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Assessment of European Use tables at basic prices and valuation matrices in the absence of official data

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ABSTRACT
Input–Output modellers are often faced with the task of estimating missing Use tables at basic prices and also valuation matrices of the individual countries. This paper examines a selection of estimation methods applied to the European context where the analysts are not in possession of superior data. The estimation methods are restricted to the use of automated methods that would require more than just the row and column sums of the tables (as in projections) but less than a combination of various conflicting information (as in compilation). The results are assessed against the official Supply, Use and Input–Output tables of Belgium, Germany, Italy, Netherlands, Finland, Austria and Slovakia by using matrix difference metrics. The main conclusion is that using the structures of previous years usually performs better than any other approach.

1. Introduction

An Input–Output (I–O) framework is based on so-called Supply and Use tables. Supply and Use tables can be interpreted as the mixed output of industries and the use of inputs by industries, respectively. On the one hand, the Supply table comprises an intermediate matrix of goods and services (rows) produced by industries (columns), plus additional information on imports, trade and transport margins and taxes less subsidies on products, all of which make the total supply of products of an economy. On the other hand, the Use table depicts domestically produced and imported intermediate and final uses. They may be valued at basic and at purchaser's prices. There are additional column vectors that show the final use categories, i.e. final consumption, investment and exports, and additional rows, which depict gross value-added split into labour costs, capital use, other taxes less subsidies on production and net operating surplus (Rueda-Cantuche et al., 2009).

Supply and Use tables are not measured under the same valuation concepts. The Supply table is shown in basic prices, which means the price that is paid by users excluding associated trade and transport margins and taxes less subsidies on products. Use tables are

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shown in purchaser's price, which means the price users pay for goods and services for final use or intermediate inputs (including trade and transport margins and taxes less subsidies on products). With the appropriate reallocation of trade and transport margins from the goods to the corresponding trade and transport sectors and the reallocation of the associated taxes less subsidies on products into a separate row, Use tables can also be shown in basic prices.

As stated by Eurostat (2008), basic prices are preferable in the Supply and Use framework in the sense that they provide a more homogeneous valuation. Thus, for analytical purposes, a valuation as homogeneous as possible will be required as the I–O relations are to be interpreted as technical coefficients.

Use tables at basic prices are the basis for the construction of Input–Output tables (IOTs) and therefore of I–O modelling. They are also the basis for Supply-Use modelling and comparative cost structures analysis. ten Raa and Rueda-Cantuche (2007), Rueda-Cantuche (2011) and Lenzen and Rueda-Cantuche (2012) discuss the theoretical and empirical advantages of using Supply and Use tables (SUTs) instead of IOTs for analytical modelling. Heijungs and Suh (2002) and Suh et al. (2010) previously suggested SUTs for use in Life-Cycle Assessment. The importance of basic prices relies on the fact that, unlike purchaser's prices (pp), basic prices (bp) do not include trade and transport margins (TTM) and taxes less subsidies (TLS) on products. All these features would distort the input structures of the Use table in such a way that any kind of further I–O analysis in terms of technical coefficients would be impossible.

Use tables at basic prices – Use (bp) – are often not available (Dietzenbacher et al., 2013), i.e. according to the current EU regulation (in force since 2014), the National Statistical Institutes (NSIs) are obliged to submit annually the Supply table (Sup) and the Use table at purchaser's prices – Use (pp) – only. The Use (bp) table submission is only compulsory once every five years. The previous regulation did not even require the submission of any Use (bp) tables anytime as they were considered only voluntary tables. This EU situation can be easily extrapolated worldwide[1] to many countries that do not produce Use (bp) tables annually, including Brazil, Israel, Switzerland, South Africa, Macedonia, Norway, Taiwan, among others. Besides, some such as the US and New Zealand have only recently started producing them, thus making it difficult to find available time series of Use (bp) tables. This paper aims to improve this situation by examining a set of methods and making a comparative analysis with some available official EU SUTs at basic prices.

The estimation of missing national Use (bp) tables requires additional information that can take the form of Use (bp) tables or IOTs of previous years, wherever available, and output of industries by product, among other relevant information. Following the UN (forthcoming) approach, we distinguish between the concepts of compilation, estimation and projection. The borders between these concepts may be difficult to trace but the idea of developing different methods depending on the available information (the most information in compilation; the least in projection) is useful in our view.

Projections are based on pure mathematical processes that do not use any extra information besides the row and column totals of the target tables (or none of them) or key variables (e.g. Temurshoev et al., 2011; Valderas et al., 2016, among others) while the estimation

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[1] Erumban et al. (2012) include the detailed data situation of all countries covered in WIOD tables.

process uses additional external information and/or additional external constraints to the target tables (different from those of column and row totals).

Compilation refers to instances in which conflicting/combined external data sources are used, which is the case of national statistical institutes (NSIs), when building Supply, Use and Input–Output tables. Compilation methods are – generally speaking – superior to estimation methods because they are able to consider more information. Moreover, more superior external information means better-constrained tables, which in turn means tables that better reflect measured superior external data (Lenzen et al., 2006). For example, IDE-JETRO researchers include significant information into the compilation of the Asian Input–Output Tables (AIOT) database, the Australian IELab balances time series of multi-regional Supply and Use tables using State Accounts, Business registers, Household Expenditure Surveys, and all kinds of very valuable sources (Lenzen et al., 2017), and the IndoLab (Faturay et al., 2017) uses extensive labour surveys. All these developments are contributing positively and significantly to deal with complex issues in a compilation process. Not so long ago, national statistical offices or other similar statistical agencies attempted to use all kinds of national data sources (conflicting or not) struggling to balance the whole system almost on a manual basis. Some of them still do it like this. Now, with the IELabs, the work has somewhat been semi-automated and national statistical offices such as the Australian Bureau of Statistics are applying these methods. The same can be applied for multi-regional input–output (MRIO) systems. Nevertheless, not everyone has the time and resources to collect, treat and deal with so many varieties of data sources to compile IOTs; therefore, sometimes, a more humble process of estimation takes place. This can serve us as the actual problem statement of the article. In the case of lacking resources, an estimation process is chosen over compilation as a second-best solution, and this article provides our assessment with EU countries so that others hopefully can benefit from.

Therefore, we limit the scope of our article to the estimation process of Use (bp) tables. Therefore, this paper examines some non-exhaustive methods with a selection of additional information and provides an indication of how accurately the estimates fit the reality[2] in the absence of superior data, which belong to national statistical offices (i.e. compilation process). The analysis is carried out within the EU context provided additional usable data are available, which might not currently be the case for most non-EU countries.[3] However, countries are progressively moving towards the publication of Supply and Use frameworks and an empirical comparison such as the one made in this paper might also be helpful for non-EU countries in the near future. A global view of other estimation processes can be found in Gallego and Lenzen (2009) and Lenzen et al. (2009, 2012, 2013).

The selection of the methods is based as much as possible on the conceptual features of the various tables, such as the estimation of trade and transport margins using GRAS (Junius and Oosterhaven, 2003) with a fixed restriction (imposed by definition) of the column sums over the rows equal to zero or the estimation of Use (bp) tables using available IOTs, provided that Supply and Use tables are the main source used for their construction.

Our paper can also be useful for compilers of MRIO tables but only in relation to the estimation of missing national Supply and Use tables and not to the specific features such

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[2] Other similar studies trying to reproduce NSI official tables are Bonfiglio and Chelli (2008) and Sargento et al. (2012).
[3] Besides some EU Member States, it is common for countries such as Australia, Canada, Chile, Colombia, Costa Rica, Korea, Mexico and the USA to not provide valuation matrices, for instance.

as their combination with bilateral trade statistics. Lenzen et al. (2013) state (regarding the Eora database) that it is worth setting an initial realistic set of national Supply and Use tables. The EXIOBASE database calculates the Use (bp) tables using, for instance, available IOTs and assuming a diagonal Supply table. The valuation matrices are then made proportionally to a previous year structure or over the Use (pp) table. They finally apply a proportional approach to distribute imports in the absence of previous years' structures (Tukker et al., 2013). The GTAP database is made of individual contributions, therefore methods vary across countries since the guidance from the Center for Global Trade Analysis mostly focuses on aggregations, types of tables, etc. (i.e. Huff et al. 2000, suggest using proportionality to split total uses between imports and domestic uses wherever the split is missing). Dietzenbacher et al. (2013) indicate that the valuation matrices are estimated using average rates by product (with some adjustments to match the totals in the National Accounts aggregates).

To summarise, this paper therefore seeks to shed some light on the estimation of single national Supply and Use tables and valuation matrices with comparative analyses of a set of non-exhaustive methods, mostly applied to the EU context and whenever superior data are not available. Our approach uses available SUTs and IOTs; domestic and import uses; basic and purchaser's prices; and valuation matrices, and does not use other data sources besides the tables of previous periods that have already been produced by NSIs. Evidently, more information could have been used for the same purpose but (following UN, forthcoming) that would fall beyond the scope of this paper and would enter into the field of compilation.

The next section formalises the challenge (identifies estimation targets), while Section 3 proposes different options depending on the availability of the targeted tables and auxiliary data. Section 4 describes the distance measures that will be used in the subsequent sections to discuss the choice of the alternative methods analysed. Sections 5–7 show the results of the empirical analysis. The last section summarises the conclusions. The Online Appendix gives further details about the selected methods and other related topics.

2. Estimation targets: domestic/imported Use table (BP) and valuation matrices

This section sets the estimated targets: the estimation of a Use table at basic prices, distinguishing between domestic and import uses; and valuation matrices (taxes less subsidies on products (TLS) and trade and transport margins (TTM)).

Within the European context, the official transmission programme of Eurostat (compulsory for EU Member States) for the ESA2010[4] (European System of Accounts, compliant with the System of National Accounts 2008 of the UN) classifies the tables as follows:

- Annual tables (most commonly available outside the EU):
  T1. Supply table at basic prices, with transformation into purchaser's prices: Sup (pp);
  T2. Use table at purchaser's prices: Use (pp).
- Five-yearly tables (less commonly available outside the EU):
  T3. Input–Output table at basic prices: IOT (total);
  T4. Input–Output table of domestic output: IOT (dom);

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[4] The previous transmission programme under ESA1995 was less ambitious and Tables T7–T11 were not compulsory.

T5. Input–Output table of imports: IOT (imp);
T7. Use table at basic prices (total): Use (bp);
T8. Use table of domestic output at basic prices: Usedom;
T9. Use table of imports at basic prices: Useimp;
T10. Trade and transport margins: TTM;
T11. Taxes less subsidies on products: TLS.

In particular, we will use annual tables (T1, T2) as exogenously given data and IO tables (T3 to T5) as auxiliary data that might be available. Hence, our main targets consist of the tables included in the list as T7, T8, T9, T10 and T11, i.e. the Use (bp) table, which is split into domestic and imported uses and the valuation matrices (i.e. TLS and TTM). Other auxiliary data that can be used will be those of a previous year[5] or similar country.[6]

3. Identification of different scenarios depending on the data availability

There are five alternative scenarios depending on the *availability* of the main elements of an SUT framework (rows of Table 1): Supply table, Use tables at purchaser's prices and at basic prices, domestic and imported Use tables and the so-called valuation matrices, i.e. taxes less subsidies on products and trade and transport margins matrices. The different scenarios are represented in columns (see Table 1) in a nested format.

Scenario 0 refers to the situation in which all tables are available.
Scenario 1 refers to the situation in which the TTM and TLS matrices are missing but the rest of the tables are available.
Scenario 2 refers to the scenario[7] in which a distinction is to be derived between domestic and import uses at basic prices.[8]
Scenario 3 refers to the estimation of the Use table at basic prices (total uses). Then, a further distinction between domestic and import uses and, eventually, the valuation matrices can be estimated as in scenarios 1 and 2.
Scenario 4 refers to the standard situation of updating/projecting SUTs in order to use previous year SUTs or SUTs of similar countries to make projections.

The focus of the paper is therefore on scenarios 1–3 provided that in scenario 0 (all tables are available) there is nothing to estimate and scenario 4 (no SUT framework is available) is not an estimation but a projection process.[9]

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[5] In times of deep economic crisis or bust, it might be recommendable to use time series data (if available) to capture structural changes rather than just using the previous year's reference table.

[6] Only previous year tables have been used so far instead of creating a system of criteria to select similar countries in terms of production structure, economy size, etc. This would have enlarged the paper considerably.

[7] Note that, for this task, the availability of the valuation matrices is irrelevant.

[8] Import matrices could also be obtained using other detailed data sources and approaches such as BEC (Broad Economic Classification) but our approach is conceived as an estimation process (Section 1.2) rather than as a compilation process, where international trade statistics are used.

[9] There are many updating methods in the literature (e.g. SUT-RAS, SUT-Euro, PATH-RAS method; see, for instance, Eurostat 2008, Chapter 14) but their full assessment is not within the scope of this paper; as mentioned earlier in the Introduction, we focus only on estimation processes, excluding projection and compilation activities.

Table 1. Scenarios according to the data availability.

	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	–	*Estimation of valuation matrices*	*Estimation of domestic/ imported uses*	*Estimation of Use (bp) tables*	*Projection of SUTs*
Supply	Yes	Yes	Yes	Yes	**No**
Use (pp)	Yes	Yes	Yes	Yes	**No**
Use (bp)	Yes	Yes	Yes	**No**	**No**
Usedom (bp)	Yes	–	**No**	No	**No**
Useimp (bp)	Yes	–	**No**	No	**No**
TTM	Yes	**No**	–	No	**No**
TLS	Yes	**No**	–	No	**No**

Note: **Bold** indicates the target table in each scenario.

The scenarios are presented as five independent situations (i.e. columns in Table 1) because they represent five alternative situations that a practitioner might face when estimating Use (bp) tables with a split between domestic and imported uses and valuation matrices: (a) Full availability of all tables; (b) Use (bp) tables available but not valuation matrices; (c) Use (bp) tables available but not split between domestic and imported uses; (d) Use (pp) table available without Use (bp) tables, therefore, also missing the valuation matrices; and (e) no available tables for the targeted year.[10]

As a general rule for each scenario, we expect that using tables from previous years is likely to be the best option, mainly because they gather detailed country-specific information that is not expected to change drastically in the short term.

The results presented in Sections 5–7 are focused on a selection of the best-performing methods for each scenario and the identification of their estimation strategies. Complementarily, we have drawn up comprehensive lists of feasible methods for each scenario and reported the results in the Online Appendix.

4. Data and matrix comparisons

The analysis will be carried out for the countries with a complete dataset available: Austria, Belgium, Germany, Finland, Italy, the Netherlands and Slovakia with SUTs of the years 2004 and 2005 and IOTs of 2004 (Germany, Finland and the Netherlands) and 2000 (Austria, Belgium and Italy). Finland and the Netherlands provided industry-by-industry IOTs while the others gave product-by-product IOTs. Seven tables are reported on; so 2005 is the target year and 2004 is used for the previous year.

In order to produce the estimation for the targeted tables, we use the following indicators:

(a) Weighted Average Percentage Error (*WAPE*) – this indicator weights each percentage deviation of the elements of a matrix from the true[11] value by the relative size of the latter in the overall sum of the elements of the true matrix. This indicator considers

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[10] The reader should not be confused by the fact that the five scenarios have been identified separately and as independent processes; the SUTs and IOTs are actually interrelated. More precisely, the inter-connection between SUTs, IOTs, TLS and TTM is used to develop the estimation strategies.

[11] Given that we are trying to estimate official data, we consider the official tables as 'true' for the calculation of the WAPEs. Besides, Dietzenbacher et al. (2013) state that "officially published data are more reliable because thorough checking and validation procedures have been adopted by the National Statistical Institutes (when compared to data generated on an ad hoc basis for specific research purposes)".

errors in absolute value in order to avoid potential compensations of deviations due to different signs. The method giving the least value will be the best according to this indicator:

$$WAPE = \sum_{i=1}^{m} \sum_{j=1}^{n} \left(\frac{|x_{ij}^{\text{true}}|}{\sum_k \sum_l |x_{kl}^{\text{true}}|} \right) \frac{|x_{ij}^{\text{estimate}} - x_{ij}^{\text{true}}|}{|x_{ij}^{\text{true}}|} \cdot 100$$

$$= \sum_{i=1}^{m} \sum_{j=1}^{n} \left(\frac{|x_{ij}^{\text{estimate}} - x_{ij}^{\text{true}}|}{\sum_k \sum_l |x_{kl}^{\text{true}}|} \right) \cdot 100.$$

(b) Weighted Average Square Percentage Error (*WASPE*) – this indicator is a slight modification of WAPE but making the deviations square instead of taking their absolute value. This indicator gives greater relevance to large errors and less relevance to small errors. The method giving the least value will be the best according to this indicator.

$$WASPE = \sum_{i=1}^{m} \sum_{j=1}^{n} \left(\frac{(x_{ij}^{\text{true}})^2}{\sum_k \sum_l (x_{kl}^{\text{true}})^2} \right) \frac{(x_{ij}^{\text{estimate}} - x_{ij}^{\text{true}})^2}{(x_{ij}^{\text{true}})^2} \cdot 100$$

$$= \sum_{i=1}^{m} \sum_{j=1}^{n} \left(\frac{(x_{ij}^{\text{estimate}} - x_{ij}^{\text{true}})^2}{\sum_k \sum_l (x_{kl}^{\text{true}})^2} \right) \cdot 100.$$

(c) Coefficient of determination (R^2); the square of the correlation coefficient between the elements of the true and estimated matrices, when at least one of them is different to zero. The range of values is between 0 and 1, with 1 being the best score.

(d) Difference in the number of negative elements; some approaches may lead to an increase in the number of negative elements in the estimated matrix, which should not be acceptable. This criterion may be seen as an indicator of the plausibility of the proposed approach. Notice that we will round to zero those resulting elements between -0.5 and 0.5 in order to avoid possible distortions of very small negative numbers most likely coming from mathematical and/or statistical procedures rather than from real surveyed data.

We are fully aware that more indicators exist in the literature (see Gallego and Lenzen, 2009) but, provided that none of these four indicators give us different messages or different conclusions, we do not expect significant changes using others either. The list of indicators selected was based on Temurshoev et al. (2011).

These four indicators will be calculated for:

- Use table total at basic prices – Use (bp);
- Use table domestic at basic prices – Usedom;
- Use table of imports at basic prices – Useimp;
- Trade and transport margins – TTM;
- Taxes less subsidies on products – TLS.

And separately for:

- Intermediate uses ($m = 59$ products and $n = 59$ industries);
- Final demand ($m = 59$ products and $k = 6$ categories);
- Value added (row vector of $n = 59$ industries);
- Taxes less subsidies on products (row vector of $n = 59$ industries and 6 final use categories).

The comparative analysis yielded a lot of results for each scenario, which are provided in Online Appendix C. They are organised in tables (as shown in Table 2) where the methods are depicted in rows and the different matrices compared in columns. There is one specific table for each indicator (i.e. WAPE, WASPE, R^2 and difference of negatives) and country.

The following sections summarise the main results of scenarios 1–3 in two types of tables. The first one (i.e. Table 3) shows the best-performing method in each of the scenarios (in bold) taking into account whether there are IOTs available. The second one (i.e. Table 4) shows the average and individual rankings of the different methods for every country. We have decided to show only the rankings of the different methods using WAPE values due to the fact that the rankings obtained for WASPEs and R^2 are very similar, as can be seen in Online Appendix C.

In some cases, bi-proportional adjustments methods were required. The RAS method is the most widely used in the literature and was first described by Stone (1961) and Stone and Brown (1962) and was used extensively by Bacharach (1970) to update a given IOT to a more recent or even future period for which only the row and column totals are given (Mínguez et al., 2009). The basic idea of RAS consists of changing the structure of the

Table 2. Matrix comparisons for scenarios 1–3.

Country	Scenario 1					
	TTM intermediate (only trade and transport services)	TTM intermediate (excl. trade and transport services)	TTM final use (only trade and transport services)	TTM final use (excl. trade and transport services)	TLS intermediate	TLS final use
Method 1						
Method 2						
. . .						

Country	Scenario 2			
	Domestic Use table at basic prices (intermediate)	Use table of Imports at basic prices (intermediate)	Domestic Use table at basic prices (final use)	Use table of Imports at basic prices (final use)
Method A				
Method B				
. . .				

Country	Scenario 3	
	Use table at basic prices (total intermediate use)	Use table at basic prices (total final use)
Method I		
Method II		
. . .		

Notes: One table per indicator and country: WAPE, WASPE, R^2 and difference of negatives.

Table 3. Scenario 1 – methods and results.

		Availability of previous year/similar country	
		None	TTM and TLS
Availability of IOTs	None	(1) **(2)**	(1) (2) (3) **(4)** (5) (6)
	IOT	(1) **(2)**	(1) (2) (3) **(4)** (5) (6)
	IOT (dom/imp)	(1) **(2)**	(1) (2) (3) **(4)** (5) (6)

Source: Own elaboration. Best-performing method in **bold**.

Table 4. Ranking of methods (WAPE) – scenario 1.

	AT	BE	FI	DE	IT	NL	SK	Av. Rk. (5 methods)	Av. Rk. (exc. BE, SK)
Method 1	6	4	6	6	6	6	4	**5**	**5**
Method 2	5	3	5	5	5	5	2	**3**	**4**
Method 3	3	2	3	2	1	2	8	**2**	**2**
Method 4	1	1	1	3	2	1	1	**1**	**1**
Method 5	4	6	4	4	4	4	6	**4**	**3**
Method 6	2	–	2	1	3	3	–	**–**	**2**

Source: Own elaboration.
Note: The average rankings are calculated using rankings including all methods described in Online Appendix A. Two average rankings are computed because no results are reported under method 6 for BE and SK due to lack of convergence.
AT = Austria; BE = Belgium; FI = Finland; DE = Germany; IT = Italy; NL = Netherlands; SK = Slovakia.

known base table as little as possible so that it meets predetermined row and column sums. In this paper, we will use the so-called GRAS method (generalised RAS – Junius and Oosterhaven, 2003; Lenzen et al., 2007; Temurshoev et al., 2013), which is an improved version of the RAS method that can deal with negative values in the row and column sums of the matrices as well as in their interior parts.

5. Estimation of valuation matrices (scenario 1)

The estimation of valuation matrices is a necessary step to construct Use (bp) tables and for some EU countries, those might be missing. Besides, it is common for non-EU countries, such as Australia, Canada, Chile, Colombia, Costa Rica, Korea, Mexico and the US, that these matrices are rarely available.

The selection of the methods used for the estimation of valuation matrices is based on the assumptions that margins and taxes are mostly ad valorem (as the value-added tax, which represents a large part of the total TLS value) and that taxes and margins structures across users usually change slowly over time. Bearing this in mind, we have identified two methods based on the proportionality assumption[12] across users and other four methods using structures of previous year's tables. The methods are numbered as follows[13]:

(1) TLS is proportional to the row structure of the Use table at basic prices.
(2) TLS is proportional to the row structure of the Use table at purchaser's prices.

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[12] An alternative approach would have been to calculate the implicit rate of TLS and TTM over one previous year's or similar country's Use (bp) table and subsequently, apply such rates to the available Use (bp) table. However, these results would not have been consistent with the TTM/TLS constraints in the Supply and Use (bp) tables, thus requiring bi-proportional adjustments (GRAS).

[13] In this section, we analyse the best performing methods. See Online Appendix A for the full list of methods considered and all their results. Further refinements were implemented during the course of the calculations so that the estimated tables were consistent. In brief, we did not allow non-zero values in the TTM/TLS wherever there was no transaction in the Use (pp) table. For further details, see Online Appendix B.

(3) TTM is proportional to the row structure of a previous year's/similar country's TTM.
(4) TLS is proportional to the row structure of a previous year's/similar country's TLS.
(5) TTM is bi-proportionally adjusted (GRAS) over the row structure of a previous year's/similar country's TTM.[14]
(6) TLS is bi-proportionally adjusted (GRAS) over the structure of a previous year's/similar country's TLS.[15]

Since both Use (bp) tables and Use (pp) tables are available in this scenario, the difference between them will give us the correct sum of TTM and TLS matrices. Therefore, whenever TTM (or TLS) is calculated using the appropriate assumptions from (1) to (6), the TLS (or TTM) matrix is calculated by difference against this sum.[16] This approach reduces the assumptions made and ensures the consistency of the SUT framework.

As shown in Table 3, the availability of IOTs does not make a difference to the estimation of TLS/TTM since none of the assumptions mentioned above involve them[17] (i.e. same options in every row of Table 3). Then, either with or without IOTs, if we have no TTM/TLS from a previous year or similar country, then we would choose the method yielding the smallest error from methods (1) or (2). If we happen to have the previous year TTM or TLS, then the selection will have to be made taking into account all methods from (1) to (6).

Table 4 shows the performance of the six methods for the countries analysed, which are ranked according to the WAPE indicator. Online Appendix C contains the full detailed results of all the methods. The use of row structures of previous TLS matrices to proportionally allocate the new TLS totals by row from the Sup (pp) table – method (4) – proved to be the best method. TTM is then calculated by difference. Moreover, this conclusion is completely independent of the availability of (domestic or total) IO tables. It is not surprising from the results (see Online Appendix C) that the derived estimations of TTM are generally more accurate than those of TLS, especially regarding intermediate uses. The estimations of the TTM values of trade and transport sectors generally suffer from less error (i.e. 1.7% on average for intermediate uses and 0.6% on average for final demand). The estimations of the other elements of the TTM matrix are relatively accurate too (around 6% for intermediate uses and 2% for final demand, except for Slovakia and Belgium).

The second-best ranked method is to use the structures of a previous TTM to proportionally allocate the new TTM totals by row from the Sup (pp) table – method (3). However, provided that the previous year's TTM and TLS tables are generally available jointly,[18] we would generally use method (4) – ranking first – instead of method (3).

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[14] The available column vector of TTM from the Supply table is used as a benchmark and split across users using the row structures of a TTM table of a previous year or similar country. For the columns totals, they must be null by definition. That is, the TTM matrix depicts the reallocation of transport and trade margins incorporated into products to the corresponding transport and trade services.

[15] The available column vector of TLS from the Supply table is used as a benchmark and split across users using the row structures of a TLS table of a previous year or similar country. For the column totals, the row vector of TLS available in the Use (bp) table serves as benchmark too.

[16] Note that whenever a target table is calculated as a residual this is not included in the list of methods because it does not constitute an assumption itself.

[17] Industry-by-industry IOTs might provide further information on TLS by industry which would serve as constraints in the estimation of TLS matrices. However, in the EU context industry-by-industry IOTs are far less common than product-by-product tables.

[18] It is unusual to have the TLS tables available and not the TTM tables or the other way round.

The more refined options of bi-proportionally adjusting TTM (5) and TLS (6) instead of simply distributing the TTM/TLS vector proportionally rank next, respectively. In principle, it does not seem intuitive that bi-proportional adjustments perform worse than simple proportional allocations. However, the fact that TLS tables have both positive and negative elements might be the reason behind. The convergence problems of Belgium and Slovakia may also serve as proof of it.

Similar to methods (3) and (4), the fact that method (5) ranks next is irrelevant. Indeed, provided that previous year's TTM and TLS tables are both generally available, we would generally use method (6), performing better than method (5).

Moreover, the methods using bi-proportional methods (5 and 6) performed worse than method (4), which is much simpler. Hence, we have only considered method (4) whenever previous year's valuation matrices exist.

Alternatively, whenever there is no information on TLS/TTM structures from a previous year and independently of the availability of IOTs, the best way to estimate the valuation matrices proved to be method (2), i.e. to allocate the new TLS totals proportionally to the row structure of the Use table at purchaser's prices and calculate the TTM matrix by difference.

However, the weighted average percentage errors of method (2) might be considered too high (see Online Appendix B) to be used but, given the data availability, it is shown that there is no better alternative (e.g. around 50% error on average in the estimation of the intermediate and final uses of non-trade and non-transport services and around 100% on average as regard the estimation of the intermediate and final use parts of the TLS matrix).

Generally speaking, all methods will lead to an increase in the number of negative elements and are particularly important in the trade and transport margins of commodities excluding trade and transport services. Therefore, these results show evidence of a high sensitivity of the TTM and TLS estimates to the available information provided by NSIs.

Indeed, the results show what was expected, i.e. it does not seem plausible to estimate TLS and TTM matrices using row structures of Use tables at purchaser's prices but rather information on previous years. The estimations of the TTM values of trade and transport sectors tend to suffer from less error (i.e. 4.3% on average for intermediate uses and 2.7% on average for final demand).

6. Estimation of domestic and import use matrices (scenario 2)

The estimation of domestic and import use matrices is necessary for policy studies where the domestic input structures differ greatly with respect to non-domestic structures, thus leading to different carbon dioxide emissions (Rueda-Cantuche, 2012), value-added contents (Arto et al., 2015) and other related topics. Besides, it is common for non-EU countries (e.g. New Zealand) not to split Use (bp) tables appropriately.

In this second scenario, the key issue[19] is estimating domestic and import use matrices from a Use table (total) at basic prices. The column vector of imports by product provided by the Supply table shall be allocated row-wise to industries and final demand components. The choice of the allocation rule shall be based on using the same row structures as that of

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[19] Note that the availability of TTM/TLS is not necessary for the estimation of the domestic/imported split and vice versa, therefore, scenarios 1 and 2 are completely independent.

the IO tables of imports, current or from a previous year, if available. Alternatively, the row structures of the Use table (total), either at basic or purchaser's prices, can also be used as proxies. It is, however, evident that the assumptions using import values from the IO tables are much more appropriate than the other two alternatives, even though there would be some distortion caused by the treatment of secondary activities in the compilation of IO tables from original (unknown) Use (bp) tables of imports.

The reason that we do not estimate first a Use table of domestic uses and subsequently, the Use table of imports by difference (but instead the other way round) is that it leads to a higher number of undesired negative values. Indeed, errors in the estimation of the largest part of the total use in each cell (i.e. domestic) lead to negative imports more easily than the other way round.

The methods are classified with letters[20]:

(A) The Use table of imports at basic prices is proportional to the row structure of the Use table (total) at basic prices.
(B) The Use table of imports at basic prices is proportional to the row structure of the Use table (total) at purchaser's prices.
(C) The Use table of imports at basic prices is proportional to the row structure of the IOT of imports, if available.
(D) The Use table of imports at basic prices is proportional to the row structure of the IOT of imports of a previous year or similar country, if available.

Table 5 shows the assumptions to be empirically assessed in order to decide the best approach in each situation, which will greatly depend on the availability of auxiliary data. Note that bi-proportional adjustment methods are not considered in this case because the targeted totals of import uses by industry would not be available.

Scenario 2 requires that a total Use table at basic prices is available. As shown in Table 1, we will also assume that Supply tables at basic prices and Use tables at purchaser's prices are available in the current year. In addition, we could optionally have, as extra information, IOTs (distinguishing between domestic and import uses) of the current year[21] and/or previous year IOTs, Use tables at purchaser's prices and Supply tables.

As shown in Tables 5 and 6, the row structures of an IOT of imports, if available, seem to be the best assumption to estimate a Use table of imports (method C). This conclusion is independent of the availability of previous year SUTs and IOTs (obviously a current IOT is better than a previous IOT). It is noteworthy that in Finland this method yields WAPEs very close to 0% in all estimated tables (see Online Appendix C). The same happens but only in final demand in Italy, Belgium and Austria. In general, domestic Use tables are better estimated (ca. 2–9%) than import Use tables (ca. 7–15%).

Analogously, whenever there is no IOT for the current year available but one for a previous year, then the most appropriate approach seems to be the use of the row structures

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[20] Further refinements were implemented during the course of the calculations so that the estimated tables were eventually consistent. In brief, we did not allow non-zero values in the Use dom/imp wherever there was no transaction in the Use (bp). For further details, see Online Appendix B.
[21] We recognise that, by definition, it is difficult to find an IOT of imports of the current year without the corresponding Use (bp) table of imports.

Table 5. Scenario2 – methods and results.

		Availability of previous year/similar country			
		None	Use (pp); Use (bp) Supply	IOT (dom/imp)	IOT (dom/imp); Use (pp); Use (bp) Supply
Availability of IOTs	None	(A) **(B)**	(A) **(B)**	(A) (B) **(D)**	(A) (B) **(D)**
	IOT (dom/imp)	(B) **(C)**	(B) **(C)**	(B) **(C)** (D)	(B) **(C)** (D)

Source: Own elaboration.
Note: Best-performing method in **bold**.

Table 6. Ranking of methods (WAPE) – scenario 2.

	AT	BE	FI	DE	IT	NL	SK	Av. Rk.
Method A	4	3	4	3	4	1	3	**4**
Method B	3	4	3	4	3	2	2	**3**
Method C	1	1	1	1	1	4	1	**1**
Method D	2	2	2	2	2	3	4	**2**

Source: Own elaboration.
Note: The average ranking is calculated using rankings including all methods described in Online Appendix A.
AT = Austria; BE = Belgium; FI = Finland; DE = Germany; IT = Italy; NL = Netherlands; SK = Slovakia.

of an IOT of imports of the previous year (method D). Similarly, this conclusion is again independent of the availability of SUTs of a previous year.

Generally speaking, Use tables of imports are not estimated so well. However, domestic Use tables continue to result in low WAPEs (e.g. 4–7% in intermediate uses and 1–2% in final demand, except for Belgium, Slovakia, the Netherlands and Austria).

In the absence of IOTs, method B proved to be the one with the lowest WAPE values. However, the errors made in this situation are far from small, especially in the Use table of imports (see Online Appendix C).

It is noteworthy that neither methods B, C nor D yield additional negative elements to the intermediate Use table of imports. Regarding the intermediate domestic Use table, method B turned out to be the one with the least new (additional) negative values. Concerning final uses, most of the countries also reported no additional negative elements when using method C while when using methods B and D there is a small increase in the number of negative values. In sum, the use of any of these methods may bring in a number of negative elements, which should be taken into account for further analyses.

7. Estimation of use tables at basic prices (scenario 3)

The estimation of Use (bp) tables is a necessary step to construct IOTs and to apply any I–O-based analysis for policy making. Due to some derogation, for some EU countries, those might be missing. In non-EU countries, the availability is scarce. To our knowledge, countries such as Brazil, Cape Verde, Israel, Mauritius, Switzerland, South Africa, Albania, Macedonia, Norway, Taiwan, Indonesia, Nepal, Russia and Venezuela, among others, do not report official Use (bp) tables. Moreover, some countries such as the US or New Zealand have only recently started to produce these tables, therefore they do not have a time series of Use (bp) tables. This paper could then be helpful to build such a time series.

The selection of the methods used for the estimation of Use (bp) tables is based on the construction process itself, i.e. either from the estimation of TTM and TLS matrices in order to subtract them from the Use (pp) tables or by using the product technology assumption to reverse the IOT back to the Use (bp) table that was originally used to compile it.[22] We are fully aware that a pure product technology assumption is not the one applied by NSIs but it can still serve us as proxy provided that it is axiomatically superior to others (Kop Jansen and ten Raa, 1990; Rueda-Cantuche and ten Raa, 2009). In Online Appendix B, we provide some additional adjustments that were needed to obtain consistent results.[23]

Regarding the estimation of TTM and TLS, this can be done either separately or using the difference between Use(pp) and (bp) tables of a previous year.[24] These assumptions worked well for scenario 1. TTM and TLS can also be considered proportional to the Use (pp) table with or without fixing a certain amount of TLS allocated to final consumption of households (given the importance of VAT in TLS).

The methods proposed are the following (in roman numbers):

(I) Reversing[25] the IOT (total uses) assuming the product technology assumption (product-by-product IOT) or the fixed industry sales structure assumption (industry-by-industry IOT).

(II) Reversing the IOT of domestic uses and the IOT of import uses assuming the product technology assumption (product-by-product IOT) or the fixed industry sales structure assumption (industry-by-industry IOT).[26]

(III) Provided that we have previous year/similar country Use tables at basic and also at purchaser's prices available, their difference would provide a matrix structure of the sum of TTM and TLS, which can be used for the estimation of a Use (bp) table.

(IV) Provided that we have previous year/similar country TTM and TLS matrices available, their matrix structures can be used to estimate them independently.

(V) Estimating TTM and TLS assuming that both are proportional to the row structure of the Use table at purchaser's prices and then subtracting them from the Use table at purchaser's prices.[27]

(VI) Estimating TTM proportional to the row structure of the Use table at purchaser's prices. Final consumption of households and exports in the TLS matrix are fixed to previous year/similar country shares and allocated column-wise using the Use table at purchaser's prices. The remainder are assumed to be proportional to the row structure of the Use table at purchaser's prices and TLS.

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[22] See Online Appendix D for an illustrative flow chart of the compilation process for official IOTs.

[23] Further refinements were implemented during the course of the calculations so that the estimated tables were consistent. In brief, we did not allow non-zero values in the Use (bp) tables wherever there was no transaction in the Use (pp). For further details, see Online Appendix B.

[24] Note that, in scenario 3, we need to estimate both TTM and TLS separately since the sum of the two cannot be estimated as a residual against the difference of Use (pp) and (bp) tables.

[25] Input–Output tables are derived from Supply and Use tables by using various assumptions, all of which can also be used for deriving Use tables from Input–Output tables (see Online Appendix D).

[26] Notice that this method is equivalent to reversing the IOT of total uses and the IOT of imports and then calculating the domestic use table by difference, as described in scenario 2.

[27] The CREEA Project (http://creea.eu/) uses this approach extensively.

Note that bi-proportional adjustment methods are not considered because the total intermediate consumption by industry and the targeted totals for the Use (bp) table would not be available.

Table 7 shows the number of assumptions to be empirically evaluated as well as the ones that provided the best results in each case, which will depend to a great extent on the availability of auxiliary data. Whenever Use (bp) and (pp) tables of a previous year are available, their difference could be used to estimate official row/column structures of joint TTM and TLS.

As shown in Table 8, by using those joint structures, method III proved to be the most appropriate. This result remains unchanged independently of the availability of IOTs (with or without distinguishing between domestic and imported uses). Interestingly, method III is even preferable to using separate TTM and TLS structures of a previous year (method IV), meaning that the errors of the independent estimation of TTM and TLS tend to cumulate instead of cancelling each other out. The WAPEs of methods III and IV were around 1%, with the exception of Belgium and Slovakia (see Online Appendix C) which behave in a different way, as in other indicators. This conclusion is also independent of the availability of current IOTs.

Conversely, whenever no other information on valuation matrices structure is available (or can be derived) from a previous year, the availability of an IOT for the current year makes a difference in the estimation of a Use (bp) table (methods I and II) by the use of the product technology assumption (product-by-product tables) or fixed industry sales structures (industry-by-industry tables). The average WAPE is around 16% for intermediate uses and less than 1% for final demand (with the exception of Finland and the Netherlands).

It is noteworthy that methods I, II and V will not lead to an increase in the number of negative elements in the intermediate domestic Use table. However, methods III and IV bring in a small number of negatives with the exception of Belgium. Generally speaking, methods I, II, III, IV and V will lead to a reduction in the number of negative elements in final uses, though they are very few with a maximum of 19 for the Netherlands and 16 for Germany. The reader should also notice that intermediate use and final use matrices have 59×59 and 59×6 dimensions, respectively, so, after all, the variations in the number of negatives is not so significant.

Methods I and II are linked to the type of IOT used (product by product or industry by industry) and in the case of product-by-product IOTs the final demand must, by definition, be very well adjusted, if not the same as that of the IOT (e.g. Italy, Belgium and Austria). For the same reason, it is not surprising to find the two biggest WAPEs of methods I and II in the Netherlands and Finland, provided that they publish industry-by-industry IOTs and the use of the fixed industry sales structure assumption does not guarantee a good fit of the final demand block.

Finally, the use of row-wise proportional allocation of the TTM and TLS product totals of the Supply table according to the row structures of the Use table at purchaser's prices seems to perform well whenever no current IOT is available (method V). This conclusion is independent of the availability of a previous year IOT (with or without a distinction between domestic and import uses). This assumption leads however to WAPE values of around 12–20%, on average.

Table 7. Scenario 3 – methods and results.

		Availability of previous year/similar country								
		None	IOT	IOT (dom/imp)	TTM TLS	Use (pp); Use (bp) Supply	IOT (dom/imp); TTM TLS	IOT (dom/imp); Use (pp); Use (bp) Supply	TTM TLS Use (pp); Use (bp); Supply	IOT (dom/imp); TTM TLS; Use (pp); Use (bp); Supply
Availability of IOTs..	None	**(V)** (VI)	**(V)** (VI)	**(V)** (VI)	**(IV)** (V) (VI)	**(III)** (V) (VI)	**(IV)** (V) (VI)	**(III)** (V) (VI)	**(III)** (IV) (V) (VI)	**(III)** (IV) (V) (VI)
	IOT	**(I)** (V) (VI)	**(I)** (V) (VI)	**(I)** (V) (VI)	(I) **(IV)** (V) (VI)	(I) **(III)** (V) (VI)	(I) **(IV)** (V) (VI)	(I) **(III)** (V) (VI)	(I) **(III)** (IV) (V) (VI)	(I) **(III)** (IV) (V) (VI)
	IOT (dom/imp)	**(II)** (V) (VI)	**(II)** (V) (VI)	**(II)** (V) (VI)	(II) **(IV)** (V) (VI)	(II) **(III)** (V) (VI)	(II) **(IV)** (V) (VI)	(II) **(III)** (V) (VI)	(II) **(III)** (IV) (V) (VI)	(II) **(III)** (IV) (V) (VI)

Source: Own elaboration.
Note: Best-performing method in **bold**.

Table 8. Ranking of methods (WAPE) – scenario 3.

	AT	BE	FI	DE	IT	NL	SK	Av. Rk.
Method I	3	4	6	4	4	6	4	**4**
Method II	4	3	5	3	3	5	3	**3**
Method III	1	2	2	1	2	1	1	**1**
Method IV	2	1	1	2	1	2	2	**2**
Method V	5	5	3	5	5	3	5	**5**
Method VI	6	6	4	6	6	4	6	**6**

Source: Own elaboration.
Note: The average ranking is calculated using rankings including all methods described in Online Appendix A.
AT = Austria; BE = Belgium; FI = Finland; DE = Germany; IT = Italy; NL = Netherlands; SK = Slovakia.

8. Conclusions

This paper examines a few non-exhaustive methods for the estimation of valuation matrices, domestic and import Use tables at basic prices and Use tables (totals) at basic prices with a selection of auxiliary information and providing an indication of how much the estimates fit the reality in the absence of superior data, which belong to national statistical offices. The analysis is carried out within the EU context because of the availability of homogenous additional data but it can be used as well in non-EU countries provided the same data are available.

The main conclusion is that the usage of tables of previous years generally provides the best options in each scenario. This is mainly because they gather detailed country-specific information that is not expected to change in the short term. Other specific lessons can be learnt from our analysis with respect to valuation matrices, domestic and imported Use tables at basic prices and Use tables (totals) at basic prices. These are the following:

(a) Valuation matrices: it is better to start the calculation with an estimation of matrices of taxes less subsidies on products. Then, the trade and transport margins matrix will be calculated by difference. This solution performs better than the other way round.
(b) Domestic and imported uses: the availability of an IOT of imports makes a difference.
(c) Use tables (totals) at basic prices: using the joint structure of the valuation matrices of a previous year is the best option (i.e. difference between the Use table at purchaser's prices and the Use table at basic prices from a previous year).

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