third class road	F	F_RoadTransport	
3325	TRUE	Buses - fourth class road	F	F_RoadTransport	
3400	TRUE	Motorcycles and mopeds	F	F_RoadTransport	
3410	TRUE	Motorcycles	F	F_RoadTransport	
3411	TRUE	Motorcycles - main road	F	F_RoadTransport	
3412	TRUE	Motorcycles - first class road	F	F_RoadTransport	
3413	TRUE	Motorcycles - second class road	F	F_RoadTransport	

Continued on next page

Table 21 – continued from previous page

Sector ID	Combustion	Description	GNFR Category	GNFR Name	Category
3414	TRUE	Motorcycles - third class road	F	F_RoadTransport	
3415	TRUE	Motorcycles - fourth class road	F	F_RoadTransport	
3420	TRUE	Mopeds	F	F_RoadTransport	
3421	TRUE	Mopeds - main road	F	F_RoadTransport	
3422	TRUE	Mopeds - first class road	F	F_RoadTransport	
3423	TRUE	Mopeds - second class road	F	F_RoadTransport	
3424	TRUE	Mopeds - third class road	F	F_RoadTransport	
3425	TRUE	Mopeds - fourth class road	F	F_RoadTransport	
3500	FALSE	Road transport - Gasoline evaporation and other sources	F4	F4_RoadTransport NonExhaust	
3600	FALSE	Road transport - Brake and tyre wear	F4	F4_RoadTransport NonExhaust	
3610	FALSE	Road transport - Brake and tyre wear - Passenger cars	F4	F4_RoadTransport NonExhaust	
3620	FALSE	Road transport - Brake and tyre wear - LDV	F4	F4_RoadTransport NonExhaust	
3630	FALSE	Road transport - Brake and tyre wear - Trucks (¿3.5t)	F4	F4_RoadTransport NonExhaust	
3640	FALSE	Road transport - Brake and tyre wear - Buses	F4	F4_RoadTransport NonExhaust	
3650	FALSE	Road transport - Brake and tyre wear - Motorcycles	F4	F4_RoadTransport NonExhaust	
3660	FALSE	Road transport - Brake and tyre wear - Mopeds	F4	F4_RoadTransport NonExhaust	
3700	FALSE	Road transport - Road abrasion	F4	F4_RoadTransport NonExhaust	
3710	FALSE	Road transport - Road abrasion - Passenger cars	F4	F4_RoadTransport NonExhaust	
3720	FALSE	Road transport - Road abrasion - LDV	F4	F4_RoadTransport NonExhaust	
3730	FALSE	Road transport - Road abrasion - Trucks (¿3.5t)	F4	F4_RoadTransport NonExhaust	
3740	FALSE	Road transport - Road abrasion - Buses	F4	F4_RoadTransport NonExhaust	
3750	FALSE	Road transport - Road abrasion - Motorcycles	F4	F4_RoadTransport NonExhaust	
3760	FALSE	Road transport - Road abrasion - Mopeds	F4	F4_RoadTransport NonExhaust	
4100	TRUE	Civil aviation - LTO	H	H_Aviation	
4200	TRUE	Railways	I	I_OffRoad	
4300	TRUE	Domestic navigation	G	G_Shipping	
4310	TRUE	Domestic navigation, inland shipping	G	G_Shipping	
4320	TRUE	Domestic navigation, coastal shipping	G	G_Shipping	
4330	TRUE	Small combustion - Agriculture/Forestry/Fishing - National fishing	G	G_Shipping	
4400	TRUE	Small combustion - Agriculture/Forestry/Fishing - Off-road vehicles and other machinery	I	I_OffRoad	
4500	TRUE	Manufacturing industry - Off-road vehicles and other machinery	I	I_OffRoad	
4600	TRUE	Other mobile combustion	I	I_OffRoad	
4610	TRUE	Other transportation, including pipeline compressors	I	I_OffRoad	
4620	TRUE	Small combustion - Commercial/institutional - Mobile	I	I_OffRoad	
4630	TRUE	Small combustion - Residential - Household and gardening	I	I_OffRoad	
4640	TRUE	Other mobile combustion	I	I_OffRoad	
4700	TRUE	International shipping	G	G_Shipping	
4710	TRUE	International shipping, at sea	G	G_Shipping	
4720	TRUE	International shipping, in ports	G	G_Shipping	
5100	TRUE	Commercial/institutional	C	C_OtherStationaryComb	
5200	TRUE	Residential	C	C_OtherStationaryComb	
5300	TRUE	Agriculture/Forestry/Fishing	C	C_OtherStationaryComb	
5400	TRUE	Other stationary combustion	C	C_OtherStationaryComb	
6100	FALSE	Enteric fermentation	L	L_AgriOther	
6110	FALSE	Enteric fermentation - Cattle	L	L_AgriOther	
6120	FALSE	Enteric fermentation - Sheep	L	L_AgriOther	
6130	FALSE	Enteric fermentation - Swine	L	L_AgriOther	
6140	FALSE	Enteric fermentation - Other animals	L	L_AgriOther	
6200	FALSE	Manure management	K	K_AgriLivestock	
6210	FALSE	Manure management - Cattle	K	K_AgriLivestock	
6211	FALSE	Manure management - Cattle - dairy	K	K_AgriLivestock	
6212	FALSE	Manure management - Cattle - non-dairy	K	K_AgriLivestock	
6220	FALSE	Manure management - Sheep	K	K_AgriLivestock	
6230	FALSE	Manure management - Swine	K	K_AgriLivestock	
6240	FALSE	Manure management - other animals	K	K_AgriLivestock	
6241	FALSE	Manure management - Buffalo	K	K_AgriLivestock	
6242	FALSE	Manure management - Goats	K	K_AgriLivestock	
6243	FALSE	Manure management - Horses	K	K_AgriLivestock	
6244	FALSE	Manure management - Mules and asses	K	K_AgriLivestock	
6245	FALSE	Manure management - Poultry	K	K_AgriLivestock	

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Table 21 – continued from previous page

Sector ID	Combustion	Description	GNFR Category	GNFR Name	Category
6246	FALSE	Manure management - Other animals	K	K_AgriLivestock	
6300	FALSE	Application of manure and fertilizer	L	L_AgriOther	
6310	FALSE	Inorganic N-fertilizers (includes also urea application)	L	L_AgriOther	
6320	FALSE	Animal manure applied to soils	L	L_AgriOther	
6330	FALSE	Sewage sludge applied to soils	L	L_AgriOther	
6340	FALSE	Other organic fertilisers applied to soils (including compost)	L	L_AgriOther	
6350	FALSE	Urine and dung deposited by grazing animals	L	L_AgriOther	
6360	FALSE	Crop residues applied to soils	L	L_AgriOther	
6400	FALSE	Other agricultural soils	L	L_AgriOther	
6410	FALSE	Indirect emissions from managed soils	L	L_AgriOther	
6420	FALSE	Farm-level agricultural operations including storage, handling and transport of agricultural products	L	L_AgriOther	
6430	FALSE	Off-farm storage, handling and transport of bulk agricultural products	L	L_AgriOther	
6440	FALSE	Cultivated crops	L	L_AgriOther	
6450	FALSE	Use of pesticides	L	L_AgriOther	
6500	FALSE	Other agriculture	L	L_AgriOther	
6510	FALSE	Rice cultivation	L	L_AgriOther	
6520	FALSE	Field burning of agricultural residues	L	L_AgriOther	
6530	FALSE	Liming	L	L_AgriOther	
6540	FALSE	Urea application	L	L_AgriOther	
6550	FALSE	Other carbon-containing fertilizers	L	L_AgriOther	
6560	FALSE	Other	L	L_AgriOther	
7100	FALSE	Landfills	J	J_Waste	
7110	FALSE	Managed waste disposal sites	J	J_Waste	
7120	FALSE	Unmanaged waste disposal sites	J	J_Waste	
7130	FALSE	Uncategorized waste disposal sites	J	J_Waste	
7200	FALSE	Composting and anaerobic digestion	J	J_Waste	
7210	FALSE	Composting	J	J_Waste	
7220	FALSE	Anaerobic digestion at biogas facilities	J	J_Waste	
7300	FALSE	Waste incineration	J	J_Waste	
7310	FALSE	Municipal waste incineration	J	J_Waste	
7320	FALSE	Industrial waste incineration	J	J_Waste	
7330	FALSE	Hazardous waste incineration	J	J_Waste	
7340	FALSE	Clinical waste incineration	J	J_Waste	
7350	FALSE	Sewage sludge incineration	J	J_Waste	
7360	FALSE	Cremation	J	J_Waste	
7370	FALSE	Other waste incineration (please specify in the IIR)	J	J_Waste	
7400	FALSE	Open burning of waste	J	J_Waste	
7500	FALSE	Waste water treatment	J	J_Waste	
7510	FALSE	Domestic wastewater	J	J_Waste	
7520	FALSE	Industrial wastewater	J	J_Waste	
7530	FALSE	Other wastewater	J	J_Waste	
7600	FALSE	Other waste	J	J_Waste	
7610	FALSE	Other waste - bbq and tobacco	J	J_Waste	
7620	FALSE	Other waste - other	J	J_Waste	

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Table 18: Regions and countries in EUREGIO.

Country	ISO3	NUTS2 detail	Number of regions
Austria	AUT	Yes	9
Belgium	BEL	Yes	11
Bulgaria	BGR	No	1
Cyprus	CYP	No	1
Czech Republic	CZE	Yes	8
Germany	DEU	Yes	41
Denmark	DNK	Yes	3
Estonia	EST	No	1
Spain	ESP	Yes	19
Finland	FIN	Yes	5
France	FRA	Yes	22
Greece	GRC	Yes	13
Hungary	HUN	Yes	7
Ireland	IRL	Yes	2
Italy	ITA	Yes	21
Lithuania	LTU	Yes	1
Luxembourg	LUX	No	1
Latvia	LVA	No	1
Malta	MLT	No	1
Netherlands	NLD	Yes	12
Poland	POL	Yes	16
Portugal	PRT	Yes	5
Romania	ROU	No	1
Sweden	SWE	Yes	8
Slovenia	SVN	No	1
Slovakia	SVK	Yes	4
United Kingdom	GBR	Yes	37
Japan	JPN	No	1
Middle and South America (Brazil)	BRA	No	1
Australia and Oceania	AUS	No	1
Northern America (Mexico)	MEX	No	1
Russia	RUS	No	1
India	IND	No	1
Indonesia	IDN	No	1
Rest of the World	ZROW	No	1
Canada	CAN	No	1
China	CHN	No	1
Korea	KOR	No	1
Turkey	TUR	No	1
United States	USA	No	1
Taiwan	TWN	No	1
Total number of regions in EUREGIO			266

Table 19: NUTS2 differences between EUREGIO and EU 2010 shapefile.

Country	Regions in EUREGIO	Regions in 2010 EU Shapefile
Austria	9	10
Belgium	11	11
Czech Republic	8	8
Germany	41	38
Denmark	3	5
Estonia	1	1
Spain	19	19
Finland	5	5
France	22	26
Greece	13	13
Hungary	7	7
Ireland	2	2
Italy	21	21
Lithuania	1	1
Luxembourg	1	1
Latvia	1	1
Malta	1	1
Netherlands	12	12
Poland	16	16
Portugal	5	7
Sweden	8	8
Slovenia	1	1
Slovakia	4	4
United Kingdom	37	37

Table 20: Bridge trable provided by PBL showing the relations between PBL sectors and WIOD. NACE rev. 1.1 added by the author based on (Genty, Arto, & Neuwhal, 2012).

WIOD industry code	Euregio	NACE rev. 1.1
AtB	ss1	1,2,5
C	ss2	10,11,12,13,14
15t16	ss3	15,16
17t18	ss4	17,18
19	ss4	19
20	ss8	20
21t22	ss8	21,22
23	ss5	23
24	ss5	24
25	ss5	25
26	ss8	26
27t28	ss8	27,28
29	ss8	29
30t33	ss6	30,31,32,33
34t35	ss6	34,35
36t37	ss8	36,37
E	ss2	40,41
F	ss9	45
50	ss10	50
51	ss10	51
52	ss10	52
H	ss11	55
60	ss12	60
61	ss12	61
62	ss12	62
63	ss12	63
64	ss12	64
J	ss13	65,66,67
70	ss14	70
71t74	ss14	71,72,73,74
L	ss15	75
M	ss15	80
N	ss15	85
O	ss15	90,91,92,93
P	ss15	95

Table 22: Difference between CO_2 emissions in the MACC inventory and in EUROSTAT air emission accounts (table *[env_ac_ainah_r2]*).

	Shipping emissions [Mt CO2]		Air transport emissions [Mt CO2]	
Country	MACC	EUROSTAT	MACC	EUROSTAT
Austria	-	87.5	969.1	2,710.3
Belgium	1,151.4	634.3	2,320.5	4,141.0
Bulgaria	25.2	66.1	390.5	46.9
Cyprus	2.3	304.8	58.6	385.9
Czech Republic	-	38.2	1,200.5	20.8
Denmark	195.6	35,150.3	1,342.3	2,348.8
Estonia	65.6	757.0	8.5	7.9
Finland	135.0	3,263.7	250.0	2,554.4
France	609.1	3,617.8	11,226.3	19,581.4
Germany	1,568.0	26,601.6	274.5	26,314.8
Greece	328.0	2,331.4	1,458.9	470.1
Hungary	-	21.2	739.7	311.9
Ireland	58.2	146.5	1,142.4	7,747.6
Italy	796.0	16,264.3	4,634.3	7,040.9
Latvia	51.2	32.4	189.8	562.5
Lithuania	34.6	164.6	278.1	40.9
Luxembourg	-	1.3	13.5	3,221.6
Malta	63.5	2,133.4	-	141.8
Poland	111.0	103.5	4,123.4	514.4
Portugal	173.1	612.0	1,364.0	1,147.9
Romania	41.7	248.6	1,036.2	691.2
Slovakia	-	0.6	306.5	5.4
Slovenia	33.0	-	115.5	4.8
Spain	809.7	3,396.1	3,707.4	10,069.1
Sweden	343.8	7,158.6	556.0	2,587.6
The Netherlands	2,750.7	7,004.5	3,335.3	11,151.3
United Kingdom	849.4	18,027.4	4,305.4	39,965.8
TOTAL	10,196	128,168	45,347	143,787

Table 23: Bridge table between NACE rev. 2 sectors, EUREGIO sectors and sectors defined in the carriage of goods. The correspondence was done manually based on the description of the sectors for carriage of goods. The last 3 sectors represent a very small share of the transported weight thus they are ignored.

EUREGIO sectors	NACE rev. 2 sectors	Carriage of goods categories
1	1-5	Products of agriculture, hunting, and forestry; fish and other fishing products
2	10-12	Coal and lignite; crude petroleum and natural gas
2	13	Metal ores and other mining and quarrying products; peat; uranium and thorium
3	15, 16	Food products, beverages and tobacco
4	17-19	Textiles and textile products; leather and leather products
8	20-22	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media
5	23	Coke and refined petroleum products
5	24, 25	Chemicals, chemical products, and man-made fibers; rubber and plastic products ; nuclear fuel
8	26	Other non metallic mineral products
8	27, 28	Basic metals; fabricated metal products, except machinery and equipment
6	29-33	Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks
6	34, 35	Transport equipment
8	36	Furniture; other manufactured goods n.e.c.
8	37	Secondary raw materials; municipal wastes and other wastes
12	64	Mail, parcels
12	60	Equipment and material utilized in the transport of goods
HH	HH	Goods moved in the course of household and office removals; baggage and articles accompanying travellers; motor vehicles being moved for repair; other non market goods n.e.c.
NA	NA	Grouped goods: a mixture of types of goods which are transported together
NA	NA	Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.
NA	NA	Other goods n.e.c.

Table 24: CO_2 emission differences in both transport activities by households and fuel combustion in cars. EUROSTAT data was obtained from tables env_ac_ainah_r2 and env_air_gge and respectively. MACC data was obtained by summing the regional values.

	Transport activities by households [kt]			Fuel combustion in cars [kt]		
Country	BUA	TDA	Difference [%]	BUA	TDA	Difference [%]
Austria	13,306	8,335	60%	13,154	12,709	4%
Belgium	15,944	11,138	43%	15,765	14,821	6%
Bulgaria	4,767	1,160	311%	4,742	4,578	4%
Cyprus	2,147	1,432	50%	2,147	2,243	-4%
Czech Republic	10,034	5,839	72%	9,992	9,665	3%
Denmark	6,658	6,030	10%	6,590	6,654	-1%
Estonia	1,216	708	72%	1,213	1,242	-2%
Finland	6,674	5,189	29%	6,674	11,723	-43%
France	77,131	70,093	10%	75,502	70,359	7%
Germany	100,955	98,209	3%	99,625	94,569	5%
Greece	10,722	13,316	-19%	9,867	10,066	-2%
Hungary	6,378	6,657	-4%	6,265	5,809	8%
Ireland	7,184	6,362	13%	7,169	7,248	-1%
Italy	64,812	59,666	9%	62,170	61,703	1%
Latvia	1,720	1,311	31%	1,712	1,713	0%
Lithuania	2,650	2,854	-7%	2,642	2,542	4%
Luxembourg	1,076	597	80%	1,070	2,494	-57%
Malta	499	202	147%	499	341	46%
Poland	26,452	10,539	151%	26,152	25,004	5%
Portugal	12,032	7,369	63%	11,640	9,757	19%
Romania	6,675	7,193	-7%	6,299	6,365	-1%
Slovakia	2,612	2,265	15%	2,601	3,154	-18%
Slovenia	3,481	2,308	51%	3,456	3,463	0%
Spain	54,758	48,500	13%	53,123	51,287	4%
Sweden	12,502	9,620	30%	12,407	11,839	5%
The Netherlands	20,318	17,987	13%	19,816	19,375	2%
United Kingdom	73,898	62,922	17%	69,506	69,632	0%

Table 25: Energy demand for heating and DHW expressed in PJ for the year 2009 in Europe for selected commercial and public buildings. From (Pardo, Vatopoulos, Krook-Riekkola, Moya, & Perez, 2012).

	Hospital		Hotels & restaurants		Sport & recreation		Shop- Large		Shop-Small		Offices	
	Heating	DHW	Heating	DHW	Heating	DHW	Heating	DHW	Heating	DHW	Heating	DHW
Austria	4.3	1.3	14.9	4.4	5.1	1.5	9.5	2.8	6.2	1.8	21.7	6.4
Belgium	10.6	2.7	15.8	4	7.6	1.9	8.7	2.2	8.7	2.2	30.2	7.7
Bulgaria	0.9	0.2	3	0.8	1	0.3	1.9	0.5	1.3	0.3	4.4	1.2
Cyprus	0.1	0	0.3	0.1	0	0	0.1	0	0.1	0	0.3	0.1
Czech Republic	4	1.1	13.6	3.7	4.7	1.3	8.7	2.3	5.7	1.5	19.9	5.4
Denmark	8.2	2.6	2.1	0.7	6.7	2.1	2.4	0.8	2	0.7	11.7	3.7
Estonia	1.7	0.5	0.5	0.1	1.4	0.4	0.5	0.1	0.4	0.1	2.5	0.7
Finland	4	1.2	1	0.3	3.2	0.9	1.2	0.3	1	0.3	5.7	1.6
France	47.4	13.7	70.5	20.4	34	9.9	38.9	11.3	38.9	11.3	134.8	39.1
Germany	33.6	8.8	115.3	30.2	39.5	10.3	73.6	19.3	48.1	12.6	168.1	44
Greece	2.2	0.9	5.9	2.4	0.8	0.3	2	0.8	2.4	0.9	6.5	2.6
Hungary	5.4	1.1	18.7	3.8	6.4	1.3	11.9	2.4	7.8	1.6	27.2	5.5
Ireland	2.2	0.7	3.2	1	1.2	0.4	5.5	1.7	2.3	0.7	10	3
Italy	27.5	7.3	75.1	19.8	10	2.6	25.1	6.6	30	7.9	82.6	21.8
Latvia	2.7	0.6	0.7	0.2	2.2	0.5	0.8	0.2	0.7	0.2	3.9	0.9
Lithuania	2.6	0.7	0.7	0.2	2.1	0.6	0.8	0.2	0.7	0.2	3.7	1
Luxembourg	0.4	0.2	0.6	0.3	0.3	0.2	0.3	0.2	0.3	0.2	1.2	0.6
Malta	0	0	0.1	0	0	0	0	0	0	0	0.1	0
The Netherlands	19.5	5	28.9	7.5	14	3.6	16	4.1	16	4.1	55.4	14.3
Poland	7	1.9	24.2	6.4	8.3	2.2	15.4	4.1	10.1	2.7	35.2	9.4
Portugal	3.2	1	8.8	2.7	1.2	0.4	2.9	0.9	3.5	1.1	9.7	3
Romania	2.8	0.5	9.5	1.8	3.3	0.6	6.1	1.2	4	0.8	13.8	2.7
Slovakia	2.4	0.6	8.2	1.9	2.8	0.7	5.2	1.2	3.4	0.8	11.9	2.8
Slovenia	0.8	0.2	2.3	0.6	0.3	0.1	0.8	0.2	0.9	0.2	2.5	0.6
Spain	11	3.6	30.1	10	4	1.3	10.1	3.3	12	4	33.1	10.9
Sweden	19.2	5.6	5	1.5	15.6	4.6	5.7	1.6	4.8	1.4	27.3	8
United Kingdom	21.8	6.1	31.5	8.8	12.1	3.4	54.9	15.4	22.7	6.4	99.4	27.9

Table 26: Allocation of the consumption of oil products to fisheries. Column $alpha_{p,c}$ (1) is the raw ratio whereas $alpha_{p,c}$ (2) includes assumptions when necessary.

Country	Agriculture [kt]	Fishing [kt]	$alpha_{p,c}$ (1)	$X_{c,ss1e}$ [M€]	$alpha_{p,c}$ (2)	Remarks
Belgium	438	0	-	161	10%	Same as Finland
Bulgaria	122	1	1%	38	1%	
Czech Republic	326	0	-	81	-	Assuming no ships
Denmark	383	141	37%	605	37%	
Germany	0	0	-	493	19%	Same as Sweden
Estonia	64	0	-	44	11%	Same as Latvia
Ireland	221	24	11%	467	11%	
Greece	536	0	-	1594	10%	Same as France
Spain	1635	0	-	2969	10%	Same as France
France	3108	301	10%	2386	10%	
Italy	2039	183	9%	2462	9%	
Cyprus	20	4	20%	7	20%	
Latvia	95	10	11%	42	11%	
Lithuania	42	2	5%	70	5%	
Luxembourg	21	0	-	19	-	Assuming no ships
Hungary	270	0	-	68	0%	Assuming no ships
Malta	5	2	40%	72	40%	
The Netherlands	379	207	55%	805	55%	
Austria	245	0	-	56	0%	Assuming no ships
Poland	1771	0	-	203	10%	Same as Finland
Portugal	251	112	45%	899	45%	
Romania	220	0	-	79	1%	Same as Bulgaria
Slovenia	66	0	-	113	0%	Assuming no ships
Slovakia	67	0	-	25	0%	Assuming no ships
Finland	378	36	10%	149	10%	
Sweden	186	36	19%	432	19%	
United Kingdom	278	89	32%	1307	32%	

Table 27: Country accounts disaggregated by sector using the BUA method. All values in kt of CO_2 except where indicated.

	Sector																	
Country	*ss1a*	*ss1b*	*ss1c*	*ss1d*	*ss1e*	*ss2*	*ss3*	*ss4*	*ss5*	*ss6*	*ss8*	*ss9*	*ss10*	*ss11*	*ss12*	*ss13*	*ss14*	*ss15*
Austria	1,767	196	196	196	-	18,879	1,144	1,283	5,716	32	24,295	3,341	862	820	6,920	149	527	1,085
Belgium	2,668	144	144	144	9	26,908	2,654	173	14,893	51	21,948	449	1,389	1,262	10,941	337	1,125	3,283
Bulgaria	1,812	92	92	92	4	31,104	440	59	2,636	2	5,287	123	100	95	2,190	21	57	135
Cyprus	93	-	-	-	-	3,886	59	15	17	-	1,224	13	22	45	10	6	17	33
Czech Republic	2,270	254	254	254	-	61,892	1,240	331	6,689	10	20,397	66	817	776	5,938	133	557	1,397
Denmark	1,700	203	203	203	280	30,066	1,440	38	1,439	10	3,064	988	148	70	5,056	43	154	904
Estonia	383	39	39	39	19	16,940	11	36	289	1	789	58	13	7	831	3	17	64
Finland	2,597	197	197	197	25	37,383	254	395	4,655	57	24,499	565	178	83	4,336	32	203	820
France	13,408	2,176	2,176	2,176	51	65,632	11,978	2,315	35,358	449	65,896	1,884	6,359	5,757	48,657	1,283	5,388	12,570
Germany	11,669	957	957	957	27	385,713	1,264	3,284	41,268	163	168,243	393	10,601	10,042	51,401	1,933	6,512	12,563
Greece	2,313	375	375	375	10	41,104	1,582	33	4,732	14	14,336	513	0	0	4,761	0	0	159
Hungary	1,615	204	204	204	-	19,976	829	127	4,127	19	5,186	240	1,075	1,020	4,345	171	622	1,503
Ireland	1,128	142	142	142	35	13,473	1,253	71	918	14	5,180	64	739	304	2,523	191	394	735
Italy	5,825	1,544	1,544	1,544	30	106,546	4,774	1,839	38,885	90	65,986	913	6,875	9,374	40,896	1,295	4,558	9,304
Latvia	737	66	66	66	33	2,867	197	431	189	1	1,587	364	145	69	1,249	42	171	622
Lithuania	1,155	27	27	27	6	4,835	287	31	2,998	2	1,241	84	70	33	1,471	14	64	336
Luxembourg	29	7	7	7	-	1,392	15	21	181	1	1,642	111	100	90	314	127	32	131
Malta	11	-	-	-	-	1,881	-	2	3	-	14	2	1	38	64	5	11	25
Poland	11,912	1,324	1,324	1,324	32	176,248	4,430	902	21,067	23	32,776	1,687	2,940	2,785	17,555	513	1,644	4,111
Portugal	2,077	177	177	177	59	14,646	1,440	290	4,558	13	15,833	1,303	277	380	4,809	62	145	502
Romania	5,801	2	2	2	0	35,532	1,193	336	9,832	18	13,785	2,694	611	571	5,363	66	377	780
Slovakia	796	47	47	47	-	7,514	338	120	4,468	4	15,445	283	671	639	4,194	112	387	855
Slovenia	262	53	53	53	-	6,904	120	65	117	2	2,330	220	153	212	1,500	26	94	218
Spain	15,088	1,847	1,853	1,839	68	65,090	4,136	2,199	26,568	34	59,461	2,001	3,215	4,116	35,213	552	1,782	4,748
Sweden	2,194	310	310	310	14	28,835	597	175	4,493	12	17,233	19	113	55	6,818	23	132	1,078
The Netherlands	10,976	250	250	250	40	64,790	3,662	249	29,496	63	11,307	2,322	2,099	1,901	15,639	622	1,391	4,079
United Kingdom	5,795	898	898	883	39	173,425	6,977	507	30,789	623	65,722	1,072	7,352	2,981	29,147	1,574	3,701	10,892
Total [Mt]	106.1	11.5	11.5	11.5	0.8	1,443.5	52.3	15.3	296.4	1.7	664.7	21.8	46.9	43.5	312.1	9.3	30.1	72.9

Table 28: Relative difference Φ for PBA at the national level across sectors. All values are dimensionless and values in () are negative.

	Sector																	
Country	*ss1a*	*ss1b*	*ss1c*	*ss1d*	*ss1e*	*ss2*	*ss3*	*ss4*	*ss5*	*ss6*	*ss8*	*ss9*	*ss10*	*ss11*	*ss12*	*ss13*	*ss14*	*ss15*
Austria	1.10	(0.60)	0.42	1.14	(1.00)	0.52	(0.01)	9.15	(0.46)	(0.92)	0.59	0.24	(0.32)	0.99	0.06	0.53	0.00	(0.41)
Belgium	1.57	(0.73)	(0.78)	2.15	(0.77)	0.15	0.06	(0.47)	(0.40)	(0.81)	1.47	(0.79)	(0.40)	1.47	0.11	(0.26)	(0.62)	(0.26)
Bulgaria	1.40	4.57	1.39	1.28	0.54	(0.05)	0.34	(0.34)	(0.48)	(0.97)	5.94	(0.77)	(0.74)	0.70	(0.45)	(0.28)	(0.56)	(0.67)
Cyprus	3.00	(1.00)	(1.00)	(1.00)	(1.00)	(0.01)	(0.29)	7.57	(0.99)	(1.00)	22.80	(0.91)	(0.87)	(0.18)	(0.99)	(0.77)	(0.69)	(0.69)
Czech Republic	1.59	1.14	1.66	6.78	(1.00)	0.00	0.00	1.05	(0.33)	(0.99)	1.69	(0.97)	(0.24)	3.40	(0.34)	0.58	(0.69)	(0.02)
Denmark	0.46	(0.01)	(0.49)	2.24	(0.41)	0.25	0.05	(0.04)	(0.56)	(0.97)	3.39	(0.38)	(0.86)	(0.48)	(0.88)	(0.32)	(0.72)	0.02
Estonia	5.62	6.51	30.74	3.92	0.58	0.21	(0.89)	1.98	(0.69)	(0.91)	4.20	(0.39)	(0.86)	(0.30)	(0.57)	(0.48)	(0.86)	(0.57)
Finland	1.69	(0.62)	0.12	(0.34)	(0.81)	0.32	(0.01)	26.98	(0.23)	0.27	1.49	(0.64)	(0.03)	8.96	(0.58)	(0.87)	(0.87)	(0.14)
France	0.35	0.15	0.80	2.99	(0.96)	0.25	0.16	1.16	(0.48)	(0.85)	1.46	(0.75)	(0.38)	0.55	0.03	(0.01)	(0.51)	(0.09)
Germany	0.06	(0.09)	1.46	1.09	(0.51)	0.06	(0.87)	2.49	(0.53)	(0.99)	1.79	(0.96)	(0.38)	1.69	(0.39)	0.05	(0.27)	(0.50)
Greece	1.52	(0.45)	2.59	340.08	0.34	(0.15)	4.95	14.73	(0.54)	5.88	6.31	1.56	(1.00)	(1.00)	(0.45)	(1.00)	(1.00)	(0.90)
Hungary	0.19	2.05	(0.09)	1.11	(1.00)	0.16	0.20	1.86	(0.36)	(0.97)	1.57	(0.66)	(0.32)	6.22	(0.04)	(0.48)	(0.56)	(0.05)
Ireland	4.56	(0.86)	4.89	255.91	(0.73)	0.02	0.11	3.36	(0.70)	(0.95)	1.87	(0.81)	(0.47)	0.33	(0.18)	0.69	1.04	(0.23)
Italy	(0.04)	1.41	1.47	55.58	(0.95)	(0.14)	(0.21)	(0.31)	(0.49)	(0.97)	1.30	(0.84)	0.07	2.94	(0.22)	1.73	0.58	1.03
Latvia	5.55	1.81	(0.28)	(0.71)	(0.35)	0.18	0.01	19.89	(0.78)	(0.95)	1.76	0.56	(0.52)	2.21	(0.56)	2.82	(0.05)	1.52
Lithuania	7.36	6.75	10.03	0.04	(0.47)	0.22	0.02	0.34	(0.17)	(0.85)	5.12	(0.05)	(0.16)	1.01	(0.68)	0.24	0.04	0.68
Luxembourg	0.32	(0.78)	0.36	0.19	NA	0.04	(0.50)	(0.54)	(0.80)	(0.94)	1.41	(0.32)	(0.59)	2.68	(0.91)	(0.35)	(0.48)	(0.06)
Malta	(0.09)	(1.00)	(1.00)	NA	(1.00)	0.00	(1.00)	0.75	(0.51)	(1.00)	(0.30)	(0.88)	(0.99)	6.32	(0.98)	0.17	(0.67)	0.06
Poland	(0.05)	(0.27)	(0.36)	3.34	(0.90)	0.09	(0.09)	2.76	(0.49)	(0.98)	1.51	1.01	(0.59)	2.58	(0.35)	(0.54)	(0.54)	(0.60)
Portugal	1.15	(0.24)	(0.28)	0.68	(0.86)	(0.02)	0.18	(0.69)	(0.64)	(0.95)	6.42	(0.28)	(0.85)	(0.27)	(0.19)	(0.51)	(0.64)	(0.66)
Romania	5.35	(0.97)	(0.98)	(0.94)	(1.00)	0.11	0.01	2.08	(0.38)	(0.95)	1.04	1.16	(0.62)	2.69	(0.16)	(0.70)	(0.71)	(0.41)
Slovakia	6.13	16.93	12.75	0.26	NA	0.08	(0.60)	1.76	(0.39)	(0.99)	0.61	1.50	(0.38)	22.41	(0.16)	19.79	1.43	(0.35)
Slovenia	3.45	(0.65)	16.79	3.15	NA	0.06	0.07	0.56	(0.91)	(0.98)	1.63	1.36	NA	1.31	(0.61)	2.23	(0.46)	(0.22)
Spain	1.11	2.66	0.85	27.20	(0.98)	0.02	(0.24)	2.54	(0.55)	(0.99)	2.47	1.37	(0.43)	1.88	(0.21)	0.74	(0.14)	0.07
Sweden	1.00	0.38	1.42	(0.73)	(0.91)	1.50	(0.07)	2.86	(0.42)	(0.97)	1.22	(0.99)	(0.93)	(0.24)	(0.52)	(0.72)	(0.88)	(0.11)
The Netherlands	1.42	(0.95)	(0.89)	2.18	(0.92)	(0.04)	(0.02)	0.08	(0.06)	(0.93)	0.18	(0.32)	(0.59)	0.71	(0.45)	0.19	(0.66)	(0.34)
United Kingdom	0.34	(0.19)	0.14	27.74	(0.89)	(0.05)	(0.02)	(0.72)	(0.37)	(0.85)	1.38	(0.90)	(0.44)	(0.15)	(0.65)	10.75	(0.35)	(0.39)
Total	0.58	(0.29)	0.08	2.03	(0.89)	0.05	(0.14)	0.58	(0.46)	(0.95)	1.55	(0.61)	(0.43)	1.24	(0.40)	0.19	(0.41)	(0.29)

Table 29: National PBA totals and respective relative difference Φ. Values in () are negative.

	BUA totals [Mt]			Φ [-]		
Country	Sector	HH	Total	Sector	HH	Total
Austria	67.4	27.6	95.0	0.19	0.79	0.35
Belgium	88.5	38.3	126.8	0.04	0.35	0.12
Bulgaria	44.3	9.0	53.4	(0.03)	3.31	0.12
Cyprus	5.4	2.5	7.9	(0.26)	0.38	(0.08)
Czech Republic	103.3	26.3	129.6	0.05	1.81	0.20
Denmark	46.0	14.1	60.2	(0.69)	0.53	(0.31)
Estonia	19.6	3.3	22.9	0.10	2.57	0.23
Finland	76.7	15.0	91.7	0.20	1.37	0.36
France	283.5	168.6	452.2	0.04	0.27	0.12
Germany	707.9	235.4	943.3	0.02	0.17	0.05
Greece	70.7	21.0	91.7	(0.04)	0.05	(0.02)
Hungary	41.5	22.4	63.9	0.06	0.42	0.17
Ireland	27.4	14.7	42.2	0.01	0.03	0.02
Italy	301.8	147.0	448.8	(0.08)	0.26	0.02
Latvia	8.9	5.0	13.9	0.05	1.76	0.35
Lithuania	12.7	5.8	18.5	(0.05)	0.61	0.09
Luxembourg	4.2	2.3	6.5	(0.78)	0.32	(0.30)
Malta	2.1	0.5	2.6	(1.83)	0.38	(0.58)
Poland	282.6	80.4	363.0	(0.03)	0.50	0.06
Portugal	46.9	17.7	64.6	0.02	0.75	0.15
Romania	77.0	28.9	105.9	0.09	1.27	0.28
Slovakia	36.0	7.9	43.9	0.08	0.49	0.14
Slovenia	12.4	7.2	19.6	(0.11)	1.04	0.13
Spain	229.8	86.2	316.0	0.04	0.25	0.09
Sweden	62.7	18.0	80.7	0.18	0.71	0.31
The Netherlands	149.4	45.4	194.7	(0.17)	0.04	(0.11)
United Kingdom	343.3	162.7	505.9	(0.20)	0.09	(0.10)
Total [Mt]	3152.0	1213.2	4365.2	(0.02)	0.29	0.05

Table 30: Values in national accounts boxplot (figure 8)

Sector	Medians	Whiskers	Boxes
ss1a	1.4	[0.34, -0.09, 3.22, 7.36]	[0.34, 3.22]
ss1b	-0.19	[-0.69, -1.0, 1.61, 4.57]	[-0.69, 1.61]
ss1c	0.42	[-0.32, -1.0, 1.56, 2.59]	[-0.32, 1.56]
ss1d	1.28	[0.12, -1.0, 3.63, 6.78]	[0.12, 3.63]
ss1e	-0.91	[-1.0, -1.0, -0.62, -0.35]	[-1.0, -0.62]
ss2	0.06	[-0.0, -0.15, 0.2, 0.32]	[-0.0, 0.2]
ss3	-0.01	[-0.23, -0.6, 0.06, 0.34]	[-0.23, 0.06]
ss4	1.76	[0.02, -0.72, 2.81, 3.36]	[0.02, 2.81]
ss5	-0.49	[-0.6, -0.91, -0.39, -0.17]	[-0.6, -0.39]
ss6	-0.95	[-0.98, -1.0, -0.92, -0.85]	[-0.98, -0.92]
ss8	1.57	[1.34, -0.3, 2.93, 5.12]	[1.34, 2.93]
ss9	-0.39	[-0.82, -0.99, 0.4, 1.56]	[-0.82, 0.4]
ss10	-0.47	[-0.8, -1.0, -0.35, 0.07]	[-0.8, -0.35]
ss11	1.31	[0.09, -1.0, 2.68, 6.32]	[0.09, 2.68]
ss12	-0.45	[-0.6, -0.99, -0.18, 0.11]	[-0.6, -0.18]
ss13	-0.01	[-0.5, -1.0, 0.64, 2.23]	[-0.5, 0.64]
ss14	-0.56	[-0.69, -1.0, -0.21, 0.04]	[-0.69, -0.21]
ss15	-0.23	[-0.45, -0.9, -0.04, 0.07]	[-0.45, -0.04]
HH	0.49	[0.27, 0.03, 0.91, 1.81]	[0.27, 0.91]

Table 31: Values in regional accounts boxplot (figure 9)

Sector	Medians	Whiskers	Boxes
ss1a	0.57	[-0.05, -1.0, 1.99, 4.81]	[-0.05, 1.99]
ss1b	-0.15	[-0.6, -1.0, 1.21, 3.66]	[-0.6, 1.21]
ss1c	0.55	[-0.24, -1.0, 2.25, 5.76]	[-0.24, 2.25]
ss1d	4.07	[0.64, -1.0, 18.15, 43.75]	[0.64, 18.15]
ss1e	-0.96	[-1.0, -1.0, -0.86, -0.67]	[-1.0, -0.86]
ss2	-0.05	[-0.55, -1.0, 0.63, 2.4]	[-0.55, 0.63]
ss3	-0.18	[-0.63, -1.0, 0.23, 1.5]	[-0.63, 0.23]
ss4	1.57	[-0.24, -1.0, 4.77, 11.74]	[-0.24, 4.77]
ss5	-0.51	[-0.9, -1.0, 1.45, 4.73]	[-0.9, 1.45]
ss6	-0.96	[-0.99, -1.0, -0.85, -0.66]	[-0.99, -0.85]
ss8	1.00	[0.12, -1.0, 3.05, 7.41]	[0.12, 3.05]
ss9	-0.77	[-0.93, -1.0, -0.19, 0.93]	[-0.93, -0.19]
ss10	-0.38	[-0.58, -1.0, -0.15, 0.45]	[-0.58, -0.15]
ss11	1.55	[0.17, -1.0, 2.68, 6.32]	[0.17, 2.68]
ss12	-0.19	[-0.53, -0.99, 0.17, 1.2]	[-0.53, 0.17]
ss13	0.34	[-0.17, -1.0, 1.82, 4.63]	[-0.17, 1.82]
ss14	-0.32	[-0.58, -1.0, -0.05, 0.74]	[-0.58, -0.05]
ss15	-0.31	[-0.49, -1.0, 0.02, 0.77]	[-0.49, 0.02]
HH	0.34	[0.09, -0.6, 0.64, 1.32]	[0.09, 0.64]

Table 32: Values in national consumption-driven emissions boxplot (figure 16)

Sector	Medians	Whiskers	Boxes
ss1a	0.88	[0.43, 0.02, 1.14, 1.65]	[0.43, 1.14]
ss1b	-0.31	[-0.49, -0.77, 0.3, 0.86]	[-0.49, 0.3]
ss1c	-0.01	[-0.26, -0.68, 0.56, 1.63]	[-0.26, 0.56]
ss1d	1.26	[0.74, -0.63, 3.22, 6.33]	[0.74, 3.22]
ss1e	-0.75	[-0.83, -0.94, -0.66, -0.44]	[-0.83, -0.66]
ss2	0.03	[0.02, -0.04, 0.08, 0.17]	[0.02, 0.08]
ss3	-0.07	[-0.19, -0.48, 0.03, 0.21]	[-0.19, 0.03]
ss4	0.30	[0.08, -0.21, 0.69, 0.83]	[0.08, 0.69]
ss5	-0.29	[-0.35, -0.45, -0.26, -0.14]	[-0.35, -0.26]
ss6	-0.54	[-0.63, -0.71, -0.33, -0.03]	[-0.63, -0.33]
ss8	0.61	[0.5, 0.29, 0.81, 1.13]	[0.5, 0.81]
ss9	-0.38	[-0.73, -0.92, 0.36, 1.07]	[-0.73, 0.36]
ss10	-0.40	[-0.52, -0.73, -0.29, -0.01]	[-0.52, -0.29]
ss11	0.97	[0.13, -0.66, 1.87, 2.51]	[0.13, 1.87]
ss12	-0.32	[-0.49, -0.87, -0.18, -0.09]	[-0.49, -0.18]
ss13	0.03	[-0.21, -0.62, 0.22, 0.81]	[-0.21, 0.22]
ss14	-0.48	[-0.54, -0.76, -0.22, 0.03]	[-0.54, -0.22]
ss15	-0.21	[-0.43, -0.8, -0.04, 0.53]	[-0.43, -0.04]
HH	1.12	[1.0, 0.89, 1.18, 1.36]	[1.0, 1.18]

Table 33: Values in regional consumption-driven emissions boxplot (figure 19)

Sector	Medians	Whiskers	Boxes
ss1a	0.49	[0.29, -0.24, 0.83, 1.65]	[0.29, 0.83]
ss1b	-0.33	[-0.51, -0.83, 0.09, 0.95]	[-0.51, 0.09]
ss1c	-0.01	[-0.16, -0.68, 0.46, 1.35]	[-0.16, 0.46]
ss1d	2.39	[1.11, -0.89, 4.38, 9.27]	[1.11, 4.38]
ss1e	-0.82	[-0.88, -0.98, -0.76, -0.6]	[-0.88, -0.76]
ss2	0.00	[-0.11, -0.4, 0.14, 0.5]	[-0.11, 0.14]
ss3	-0.14	[-0.33, -0.76, -0.02, 0.41]	[-0.33, -0.02]
ss4	0.19	[0.1, -0.25, 0.37, 0.76]	[0.1, 0.37]
ss5	-0.33	[-0.41, -0.61, -0.26, -0.05]	[-0.41, -0.26]
ss6	-0.58	[-0.63, -0.78, -0.5, -0.37]	[-0.63, -0.5]
ss8	0.68	[0.53, 0.16, 0.95, 1.58]	[0.53, 0.95]
ss9	-0.72	[-0.83, -0.95, -0.1, 0.98]	[-0.83, -0.1]
ss10	-0.36	[-0.46, -0.76, -0.23, 0.03]	[-0.46, -0.23]
ss11	1.15	[0.1, -0.72, 1.86, 4.42]	[0.1, 1.86]
ss12	-0.25	[-0.44, -0.87, -0.13, 0.32]	[-0.44, -0.13]
ss13	0.11	[-0.18, -0.66, 0.55, 1.56]	[-0.18, 0.55]
ss14	-0.34	[-0.49, -0.77, -0.18, 0.26]	[-0.49, -0.18]
ss15	-0.30	[-0.46, -0.86, -0.01, 0.65]	[-0.46, -0.01]
HH	0.34	[0.09, -0.6, 0.64, 1.32]	[0.09, 0.64]

Table 34: Main contributors for largest region/sector in table 8

	BUA - NL11 *ss1d*			TDA - NL33 *ss1d*		
Rank	Region	Sector	$[\frac{t}{€}]$	Region	Sector	$[\frac{t}{€}]$
1	NL11	*ss1d*	47,045.8	NL33	*ss1d*	1,814.7
2	NL11	*ss2*	77.5	NL33	*ss2*	52.8
3	NL11	*ss1a*	11.5	NL31	*ss2*	6.3
4	NL13	*ss1a*	3.9	NL41	*ss2*	6.3
5	NL41	*ss2*	2.7	NL33	*ss12*	5.7
6	NL11	*ss3*	2.3	NL32	*ss2*	5.5
7	NL22	*ss1a*	1.9	NL22	*ss2*	4.9
8	NL33	*ss2*	1.8	NL33	*ss10*	3.5
9	NL32	*ss2*	1.8	NL33	*ss5*	3.3
10	UKC1	*ss5*	1.7	NL42	*ss2*	3.1

Table 35: Country total consumption-driven emissions and relative difference Φ. Column CO_2 depicts the associated upstream emissions per FD category. Values in () are negative.

	ss16 - HH & non-profit		*ss17* - Government		*ss17* - Net capital form.		*ss18* - Inventory adj.		Direct HH		Total	
Country	CO_2 [Mt]	Φ [-]	CO_2 [Mt]	Φ [-]	CO_2 [Mt]	Φ [-]	CO_2 [Mt]	Φ [-]	CO_2 [Mt]	Φ [-]	CO_2 [Mt]	Φ [-]
Italy	319.2	(0.02)	50.1	(0.03)	88.8	0.06	3.2	(0.01)	147.0	0.26	608.26	0.04
Czech Republic	61.8	0.05	12.2	(0.07)	16.1	(0.01) (0.8)	(4.19)	26.3	1.81	115.54	0.18	
Lithuania	15.3	(0.01)	2.6	0.05	2.8	0.00	(0.5)	0.12	5.8	0.61	26.00	0.09
Malta	2.1	(0.32)	0.5	(0.27)	0.5	(0.20)	0.0	(0.16)	0.5	0.38	3.66	(0.24)
France	301.6	0.01	57.0	(0.10)	70.6	0.05	(1.7)	0.43	168.6	0.27	596.23	0.06
Slovakia	26.4	0.05	4.8	(0.07)	7.7	0.10	(0.9)	(0.12)	7.9	0.49	45.83	0.10
Ireland	27.0	0.00	5.7	(0.06)	5.4	(0.01)	(0.5)	0.09	14.7	0.03	52.29	0
Slovenia	10.0	(0.06)	1.7	(0.07)	3.3	0.06	(0.3)	(0.01)	7.2	1.04	21.92	0.16
Germany	562.0	0.03	85.0	(0.13)	171.0	0.05	(5.6)	(2.33)	235.4	0.17	1,047.79	0.04
Belgium	71.5	0.00	17.1	(0.08)	25.5	0.05	0.9	(0.07)	38.3	0.35	153.39	0.07
Spain	201.4	0.05	46.8	(0.09)	57.0	0.20	2.6	0.01	86.2	0.25	394.02	0.09
The Nether-lands	90.1	(0.07)	27.7	(0.11)	29.3	(0.02)	2.1	0.06	45.4	0.04	194.56	(0.04)
Denmark	34.0	(0.12)	8.7	(0.20)	10.1	(0.07)	(0.1)	0.12	14.1	0.53	66.74	(0.04)
Poland	181.3	(0.02)	31.7	(0.12)	46.8	0.03	3.5	0.04	80.4	0.50	343.77	0.06
Finland	48.3	0.07	12.3	0.00	19.2	0.11	(0.6)	(0.03)	15.0	1.37	94.11	0.17
Sweden	60.8	0.14	14.0	(0.06)	24.2	0.11	0.7	0.09	18.0	0.71	117.82	0.16
Latvia	7.7	0.06	1.4	0.21	2.9	0.06	(0.1)	1.86	5.0	1.76	16.75	0.30
Bulgaria	21.1	(0.06)	3.7	(0.12)	9.8	0.01	(0.9)	(0.23)	9.0	3.31	42.75	0.15
Romania	55.0	0.05	12.9	0.01	20.2	0.14	(1.3)	0.13	28.9	1.27	115.69	0.22
Luxem-bourg	4.5	(0.06)	0.9	(0.14)	1.9	(0.03)	(0.2)	0.10	2.3	0.32	9.42	0
Estonia	10.9	0.11	2.5	0.09	3.0	0.06	(0.5)	0.08	3.3	2.57	19.21	0.25
Portugal	37.9	(0.05)	6.3	(0.20)	13.5	0.15	(0.5)	4.83	17.7	0.75	74.74	0.08
United Kingdom	328.6	(0.09)	54.7	(0.18)	60.3	(0.06)	2.1	0.22	162.7	0.09	608.43	0.05
Austria	54.5	0.08	10.0	(0.01)	23.5	0.14	1.4	0.13	27.6	0.79	116.98	0.19
Greece	92.0	0.08	10.9	(0.10)	55.4	1.03	(43.6)	4.95	21.0	0.05	135.76	(0.01)
Hungary	37.3	0.07	9.4	0.00	11.0	0.03	0.4	0.13	22.4	0.42	80.50	0.13
Cyprus	7.7	(0.04)	1.1	(0.06)	3.3	0.11	(1.0)	(0.05)	2.5	0.38	13.53	0.06
Total	2,667	0	491.6	(0.10)	783	0.09	42.1	(9.30)	1,213.2	0.29	5,115.7	0.05

Table 36: Top 15 contributing countries for the indirect consumption-driven emissions of The Netherlands for FD category *ss16*. Countries outside of Europe have no relative difference Φ since the same account values are used

Rank	Country	BUA [kt]	TDA [kt]	Φ [-]
1	The Netherlands	33126.0	40074.4	-0.173
2	Germany	10315.0	10233.4	0.008
3	China	9726.9	9726.9	0
4	Russia	8483.9	8483.9	0
5	Rest of world	5539.8	5539.8	0
6	United States	4384.1	4384.1	0
7	United Kingdom	3367.9	3791.6	-0.112
8	Belgium	2731.6	2608.3	0.047
9	France	1987.7	1696.8	0.171
10	Indonesia	1923.2	1923.2	0
11	Poland	1086.7	1092.1	-0.005
12	Canada	720.6	720.6	0
13	Czech Republic	589.8	558.4	0.056
14	Brazil	562.3	562.3	0.
15	Spain	552.6	671.0	-0.176
16	India	447.9	447.9	0
17	Italy	432.9	547.2	-0.209
18	Japan	412.6	412.6	0
19	Taiwan	397.5	397.5	0
20	Denmark	371.4	552.7	-0.328
21	South Korea	350.3	350.3	0
22	Australia	347.2	347.2	0
23	Sweden	302.4	309.5	-0.023
24	Turkey	234.0	234.0	0
25	Mexico	220.4	220.4	0
26	Finland	203.7	160.3	0.271
27	Austria	194.4	161.8	0.202
28	Lithuania	140.3	131.8	0.065
29	Bulgaria	139.1	138.8	0.003
30	Romania	137.4	112.9	0.217
31	Estonia	123.6	108.9	0.135
32	Hungary	118.3	119.7	-0.012
33	Portugal	116.6	119.6	-0.025
34	Ireland	92.1	96.7	-0.048
35	Slovakia	89.6	87.5	0.023
36	Greece	45.8	61.1	-0.250
37	Luxembourg	43.5	92.3	-0.528
38	Slovenia	23.3	25.0	-0.068
39	Latvia	20.3	19.2	0.056
40	Cyprus	4.2	7.3	-0.425
41	Malta	2.6	7.1	-0.628
	Total [Mt]	90.11	97.34	

Table 37: Sector of origin of upstream emissions in The Netherlands for FD category *ss16*.

Sector	Designation	BUA [kt]	TDA [kt]	Φ [-]
ss1a	Crops	2828.8	1677.0	0.69
ss1b	Livestock with land	238.6	786.8	-0.70
ss1c	Livestock without land	209.9	443.2	-0.53
ss1d	Forestry	201.2	103.8	0.94
ss1e	Fisheries	19.9	94.6	-0.79
ss2	Mining, quarrying and energy supply	48734.2	49371.9	-0.01
ss3	Food, beverages and tobacco	1372.9	2025.7	-0.32
ss4	Textiles and leather, etc	643.0	341.9	0.88
ss5	Coke, refined petroleum, nuclear fuel, chemicals, etc	7458.9	9528.3	-0.22
ss6	Electrical, optical equipment, transport equipment	279.9	623.6	-0.55
ss8	Other manufacturing	12258.8	8739.1	0.40
ss9	Construction	448.0	634.9	-0.29
ss10	Distribution	1364.9	2670.8	-0.49
ss11	Hotels and restaurant	1525.9	904.8	0.69
ss12	Transport, storage and communication	10009.6	15516.8	-0.35
ss13	Financial intermediation	558.8	508.3	0.10
ss14	Real estate, renting and business activities	853.5	1888.8	-0.55
ss15	Non-Market service	1102.6	1475.8	-0.25