Disaggregating air, land and maritime transport sectors in the GTAP database

Abstract

In the Global Trade Analysis Project (GTAP) data base (Aguiar et al., 2019), transport sectors (air, land and maritime) are too aggregated for modelling transport policies for specific modes (aviation/rail/road) and operations (passenger/freight). This limitation is already recognised in the literature, with a number of studies focusing on data quality and transport analysis (e.g., Karkatsoulis et al., 2017, Nuno-Ledesma and Villoria, 2019, Robson et al., 2018). This study splits the air and maritime sectors into two sectors each (air passenger, air freight, water passenger, water freight) and the land transport sectors into four new sectors (road passenger, road freight, rail passenger and rail freight). Our contribution to the literature is an open discussion of the data available paying particular attention to GTAP's structure, and a step by step procedure on how to split the transport sectors and the data we use. Finally, this paper will discuss baseline projections of the disaggregated transport components. Our methodology to split GTAP database is a simple RAS method, which is used twice (separately for each aggregated sector and each region): first to disaggregate the cost structure of a sector and then to disaggregate its use (sales). We run RAS starting with an already aggregated GTAP database (35 sectors and 49 regions), but the method can be applied to any other dimensions.

Introduction

Methodological developments to improve the representation of the transport sector are of growing interest in the energy and climate policy arena (van Vuuren et al., 2017). Integrated assessment models (IAMs) and energy-economy models, such as Computable General Equilibrium (CGE) models, are often used to assess the economic implications of mitigation strategies, with the transport sector playing a key role, as an important contributor to greenhouse gas (GHG) emissions. Coarse, incomplete and inconsistent data remains a challenge faced by modellers pursuing a refined representation of the transport sector and the corresponding emissions. Yeh et al. (2017) highlight substantial differences in the base-year data and key parameters for future projections in transport models, including passenger and freight activity, mode shares and energy consumption.

Several CGE model-based studies that assess regional and global impacts of the transport sector, including both direct and wider economic impacts, can be found in the literature (e.g., Robson et al., 2018). These studies, particularly at global level, often rely on the GTAP database as their main economic data source, in many cases by coupling it with external data from more detailed transport technology models (such as TIMES-MARKAL models), in order to assess specific policy implications for the economy over time. However, the GTAP database represents transport modes only in an aggregated way, providing data for air, land and water transport. Such aggregation limits the potential analysis of detailed transport policies for specific operations (passenger/freight). One example is policies guiding the reduction of emissions by limiting air passenger travel, to the benefit of rail, between relatively close cities (e.g., Paris-Bordeaux, Madrid-Valencia). Another example is the climate dimension in external aviation policies expanding air transport for passengers and freight between global partners. To enable a fine-grained modelling of transport decarbonisation and its economic impacts, a bottom-up approach that details individual transport sector components is necessary. Karkatsoulis et al. (2017) is one of the few studies found in the literature that improved the representation of the transport sector by splitting the GTAP data into passenger and freight, drawing on the GTAP version 8 and Eurostat databases as main sources, in an extension of the GEM-E3 model (Capros et al., 2013). Unfortunately, they did not describe the split methodology or the specific data used, since it was not the focus of the study, leaving a gap in the research literature.

This paper aims to cover a broad range of countries worldwide in its quest to split the air, land and water transport GTAP sectors and make it easily reproducible by others. For this purpose, we discuss the global data available, and the gaps and differences between these datasets and GTAP. Similarly, we discuss differences on how the interested subsectors operate (costs structure and sales destination) and how the differences can be replicated in the (disaggregated) GTAP database. Overall, differences should not come at a surprise. In the words from Gelhar and McDougall (2016) "Except for United States routes, the modal shares estimates lack direct statistical backing". Finally, this paper will discuss baseline projections of the disaggregated transport components in the framework of the JRC-GEM-E3 model, an established global energy-environment-economy model used for policy analysis (JRC-GEM-E3 model website, Weitzel, et al., 2019, Vandyck et al, 2021).

Conceptual overview

Our split methodology relies on GTAP's service trade and margin chapters to ensure that our methodology and data sources are compatible with GTAP's transports sectors structure (Gehlhar, M. and McDougall, R. 2016, van Leeuwen and McDougall, R. A. 2016). In particular, GTAP allocates transport services trade data into non-margin services (i.e., transport sectors), margin services usage (i.e., VTWR parameter) and margin services supply (i.e., VST parameter). Therefore, to split the three modes of transport (air, maritime and land) into passenger and freight, it is necessary to independently account for transport margins and non-margin services. Here, the margin services data deals with international freight transport. The non-margin services cover passenger transport and 'other than passenger and freight'[1] transportation.

The mapping of the trade services data in GTAP is fairly straightforward, since the sectoral classification in the services area was designed with this data source in mind. Bilateral balance of payments services trade data (including transport) come from two sources, the UN Service Trade website and EUROSTAT's International trade in services (BPM6). These sources subdivide transportation in two different ways, by function and by mode. By function, transport data is divided into passenger, freight, and other; by mode, into sea, air, and other. This results in nine transport sectors across functions and modes (e.g., maritime passenger transport, etc). However, data is scarce for the mode classification, but abundant for the functional classification and the mode-by-function cross-classification. Also, there is inconsistency in reporting between countries. This means data needs to be manipulated to fill-in missing values and balance import and exports trade data.

Furthermore, GTAP's representation of international transport freight into margin services (usage and supply) considers the fact that the origin of the merchandise can be different to the country supplying the transport service. As an example, a pharmaceutical product sent by plane with a German air company (e.g., Lufthansa) from Canada to France. To allow this level of detail in GTAP's data base, the transport margin supply array (VST) is indexed by margin commodity and country of origin, and the margin usage array (VTWR) is indexed by margin commodity, merchandise commodity, country of origin of the merchandise, and country of destination. For the example above, the data base specifies

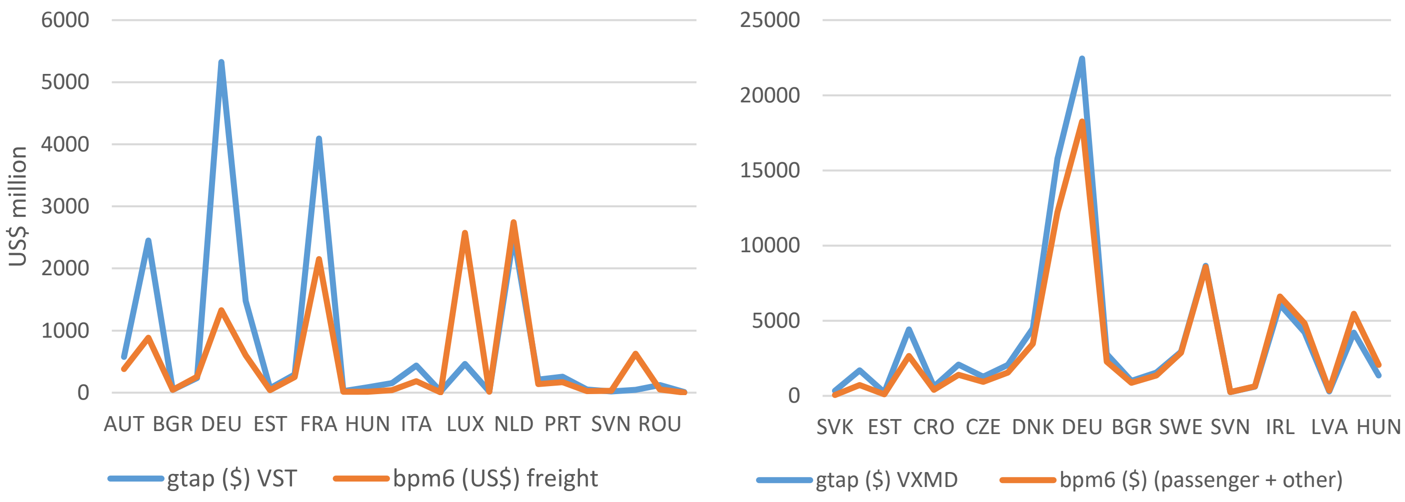
[1] The International Monetary Fund in the Balance of Payments (BPM6) guidelines (Balance of Payments and international investment position manual, 2009) defines 'other than passenger and transport' as follows; *Other transport services include services that are auxiliary to transport and not directly provided for the movement of goods and persons. The category includes cargo handling charges billed separately from freight, storage and warehousing, packing and repackaging, towing not included in freight services, pilotage and navigational aid for carriers, air traffic control, cleaning performed in ports and airports on transport equipment, salvage operations, and agents' fees associated with passenger and freight transport (e.g., freight forwarding and brokerage services).*

the value of air transport services supplied by Germany, and the value of air transport services used in exporting pharmaceutical products from Canada to France, without showing the explicit link.

Managing transport merchandise and services trade data together can result in conflicting information. In these occasions, GTAP adjusts the services freight transport data to agree with the merchandise trade data. This is because, at the relevant level of detail, the merchandise trade data is considered to be more firmly based. Having said this, until recently, merchandise trade data was purely based on US data which was a significant oversimplification. Nuno-Ledesma and Villoria (2019) improved modal shares in GTAP 9.0 Data Base (Aguiar *et al.,* 2016) by bringing a more comprehensive set of merchandise trade by transport mode, covering around 65% of global trade in 2004 and 55% in 2011. A comparison revealed that the role of water transportation services international trade in GTAP had been underestimated, while that of air transportation had been overestimated. Subsequently, their data has been used to estimate transport margins by mode in later versions of GTAP Data Base.

Given that transport margins use merchandise data instead of balance of payments' freight transport data, it should not come at a surprise that GTAP's transport margin (VST), which covers freight, varies from services trade statistics. While on the other hand, GTAP's transport service exports (VXMD), which covers passengers, has a closer trend to services trade statistics. Figure 1 highlights these differences and similarities between GTAP's VST and VXMD parameters compared to EU's transport service trade statistics (BPM6).

Figure 1. GTAP export parameters VST (left) and VXMD (right) versus service trade data statistics from Eurostat BPM6



A significant simplification in GTAP's database is that passenger transport solidly relies on service trade. As an example, imagine a Greek company purchasing a ticket from Singapore airlines for an employee flying from the Philippines to Australia. In this case, the only detail available in GTAP will be the export value of the air transport service from Singapore to Greece (VXMD parameter), ignoring the Origin-Destination pair of the flight. At least for aviation, which accounts for the majority of international passenger transport, the shortfall in GTAP's database affects climate change studies looking into the impacts of CO_2 emissions from aviation.

In summary, when splitting the transport sectors across parameters, trade margins (VST, VTWR) must be accounted to include only freight and trade exports (VXMD) only passengers. While this allocation follows GTAP's structure, it is important to recognise it may differ from actual statistics, (see Figure 1). In these circumstances, the share allocation of subsectors will be different to real observations.

Methodology

Our methodology to split the air, maritime and land transport sectors in the GTAP database is a simple RAS method, which is used twice (separately for each aggregated sector and each region): first to disaggregate the cost structure of a sector and then to disaggregate its use (sales). We run RAS starting with an already aggregated GTAP database (35 sectors and 49 regions), but the method can be applied to any other dimension. The procedure relies on a set of external data, which is discussed separately in the next section.

Figure 2 below shows a schematic representation of how GTAP is split in a two-stage RAS procedure using a simple example with two countries (A and B), three sectors (1,2,3) and where sector 3 is disaggregated into three subsectors (3a, 3b and 3c).

First, we split the output of each sub-sector (3a, 3b, 3c) as shares of the parent sector (3), using external data (see next section).

$$VOM_{s,r} = \delta_{s,r} \times VOM_{p,r} \tag{1}$$

Where:

$\delta_{s,r}$ is the share of sectoral output attributable to the subsector s

$VOM_{p,r}$ is the sectoral output of parent sector p, according to GTAP

The output estimates of each subsector (3a, 3b, 3c) are then used as column totals. The row totals are taken from the supply side output formula;

$$VOM^S_{i,r} = \sum_j VDFA_{j,i,r} + \sum_j VIFA_{j,i,r} + \sum_f EVFA_{f,i,r} + OSEP_{i,r} \tag{2}$$

Where:

$VDFA_{i,j,r}$ is an intermediate demand for a domestic commodity *i* by sector *j* in region *r*,

$VIFA_{i,j,r}$ is an intermediate demand for a imported commodity *i* by sector *j* in region *r*,

$EVFA_{f,i,r}$ are the factor payments (gross of taxes) *f* in sector *j* and in region *r*,

$OSEP_{i,r}$ is production tax in sector *i* and region *r*,

Then we transform import parameter $VIFA_{i,j,r}$ into four dimensional one using bilateral trade $VXMD_{i,r,s}$

$$VZFA_{i,j,r,s} = VIFA_{i,j,r} * \frac{VXMD_{i,r,s}}{\sum_s VXMD_{i,r,s}} \tag{3}$$

To run the first RAS we also need to have a matrix of costs structure that should ideally capture differences of interest in the disaggregated subsectors (for example, rail transport should rather use electricity as an energy while road transport oil products). In the absence of such data, we set values to 1 which means that the disaggregated subsector will have the same costs structure[2]. All the steps are schematically presented in the Figure 2 below[3].

Figure 2. Step 1 of the split procedure – RAS for costs.

	s	A			
r	i/j	row	3a	3b	3c
A	1				
	2				
	3a	VDFA			
	3b				
	3c				
B	1			costs structure	
	2				
	3a	VZFA			
	3b				
	3c				
		OSEP			
		EVFA			
column	VOM		output split		

After splitting costs in the first RAS, we need to split the use side in the second RAS. For this we use the following GTAP formula for the output from the demand side

$$VOM_{i,r}^{D} = \sum_j VDFM_{i,j,r} + VDPM_{i,r} + VDGM_{i,r} + VDKM_{i,r} + \sum_{i,s} VXMD_{i,r,s} + VST_{m(i),r} \tag{4}$$

where:

$VDFM_{i,j,r}$ - is intermediate demand for a domestic commodity *i* by sector *j* in region *r*,

$VDPM_{i,r}$ - is intermediate demand for a commodity *i* by households in region *r*,

$VDGM_{i,r}$ - is intermediate demand for a commodity *i* by government in region *r*,

$VDKM_{i,r}$ - is intermediate demand for a commodity *i* by investment in region *r*,

[2] For air and water transport, we can safely assume that costs structure shouldn't be very different. For land transport we use EXIOBASE database which has land transport divided into rail and road transport (but there is no difference between passenger and freight, either).

[3] The row totals for subsectors 3a, 3b, and 3c (not present of course in the original GTAP database) were obtained by splitting values of sector 3 in proportion to the output estimates.

$VXMD_{i,r,s}$ - is export of a commodity *i* from region *r* to region *s*,

$VST_{m(i),r}$ - is an export of a transport services *m* (a subset of) *i* from region *r*.

A numerical example in Table 1 shows the disaggregation of total output demand across the different components of demand.

Table 1. Disaggregation of total output demand.

VDFM		VDPM	VDGM	VDKM	VXMD		VST	VOM
1	2				A	B		
10	20	35	4	1	0	20	10	100

The transformation of VXMD parameter is done as follows[4]:

$$VZMD_{i,rj,s} = VXMD_{i,r,s} * VI\_S_{i,j,r} \tag{2}$$

where:

$$VI\_S_{i,j,r} = \frac{VIFM_{i,j,r}}{\sum_j VIFM_{i,j,r} + VIPM_{i,r} + VIGM_{i,r} + VIKM_{i,r}} \tag{3}$$

This operation distributes total export of good *i* from country *r* to *s* to all users in country *s* (industries and final demand) according to the structure of total import (from all countries) measured in CIF prices (including import and export taxes and trade margins).

The same we do with final demand:

$$VFMD_{i,r,FD,s} = VXMD_{i,r,s} * VI\_S_{i,FD,r} \tag{4}$$

$$VI\_S_{i,FD,r} = \frac{VIPM_{i,r}\,|VIGM_{i,r}|VIKM_{i,r}}{\sum_j VIFM_{i,j,r} + VIPM_{i,r} + VIGM_{i,r} + VIKM_{i,r}} \tag{5}$$

where *FD* set contains household, government consumption and investment

As an example, in Table 2, the total sector output (VOM) is 100, and the subsectors shares of VOM are 85 and 15. The estimation of the subsectors total output is discussed in the data section.

Table 2. We create row and column totals for RAS using (shares) output estimates

VDFM		VDPM	VDGM	VDKM	VDFM		VDPM	VDGM	VDKM	VDFM		VDPM	VDGM	VDKM	VST	VOM
1	2				1	2				1	2					
10	20	35	4	1	0	0	0	0	0	10	5	2.5	2	0.5	10	100
																85
																15

Finally, we take the following assumptions in preparation for running the first RAS.

[4] We could also use GTAP MRIO database.

For air and maritime transport sectors

We assume that:

- VST is supplied only by airport/maritime freight sector[5]. This means that we adjust column totals (and leave VST outside the RAS balancing procedure)
- Export of transport is supplied only by air/maritime passenger sector. We put weights in the VZMD and VFMD matrix to 1 for air/maritime passenger and 0 for air/maritime freight[6]
- In the absence of additional information we put weights for domestic use matrix to be 1

Table 3. Weight allocation to split aviation (maritime) into passenger and freight

																		AIR
VDFM		VDPM	VDGM	VDKM	VDFM		VDPM	VDGM	VDKM	VDFM		VDPM	VDGM	VDKM	COL	VST	VOM	
1	2				1	2				1	2							
10	20	35	4	1	0	0	0	0	0	10	5	2.5	2	0.5		10	100	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	85		85	Air p
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5	10	15	Air f

Land transport

We assume that:

- For EU countries, we calculate the split of VST that is provided by freight rail and freight road transport based on external data.
- For non-EU countries, we use output of those sectors as shares.
- No VST is supplied by passenger transport (road and rail).
- When possible (based on data availability), we calculate the weights of passenger transport (rail and road) and we use those in the RAS matrix. If not, we assign 1.
- Like for air transport, freight land transport does not supply export (VXMD)
- For domestic use, we put 1.

Table 4. Weight allocation to split land into 4 subsectors (rail passenger, rail freight, road passenger, road freight)

VDFM		VDPM	VDG M	VDKM	VDFM		VDPM	VDG M	VDKM	VDFM		VDPM	VDGM	VDKM	COL	VST	VOM	
1	2				1	2				1	2							
10	20	35	4	1	0	0	0	0	0	10	5	2.5	2	0.5		20	100	land
1	1	1	1	1	1	1	1	1	1	bpm 6	bpm 6	bpm 6	bpm 6	bpm 6	85		85	rop
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5	10	15	rof
1	1	1	1	1	1	1	1	1	1	bpm 6	bpm 6	bpm 6	bpm 6	bpm 6	-75		-55	rap

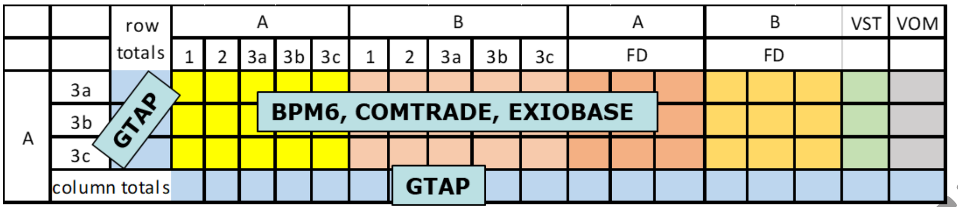
[5] We had many cases where initially the value of air freight sector was higher than the value of international margins (VST>VOM). For those cases we increased value of output as: VOM = 1.1*VST

[6] This should be equivalent to extracting VXMD from column totals similar as we did with VST

1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	-155	10	-125	raf

Similarly, the second step of the split procedure (Figure 3) uses (transformed) GTAP data as column and row constrains and external data (BPM6) as the initial matrix for the RAS method.

Figure 3. Split procedure – RAS Method using external data.



Data

In this section, we describe the data and assumptions required to inform the RAS procedure described above. We note a significant variation in data availability between EU27 countries plus UK and other countries and regions. Therefore, we present the data under two main subheadings; 1) EU27 and UK estimation; and 2) Non-EU countries estimations.

1. Splitting GTAP transport sector outputs

The first step of the disaggregation is two split the total output of the 3 GTAP transport sectors into the 8 subsectors of interest here, as shown in equation 1 (δ shares).

1.1 EU27 and UK estimation

Our global search for total production (output) value for the transport subsectors returned results only for countries covered by Eurostat Statistics. The Eurostat Structural Business Statistics (SBS) provide detailed production values[7] statistics for the 8 subsectors of interest (namely, air passenger, air freight, rail passenger, rail freight, road passenger, road freight, maritime passenger and maritime freight) for all EU27 Member States and UK in million euros. Nevertheless, there are gaps in the year 2014 (this is the year used in the GTAP MRIO table). This required data interpolation with other years to obtain an estimate when 2014 values were not available. Annex 1 provides the SBS production value of all transport subsectors and the estimates when data was missing.

Eurostat SBS uses the statistical classification of economic activities (NACE classification), while GTAP database operates rather in product classification (CPA, ISIC). Thus, on the aggregated level we have:

$$VOM_{i,r}^{CPA} \approx SBS_{i_1,r}^{NACE} + SBS_{i_2,r}^{NACE} \qquad (6)$$

i.e., the value of output from GTAP (VOM) is (more or less) equal to the sum of the industries output value at the subsectoral level.

[7] **Production value** measures the amount actually produced by the unit, based on sales, including changes in stocks and the resale of goods and services. The production value is defined as turnover, plus or minus the changes in stocks of finished products, work in progress and goods and services purchased for resale, minus the purchases of goods and services for resale, plus capitalised production, plus other operating income (excluding subsidies). Income and expenditure classified as financial or extra-ordinary in company accounts is excluded from production value.

So, our initial split of GTAP aggregated sector (*i*) for every country/region (*r*) has a form:

$$VOM_{i_1,r}^{CPA} = (SBS_{i_1,r}^{NACE} / (SBS_{i_1,r}^{NACE} + SBS_{i_2,r}^{NACE})) * VOM_{i,r}^{CPA} \quad (7)$$

This is straightforward for maritime, rail and road sectors. Since the two classifications (NACE and CPA) are comparable. However, in the case of air transport we have to make some adjustments to account for the fact that passenger flights also transport freight. As statistics suggests[8], freight carriers carried about half (56%) of cargo, and the rest was shipped by passenger flights (known as 'belly cargo') in 2013. These references suggest that the value of the air freight transport sector is higher measured in CPA than NACE category:

$$SBS_{air\ freight,r}^{CPA} \gg SBS_{air\ freight,r}^{NACE} \quad (8)$$

To take this into account in our data preparation, we adjust[9] SBS inputs as:

$$SBS_{air\ pass,r}^{CPA} = SBS_{air\ pass,r}^{NACE} - SBS_{air\ freight,r}^{NACE} \quad (9)$$

$$SBS_{air\ freight,r}^{CPA} = 2 * SBS_{air\ freight,r}^{NACE} \quad (10)$$

And use them in formula (7).

The implication of readjusting air freight to account for belly cargo in passenger flights is that freight will account for a larger share of total output than originally implied in SBS statistics.

1.2 Non-EU countries estimation

While Eurostat total production statistics (SBS) were used to split GTAP's air and land sectors total output (VOM) into 8 subsectors in EU27 and UK, similar statistics for countries outside of the EU were not available. We use other sources of information as proxy for the output of each subsector as explained below.

For the land sector we first used EXIOBASE[10] data base to split GTAP's land transport sector into rail and road subsectors. Secondly, we use transport activity values (pkm for passenger and tkm for freight) from the energy system model POLES-JRC (POLES-JRC website) combined with price estimates based on EU average cost data, to derive the output value of the subsectors[11].

We should have:

$$VOM_{air,r}^{CPA} = P_{air\ freight,r} * Q_{air\ freight,r} + P_{air\ pass,r} * Q_{air\ pass,r} \quad (11)$$

[8] Air cargo: few other industries would tolerate its structural overcapacity | CAPA (centreforaviation.com)

[9] We have assumed here that approximately 50% of freight is carried by 'belly cargo', which means that the size of freight sector in CPA category should twice as high as in NACE.

[10] **EXIOBASE** is a global, detailed Multi-Regional Environmentally Extended Supply-Use Table (MR-SUT) and Input-Output Table (MR-IOT). It was developed by harmonizing and detailing supply-use tables for a large number of countries, estimating emissions and resource extractions by industry. Subsequently the country supply-use tables were linked via trade creating an MR-SUT and producing a MR-IOTs from this. The MR-IOT that can be used for the analysis of the environmental impacts associated with the final consumption of product groups. www.exiobase.eu

[11] For air passenger, air freight, rail passenger, rail freight, road passenger, road freight. Activity values in POLES-JRC were missing passenger and freight maritime activity values, so we assumed freight represented 90% and passengers 10% of total output.

Where:

$$\frac{P_{air\ freight,r}}{P_{air\ pass,r}} = P^{EU} \qquad (12)$$

$$P^{EU} = \frac{\sum_{r(EU)} VOM^{CPA}_{air\ freight,r} \Big/ \sum_{r(EU)} Q_{air\ freight,r}}{\sum_{r(EU)} VOM^{CPA}_{air\ pass,r} \Big/ \sum_{r(EU)} Q_{air\ pass,r}} \qquad (13)$$

Is the ratio of unit prices of freight and passenger air transport calculated using EU data.

We can solve (11) and (12) – two equations and two unknowns (prices), for every non-EU region and after that we can calculate the output of subsectors[12].

Annex 2 provides a step-by-step calculation of derived total output, and prices for all EU and Non-EU countries for passenger and freight aviation using Poles activity and EU average prices. In addition, a table summary of Poles Activity values and estimated prices are available for all the other subsectors.

Although our main goal was to split total output (VOM) in values ($) for the different subsectors of interest, it is possible to interpret the values in terms of prices and quantities as well. The decomposition into prices and quantities is used as a starting point to build the baseline for our JRC-GEM-E3 model.

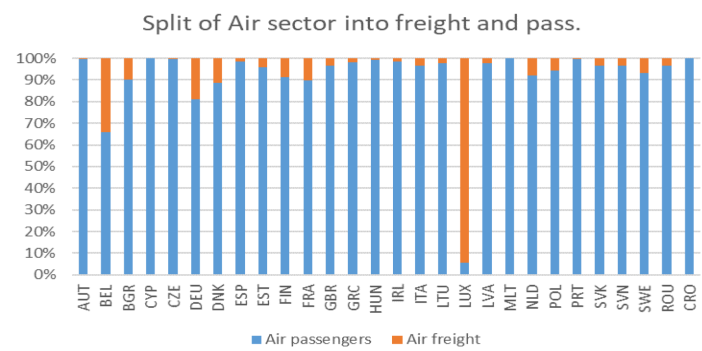
The prices for non-EU countries have been derived using a simple formula. These price estimates seem reasonable. The unit costs are lower for low income countries (IND, CHN, MEX) and also for oil rich coutries/regions (SAU, MEA). Rich non-EU countries (USA, JPN) have higher costs and small EU countries have the highest costs.

Results

NOT UPDATED

This paper aims to cover a broad range of countries worldwide. Preliminary results for the air sector from EU27 member states and UK are briefly discussed here. We derived the shares of air passengers and air freight (Figure 2) from 2014's Eurostat Structure Business Statistics (SBS), total output. These shares were later used to split GTAP's air total output (VOM). Missing values in SBS data were filled using Eurostat data on turnover, and through data interpolation from other years.

Figures 2. Shares from Eurostat Structure Business Statistics – total Output air passenger and freight



sectors (freight and passenger altogether)
passenger split like in the example above.

From Figure 2, air passenger transport represents most air total output in EU27+UK countries, as expected. Only Luxembourg (6%) and Belgium (66%) were smaller than 80%. The small air freight shares meant that we could not assume VST only came from air freight when doing the split. $VST_{i,r}$ represents the value of sales of tradable commodity 'i' to the international transport sector in region 'r', evaluated at market prices. However, given that most passenger flights carry some freight along with passengers and their baggage, it is plausible that VST combines both air passenger and air freight transport.

Final Remarks

These results highlight how the GTAP dataset can use additional data sources to derive a mode split (Gelhar and McDougall, 2016). However, global data on transport disaggregated by mode (air, rail, road) and purpose (freight, passenger) is still patchy. Our preliminary assessment indicates that EU27+UK is fairly complete for our purposes. In addition, the split of the air sector is achievable for all countries worldwide by using a detailed Origin-Destination database, but these databases are not freely available (SABRE, ICAO). The biggest data limitations can be found in the split of land into rail and road. For the purpose of our split, we use EXIOBASE to obtain the shares when other data is lacking.

By splitting the transport sector in a transparent way, with publicly available sources this paper expects to provide a simple method that delivers an initial point to be used when projecting baselines with detailed transport sectors. A consistent baseline including the disaggregation of the GTAP database for air and land transport is an expected outcome of this research.

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ANNEX 1 – Eurostat SBS Total output statistics

Eurostat provides annual detailed enterprise statistics for services using NACE Rev.2 classification. The classification of economic activities of particular interest are ‘Air transport’, ‘passenger air transport’, ‘freight air transport and space transport’, ‘land transport and transport via pipeline’, ‘passenger rail transport, interurban’, ‘freight rail transport’, ‘freight transport by road and removal services’, ‘other passenger land transport’, ‘transport via pipeline’. Their relationship is the following;

Total air transport (‘Air transport’) =

‘passenger air transport’ +

‘freight air transport and space transport’ (eq.1)

Total land transport (‘land transport and transport via pipeline’) =

‘passenger rail transport, interurban’ +

‘freight rail transport’ +

road passenger ‘other passenger land transport’ +

road freight (‘freight transport by road and removal services’ + ‘transport via pipeline’) (eq.2)

The economic indicator of interest is ‘production value’ (in million euros) in 2014. But, in some instances, when data was missing we used the indicator ‘turnover[13] or gross premium written’ (in million euro) in 2014 to approximate ‘production value’. The relationship between these two indicators is very close to 1 to 1 for most countries (see in Table 1 ratio prod/turnover).

Air transport (total, passenger and freight) SBS production value and turnover statistics in 2014 is available in Table 1. Similarly, land and maritime transport SBS production value statistics in 2014 are available respectively in Table 2, and Table 3. Missing statistics are in coloured cells. Different colours identify the method used to obtain an estimate.

Table 1. Eurostat SBS total air transport and turnover, air passenger and air freight in million euros in 2014

	Air transport in million euros in 2014					
	Total prod. Value	Total turnover	ratio prod/turnover	pass prod value	freight prod value	pass./total output
EU28 MS (2013-2020)	143,518	145,480	99%	129,926	13,592	91%
BEL	3,885	3,896	100%	2,554	1,331	66%
BGR	386	379	102%	348	39	90%
CZE	974	966	101%	971	3	100%
DNK	2,438	2,837	86%	2,164	274	89%
DEU	23,022	23,483	98%	18,702	4,320	81%

[13] **Turnover** comprises the totals invoiced by the observation unit during the reference period, and this corresponds to market sales of goods or services supplied to third parties; it includes all duties and taxes on the goods or services invoiced by the unit with the exception of the VAT invoiced by the unit to its customer and other similar deductible taxes directly linked to turnover; it also includes all other charges (transport, packaging, etc.) passed on to the customer. Price reductions, rebates and discounts as well as the value of returned packing must be deducted.

EST	133	133	100%	128	6	96%
IRL	6,992	7,179	97%	6,892	100	99%
GRC	1,412	1,485	95%	1,385	28	98%
ESP	8,906	8,959	99%	8,769	138	98%
FRA	20,524	20,287	101%	18,420	2,104	90%
CRO	293	282	104%	293	0	100%
ITA	13,405	12,953	103%	12,928	477	96%
CYP	115	114	101%	115	0	100%
LTV	432	372	116%	423	9	98%
LTU	162	161	101%	158	4	98%
LUX	2,337	2,528	92%	135	2,201	6%
HUN	1,081	1,369	79%	1,074	8	99%
MLT	60	59	101%	60	0	100%
NLD	10,839	10,854	100%	9,989	851	92%
AUT	2,519	3,737	67%	2,508	11	100%
POL	1,763	1,791	98%	1,661	102	94%
PRT	4,017	3,940	102%	4,003	14	100%
ROU	577	513	113%	558	19	97%
SVN	207	207	100%	200	7	97%
SVK	103	105	98%	99	3	97%
FIN	3,376	3,331	101%	3,075	300	91%
SWE	2,871	2,872	100%	2,676	194	93%
GBR	30,689	30692	100%	29,636	1,054	97%
When coloured, values are missing in SBS statistics and transport pocketbook	Interpolate 'production value' using 'production value' in other time periods available and 'turnover of gross premium written' in all time periods including 2014 (year of interest)					
	Column difference to balance sum of individual countries with EU28 column total					
	Use shares (pass/total and freight/total) from other year(s). Observations highlight air passenger shares (2009-2018, in data available) are stable making the assumption plausible.					
	Row difference (across categories) to balance country totals ('total production values')					
	From website statista, in 2010, 2012, and 2014* air freight revenue in Estonia was respectively 14, 18 and 21* million US$ and air passenger revenue was 321, 426 and 476* million US$. – Based on this, air freight represented about 4% of total air revenue. * is a forecast.					

From Table 1, only Luxembourg (6%) and Belgium (66%) have a ratio of passengers to total air transport below 80%. Belgium air statistics are fully available in SBS statistics (i.e., passenger, freight and total). But Luxembourg provides no air transport statistics.

Luxembourg's total production value and freight production values were obtained from the difference between EU28 totals and individual country values from all other countries. Luxembourg's passenger production value was the difference between Luxembourg's total and freight values.

The derived estimates for Luxembourg seem plausible given that Luxembourg airport is the 7^{th} most important air freight airport in Europe[14]. Overall in 2014, Luxembourg and Belgium transported by plane a similar tonnage (990 Belgium and 707 Luxembourg thousand tonnes) but Belgium also transported 28 million passengers while Luxembourg only transported 2 million passengers. This explains the low share (6%) from air passenger transport in Luxembourg.

In Table 1, most countries have a ratio of passengers to total air transport above 90%, which in turns means that freight transport represents a very small ratio according to SBS data. On the other hand, freight transport by road and rail represents a much larger share (Table 2).

[14] According to unpublished sources (statista), Europe leading airports in 2020 in 1000 metric tonnes were the following, Frankfurt (1857), Paris CDG (1636), Amsterdam (1442), Istanbul (1397), London Heathrow (1141), Liege (1114), Luxembourg (906), Cologne (842), Milan MXP (513), Brussels (506)

Table 2. Eurostat SBS total land transport, passenger rail and freight, road passenger, and freight transport via road and pipeline in million euros in 2014

	Land transport production value in million euros in 2014					
	Land transport and transport via pipelines	Passenger rail transport, interurban	Freight rail transport	Other passenger land transport	Freight road transp.& removal serv	Transport via pipeline
EU28 MS (2013-2020)	512,000	44,611	:	139,355	296,055	16,556
BEL	17,117	3,645	906	1,357	11,048	161
BGR	3,871	224	91	472	3,082	2
CZE	10,103	594	867	1,277	7,208	158
DNK	10,638	1,573	175	3,425	5,464	1
DEU	71,833	4,752	3,873	25,775	34,000	3,432
EST	1,440	9	104	152	1,174	0
IRL	4,066	192	0	2,063	1,775	37
GRC	3,999	99	3	1,707	2,077	114
ESP	35,724	2,186	329	8,310	23,214	1,684
FRA	78,396	5,880	390	27,192	42,042	2,893
CRO	2,084	45	187	665	1,116	71
ITA	70,591	7,159	272	14,753	45,113	3,293
CYP	281	0	0	138	143	0
LTV	2,072	20	396	229	1,356	71
LTU	4,044	0	533	267	3,243	0
LUX	1,134	0	44	219	870	0
HUN	5,670	373	307	1,005	3,710	275
MLT	134	0	0	60	74	0
NLD	25,936	1,977	692	3,816	18,971	481
AUT	11,990	13	1,280	4,058	6,104	536
POL	27,030	894	1,890	3,805	19,561	879
PRT	6,290	25	4	1,187	4,899	175
ROU	9,532	134	718	1,247	6,882	551
SVN	2,639	0	265	246	2,101	27
SVK	4,398	395	318	279	2,936	470
FIN	9,444	523	4	2,423	6,184	311
SWE	21,398	1,088	871	9,004	10,435	0
GBR	70,546	12,809	1,307	24,221	31,274	935
When coloured, values are missing in SBS statistics & pocket book	Interpolate 'production value' using 'production value' in other time periods & 'land transport and transport via pipelines' in all time periods available including. 2014. Indicator 'turnover of gross premium written' unavailable (blue)					
	Interpolate 'production value' using 'turnover of gross premium written'. In rail, many gaps in subsectors, require using total rail instead and shares (pass/total and freight/total) from other year(s). (grey)					
	Row difference (across categories) to balance country totals ('total production values'). In PRT no rail data available in SBS, use website statista instead [12.8% rail freight transport of total inland freight transport in 2014]. (green)					
	Column difference to balance sum of individual countries with EU28 column total (red)					

MISSING SBS MARITIME TRANSPORT STATISTICS

ANNEX 2 – Total output (VOM) step by step estimation from POLES-JRC activity (pkm,tkm) and EU average prices

Next, we explain the steps to estimate air passenger and air freight total output. The estimation for maritime, rail and road sectors was estimated in a similar way[15].

Table 3 summarises the different steps and the estimates total output, quantities and price estimates of air passenger and air freight subsectors by EU27+UK and non EU countries. GTAP's total output of air transport (VOM) in US$ millions is presented in column A (coloured in blue). PRIMES and POLES quantities (pkm passenger and tkm freight) is available in columns E and G (coloured pink).

Table 3. Disaggregated GTAP's air transport total output (VOM) into air passenger and air freight by VOM, Price and Quantity, and EU27+UK price ratio (P^{EU})

Columns	A	B	C	D	E	F	G	H
Country aggregation	Air VOM	Air Pass VOM	Air Frght VOM	Air Pass Price	Quantity	Air Frght Price	Quantity	P^{EU} (P^{frt}/P^{pass})
P^{EU} (EU27+UK)	262.26	210.54	51.72	0.47	448.56	1.30	39.85	2.77
ARG	5.76	5.65	0.11	0.18	30.78	0.43	0.25	
AUS	19.89	19.35	0.54	0.10	184.75	0.25	2.19	
AUT	9.64	9.01	0.63	1.23	7.35	1.54	0.41	
BEL	8.37	2.95	5.42	0.25	11.75	1.85	2.92	
BGR	1.71	1.37	0.34	0.43	3.18	6.05	0.06	
BRA	23.73	23.21	0.52	0.12	198.28	0.28	1.87	
CAN	19.98	19.54	0.45	0.09	213.74	0.22	2.05	
CHN	105.19	93.64	11.55	0.04	2257.17	0.18	65.04	
CYP	1.21	0.91	0.29	0.36	2.56	2.91	0.10	
CZE	2.04	1.78	0.26	0.25	7.22	1.95	0.13	
DEU	60.77	37.97	22.81	0.60	63.32	1.73	13.21	
DNK	7.01	5.38	1.62	0.51	10.66	4.03	0.40	
ESP	17.82	17.27	0.55	0.18	94.00	0.44	1.24	
EST	0.39	0.32	0.08	0.43	0.73	4.79	0.02	
FIN	4.33	3.56	0.77	0.40	8.97	1.79	0.43	
FRA	32.89	26.15	6.74	0.37	70.42	0.95	7.07	
GBR	45.44	42.32	3.12	4.29	9.85	0.60	5.17	
GRC	3.49	3.35	0.14	0.16	21.14	1.15	0.12	
HUN	1.77	1.67	0.10	0.49	3.44	0.96	0.10	
IDN	15.29	15.04	0.25	0.09	173.90	0.20	1.22	
IND	6.69	6.53	0.17	0.02	295.23	0.05	3.14	
IRL	8.65	8.41	0.25	0.85	9.88	1.08	0.23	
ITA	13.99	12.99	0.99	0.26	50.07	0.62	1.61	
JPN	31.01	25.75	5.26	0.18	143.44	0.59	8.93	
KOR	20.06	16.35	3.71	0.10	163.50	0.28	13.40	
LTU	0.29	0.27	0.02	0.19	1.39	0.82	0.03	
LUX	2.98	0.17	2.81	0.22	0.80	2.01	1.40	
LVA	0.59	0.57	0.03	0.33	1.70	0.91	0.03	
MEX	5.53	5.40	0.14	0.07	81.70	0.16	0.88	
MLT	0.93	0.89	0.04	0.45	1.97	0.54	0.07	
NLD	19.41	16.36	3.04	0.98	16.67	0.73	4.16	
POL	3.52	3.11	0.41	0.35	8.81	1.91	0.21	
PRT	6.35	6.07	0.28	0.35	17.12	0.99	0.29	
RUS	33.34	31.16	2.19	0.09	328.63	0.24	9.28	
SAU	2.25	2.10	0.15	0.02	85.88	0.06	2.62	
SVK	0.46	0.40	0.05	0.66	0.61	1.94	0.03	
SVN	0.35	0.33	0.02	1.16	0.28	3.83	0.01	
SWE	5.57	4.82	0.75	0.30	16.04	2.47	0.31	
TUR	17.64	16.87	0.77	0.04	412.62	0.10	7.97	
USA	287.71	264.65	23.06	0.17	1515.27	0.41	55.65	
ROU	1.39	1.26	0.14	0.19	6.52	1.07	0.13	

[15] Total output from rail passenger, rail freight, road passenger, road freight were estimated in a similar manner, after EXIOBASE had split GTAP's land sector into the two subsectors rail and road.

CRO	0.88	0.87	0.01	0.42	2.10	2.34	0.00	[redacted]
SAF	5.15	4.74	0.40	0.13	36.91	0.30	1.32	[redacted]
EFA	16.34	15.77	0.57	0.13	118.44	0.32	1.79	[redacted]
MEA	26.49	24.18	2.30	0.02	975.96	0.06	39.19	[redacted]
AFR	25.09	23.82	1.27	0.10	228.37	0.25	5.13	[redacted]
OAM	23.43	21.55	1.87	0.09	251.17	0.36	5.19	[redacted]
OAS	92.16	83.97	8.19	0.11	789.08	0.29	27.85	[redacted]
REA	9.33	9.16	0.16	0.12	74.82	0.34	0.48	[redacted]

Step 1. Estimate EU27+UK air passenger and air freight total output and prices

EU27 + UK's air passengers and air freight total output (VOM) (columns B and C, coloured in orange, Table 3) used SBS statistics to derive the shares of the two subsectors from GTAP's total output (VOM) (column A, Table 3).

From here, EU27 and UK air passenger and air freight prices (columns D and F, coloured in yellow, Table 3) were estimated using the subsectors total output (VOM) values and POLES activity values.

Prices (Pair freight and Pair pass) for the two subsectors are as follows;

$$VOMair,rGTAP=Pair\ freight,r*Qair\ freight,r+Pair\ pass,r*Qair\ pass,r \quad (10)$$

And of course:

$$VOMair\ freight,r=Pair\ freight,r*Qair\ freight,r \quad (11)$$

$$VOMair\ pass,r=Pair\ pass,r*Qair\ pass,r \quad (12)$$

Where, quantities (Qair freight and Qair pass) are from PRIMES for EU27 + UK and from POLES for non EU countries. The subsectors total output (VOMair freight,r and VOMair pass,r) were derived from SBS shares for EU27+UK but unknown for non EU countries due to lack of data.

Step 2. Estimate non-EU air passenger and air freight prices

If we had the prices for the subsectors, we would be able to calculate output (VOM) for non EU countries (and for the EU without SBS data).

As we miss the subsector (air passenger and air freight) prices, we calculate the price ratio (P^{EU}) of unit prices of freight and passenger air transport calculated using EU (aggregated) data;

$$\frac{P_{air\ freight,r}}{P_{air\ pass,r}} = P^{EU} \quad (13)$$

where:

$$P^{EU} = \frac{\sum_{r(EU)} VOM^{CPA}_{air\ freight,r} \Big/ \sum_{r(EU)} Q_{air\ freight,r}}{\sum_{r(EU)} VOM^{CPA}_{air\ pass,r} \Big/ \sum_{r(EU)} Q_{air\ pass,r}} \quad (14)$$

Then for each non EU country, we solve two equations (10) and (13), with two unknowns (prices). That gives us prices for non EU (yellow cells for columns D and F, Table 3).

Step 3. Estimate non-EU countries' total output for subsectors air passenger and air freight

Next we calculate the two subsectors total output (VOM) for non EU countries (red columns B and C, Table 3), using equations (11) and (12). as:

To complete the table we can also calculate prices (green cells for columns D and F) for EU countries (separately for each country) as:

$Pair\ freight{,}r{=}VOMair\ freight{,}r/Qair\ freight{,}r$ (4)

$Pair\ pass{,}r{=}VOMair\ pass{,}r/Qair\ pass{,}r$