PROJECT N. 037033

EXIOPOL

A NEW ENVIRONMENTAL ACCOUNTING FRAMEWORK USING EXTERNALITY DATA AND INPUT-OUTPUT TOOLS FOR POLICY ANALYSIS

ALGORITHM AVAILABLE AND APPLIED ON A TEST SET OF 4 COUNTRIES

Report of the EXIOPOL project

Title	Algorithm available and applied on a test set of 4 countries
Purpose	Deliverable of WP III.4.a
Filename	EXIOPOL_DIII.4.a-3_Final.doc
Authors	Maaike C. Bouwmeester
Document history	-
Current version.	Submitted
Changes to previous version.	-
Date	15.10.2008
Status	Submitted
Target readership	EXIOPOL project group
General readership	-
Dissemination level	PU

Maaike C. Bouwmeester
Rijksuniversiteit Groningen (RuG) – University of Groningen

October 2008

Prepared under contract from the European Commission

Contract no 037033-2
Integrated Project in
PRIORITY 6.3 Global Change and Ecosystems
in the 6th EU framework programme

Deliverable title:	Algorithm available and applied on a test set of 4 countries
Deliverable no. :	DIII.4.a-3
Due date of deliverable:	Month 18
Period covered:	from 1st March 2007 to 1st September 2008
Actual submission date:	15.10.2008
Start of the project:	01.03.2007
Duration:	4 years
Start date of project:	01.03.2007
Project coordinator:	**Anil Markandya**
Project coordinator organisation:	FEEM

Executive summary

This deliverable gives an overview of the algorithm to trade-link the 43 national Supply and Use tables. A list of program elements is presented accompanied by annotations to identify important decisions and assumptions made. The algorithm contains two main stages; applying the trade ratios to obtain bilateral tables, and subjecting tables to (generalized) RAS to regain consistency. In order to carry out these program elements, consistency tests are performed to check whether data that apply to the same trade flow are both equal to zero, or both non-zero. The algorithm has been tested on an aggregated set of data for four countries.

Table of contents

1 Introduction

In this report an overview is given of the algorithm developed to construct an international Supply/Use table (ISUT). This algorithm is part of the EU-funded EXIOPOL project. The objective of the project is to enable the estimation of environmental impacts and external costs of different economic activities and resource use of countries in the European Union. An important part of the project is the development of a toolbox to facilitate full cost accounting and impact assessment of different activities. This toolbox is instrumental in undertaking cost-effectiveness analysis and cost-benefit analysis of the environmental impacts related to technologies and policies (FEEM & TNO, 2006, p.4). The ISUT will form the core of this toolbox.

The rise in international trade has altered economic structures and has increased the interdependency of countries. The European Union (EU) has taken this a step further through its focus on economic integration. Production processes depend more and more on imported inputs. However, policy analysis in EU member countries have been largely based on national Supply and Use tables that do not distinguish between the spatial origin of the inputs and destination of the outputs. Especially in case of environmental studies it is important that the environmental impacts of production and consumption are correctly ascribed to products and countries at hand. The fact that a product is imported instead of purchased domestically may entail rather different environmental impacts.

Over the past decade it has been acknowledged that accounting for international trade flows and cross-boundary production processes is of vital importance for correct environmental impact analyses. For this type of analysis, the importance of trade-linked tables has been noted, among others, by Ahmad & Wyckoff (2003), Lenzen, Pade & Munksgaard (2004) and Turner et al. (2007). By combining national Supply/Use Tables (SUT) and trade statistics, international trade flows can be represented in a Supply and Use framework accounting for the interrelationships between countries at a product/industry level.

The algorithm presented in this report follows directly from the construction methodology for ISUT as covered in deliverable DIII-4.a.2 (Bouwmeester & Oosterhaven, 2008). Conceptual issues are discussed in this previous report; here we focus on a straightforward presentation of the necessary steps to be taken to obtain an ISUT. The algorithm consists of two main stages, of which the first is the splitting-up of the national tables into bilateral tables. In this stage the relevant trade ratios are applied in order to incorporate information on the origin or the destination of internationally traded products. The second stage deals with the inconsistencies that arise due to this mechanical split-up. These inconsistencies are caused by a host of different issues of which the two most important are the different data sources used, and the differences in valuation of export and import trade flows. In addition, transit trade can play a large role in distorting the import and export values associated with one and the same trade flow. The process of trade-linking by applying ratios obtained from trade data also introduces inconsistencies. Due to a lack of full information the assumption has to be made that each industry imports a product according to the percentage the country imports of this product, which may vary in reality.

The inconsistencies that arise from these data and these assumptions influence the data in the final tables in two important ways. First, it prohibits the use of both data source to obtain bilateral Supply tables and bilateral Use tables simultaneously. *This implies that only the import use table, or only the export supply table, is disaggregated into bilateral trade tables, but that both disaggregations are not integrated.* The decision to split-up the tables is directly related to whether the international import data or the international export data is assumed to provide the most relevant and correct information about the trade flows. As the national SUTs are the most important building blocks of the ISUT, the trade data of the trade databases will only be used as ratios, relying on the values for international trade from the ISUT. Second, the inconsistencies that arise in the table that is disaggregated have to be resolved using a *mechanical adjustment method*. The method used to regain consistency is called *generalized* RAS due to its ability to sensibly deal with negative values (Junius & Oosterhaven, 2003). The method of RAS was originally developed to update input-output tables given new row and column totals (Stone, 1961). It is a bi-proportional adjustment algorithm that balances matrices in a mechanical way. In a trade-linking setting, the method also takes care of the assignment of trade and transport margins to the country of production of these services of which no direct information is available in the country of destination of the trade flows. This valuation layer is largely responsible for the complexity of the problem of trade-linking.

In the next section an overview of the algorithm will be given referring to the different actions that will be undertaken by the computer program in chronological order of execution. This overview is annotated in the next section, in which the most important assumptions are described and the construction decisions in building the algorithm are elucidated. The last section indicates the remaining areas of work and challenges that may arise in trade-linking the full dataset.

2 Data

2.1 Data input

The EXIOPOL project will encompass 43 individual countries and an additional 'Rest of the World' region. The classification used distinguishes between 129 industries and 129 products, leading to a squared set-up of the tables. However, the algorithm described in this paper can also deal with rectangular SUTs.

Partners of the project will deliver the harmonized national Supply and Use tables. In figure 1 a Make table for country *S* is depicted, which is just the transposed Supply table. This lay-out is chosen here as it better represents the conceptual idea of the Supply table. The rows represent the producing industries, while the products they produce are recorded in the columns. The vector $\mathbf{x}$ denotes the total input/output of industries, while $\mathbf{q}$ is the vector of total supply/use of products. The vectors $\mathbf{m}$ represents imports. The vectors $\mathbf{d}$ and $\mathbf{t}$ are valuation vectors of trade and transport margins, and taxes and subsidies respectively.

In the national Use table of country *S*, as depicted in figure 2, all domestic and imported products that are used by industries in country *S* are incorporated. The matrix $\mathbf{F}$ records the final demand categories, while the matrix $\mathbf{W}$ represents value added. The vector $\mathbf{e}$ contains the exports of products by country *S*.

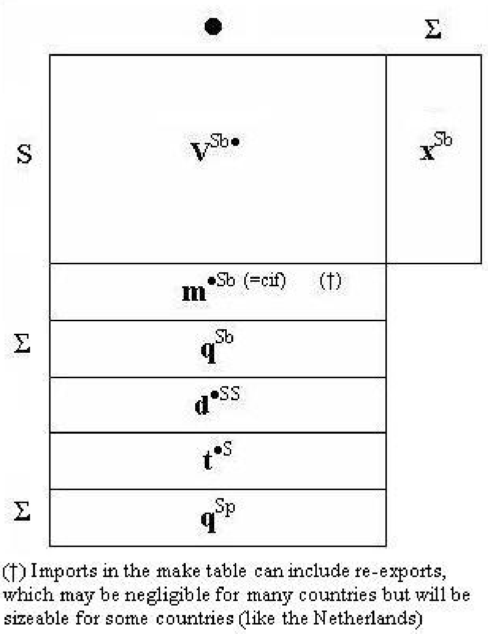

Figure 1: Make table

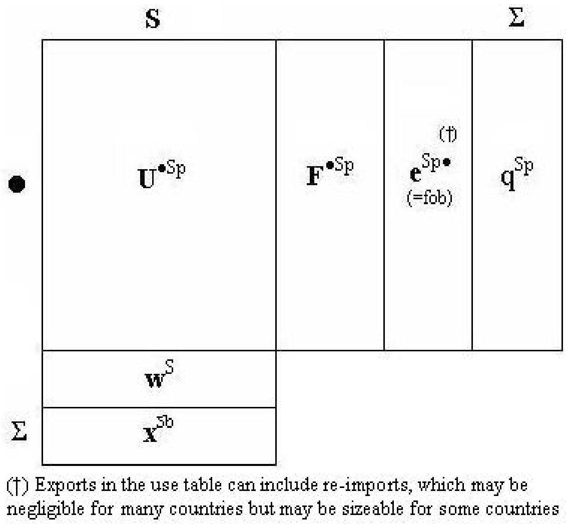

Figure 2: Use table

In addition the partners will be responsible for the split of the Use tables into a domestic Use table and an import Use table using additional information.

This may require the assumption that all industries and all domestic final demand categories import a certain product in the same proportion for those countries for which no additional data is available.

To obtain the export Supply table, the national table will be split up using information on exports as contained in the Use table. This implies that the assumption might have to be made that each industry that makes a product exports it according to the ratio of total exports of the product to output.

Both the Use table and the Supply table will be in basic prices. For modeling purposes it is important that the ISUT is denoted in basic prices, because only this valuation enables to allocate environmental impacts to the industries that actually are producing them. Using purchaser prices, for example, would allocate output related to transport and trade unjustly to the industries that produce the goods and services that are being transported and traded.

For the import use tables this implies that prices are on cost-insurance-freight basis. These prices include taxes and subsidies in the country of production, trade and transport margins from the producer to the border, and international trade and transport margins (to the border of the importing country). The valuation layers in domestic trade and in international trade are given in table 1. In international trade five valuation layers are added to a product before it reaches the buyer in another country. These valuation layers have to be taken into account to solve the inconsistencies between trade data.

Table 1: Valuation scheme

Country	Domestic valuation	International trade (exports by R/imports by S)
R	Basic prices R	Basic prices R
R	+ Valuation layer: taxes and subsidies	+ Valuation layer: taxes and subsidies
R	+ Valuation layer: trade and transport	+ Valuation layer: trade and transport
R	Purchaser prices R	= Exports f.o.b. R
International		+ Valuation layer: international trade and transport margins
S	Basic prices S	= Imports c.i.f. S
S	+ Valuation layer: taxes and subsidies	+ Valuation layer: taxes and subsidies
S	+ Valuation layer: trade and transport	+ Valuation layer: trade and transport
S	Purchaser prices S	Purchaser prices S

Instead of building one database, the project will maintain three databases to be able to strictly separate different types of data. The first database will contain all primary inputs for the trade-linking methodology. The second database will contain the trade-linked tables, and the third database will contain Input-Output tables constructed from the ISUT stored in the second database.

The required trade statistics are obtained from outside the project and first reclassified into the EXIOPOL classification, after which trade ratios are calculated that are incorporated in database I. All other data required by the algorithm will be obtained from database I. The import procedures related to entering data in this database incorporate tests regarding sizes, properties and identities that are defined by the national Supply and Use framework or within the project. These tests will be performed when data is read into the database. For example, all tables are required to have two dimensions; 129 products by 129 industries. The data will not be tested for these properties in the algorithm as they are confirmed by the fact the data is imported from database I.

2.2 Data output

The tables that are obtained by applying the trade-linking algorithm are stored in database II, which is completely kept separate from the input database I. Database II, which will contain the trade-linked Supply and Use tables, will serve as input for the Input-Output tables that will be generated within the EXIOPOL project in database III.

See for an overview of the organization of the project in different work-packages the description of work of the project (FEEM & TNO, 2006) and the report of the scoping phase (Tukker & Heijungs, 2008).

3 Algorithm

In this section an overview is given of the algorithm to trade-link the tables. The algorithm has been programmed in Matlab, and will be integrated into the database using a high-level programming language (Delphi or C++, which will be programmed by UL-CML). As replicating the full code here does not add towards transparency we have chosen to represent the algorithm as a list of consecutive small program elements that all have their own distinctive purpose. Only a short descriptive list will be given here that are accompanied by numbers that refer to annotations made in section 4.

ALGORITHM TO TRADE-LINK NATIONAL SUPPLY / USE TABLES

Determine whether use (*) or supply (**) tables will be split up (specified by user)

(*) Use table

Importing data

- **43 import Use tables (1)**
- **43 * 43 vectors of import trade ratios (2)**
- **43 export vectors from Use table (3)**
- **43 * 43 vectors of export trade ratios (4)**

For country 1 to 43:

Zero check I: vector of total imports for each product per country (SUT) and import indicator (TS) (5)

For country 1 to 43:

Adjustment I of the data if needed (6)

For country 1 to 43:

Split the tables into bilateral tables (7)

For country 1 to 43:

Calculate the implicit exports (8)

For country 1 to 43:

Zero check II: vector of implicit exports (SUT) and the sum over the destination countries of the export trade ratios (9)

For country 1 to 43:

Adjustment II of the data if needed (10)

For country 1 to 43:

Obtain the export vector aggregated over the 42 partners (11)

Concatenate the country vectors and tables

- **Concatenate the export vectors aggregated over the 42 partners into one export vector (12)**
- **Concatenate the country import vectors (as summed over the products) into one import vector (13)**
- **Concatenate the bilateral import use vectors into one large Use matrix with on the main diagonal block matrices with zeros (14)**

Rescale the aggregated export vector (15)

Store the discrepancy vector in database II (16)

Test for negative values in the large Use table (17)

- **If not present: apply RAS algorithm (18)**
- **If present: apply GRAS algorithm (19)**

Store the consistent bilateral Use tables in database II (20)

(**) Supply table

Importing data

- **43 Supply tables (21)**
- **43 export vectors from Use table**
- **43 * 43 vectors of export trade ratios**
- **43 import Use tables**
- **43 * 43 vectors of import trade ratios**

Obtain the export supply tables (21)

For country 1 to 43:

Zero check I: vector of total exports for each product per country (SUT) and export indicator (TS) (22)

For country 1 to 43:

Adjustment I of the data if needed (23)

For country 1 to 43:

Split the tables into bilateral tables (24)

For country 1 to 43:

Calculate the implicit imports (25)

For country 1 to 43:

Zero check II: vector of implicit imports (SUT) and the sum over the origin countries of the import trade ratios (26)

For country 1 to 43:

Adjustment II of the data if needed (27)

For country 1 to 43:

Obtain the import Use table aggregated over the 42 partners (28)

For country 1 to 43:

Rescale the vector of implicit imports (SUT) (29)

For country 1 to 43:

Store the discrepancy vector in database II (30)

For country 1 to 43: (31)

Test for negative values in the Use table

- **If not present: apply RAS algorithm**
- **If present: apply GRAS algorithm**

Store the bilateral Supply tables in database II

Store the consistent Use tables in database II

4 Annotations to the algorithm

Import Use tables

1) These tables include columns representing the final demand categories as these also import products directly from abroad. In addition a vector with re-exports can be imported into the program to represent transit trade. Note that at this moment, transit trade is assumed to be non-existent. In case data on transit trade is available (some European countries report transit trade as separate column), it is desirable to use this additional data to separate transit trade from exports in order to reduce the inconsistency problems. For some countries the flow of transit trade is known to be sizeable and in these cases efforts should be undertaken to justifiably account for these trade flows. In case a column of transit trade is given it can be split-up into countries of origin of the products using the trade ratios, treating this column alike the use table and final demand categories. Alternatively, it can be assigned to one, or a few, trading partners that are known to cause the transit trade flows.

2) Per country a vector of bilateral trade ratios of trade with 42 trade partners is given. One vector per country indicates whether the country does import the product or not at all {0,1} and is called the import indicator.

3) Used as consistency check and used in the generalized RAS method to regain consistency in the tables concerning the international trade flows.

4) These export ratios are needed to split the export vector from the Use table into a vector of exports to the 42 individual countries included in the database and the rest of the world.

5) The abbreviation (SUT) is used to denote trade values obtained/derived from the Supply-Use framework. The abbreviation (TS) is used to indicate that the values are from the `trade statistics'.

   The vector of imports of each product per country is the sum over all importing industries and final demand categories of the import use table. The import indicator is the vector that shows whether a country imports a product or not at all. If the import vector (SUT) records (zero) trade for a product, the import indicator should also indicate (zero) trade. In case the import vector (SUT) records zero trade and the import indicator does not, or vice versa, the values need to be made consistent.

6) In the first case (import vector SUT one or more zeros, not matched by the import indicator), it can be argued that the import indicator has to be set to zero, including all elements in bilateral vectors that are not equal to zero. This agrees with giving the largest priority to the trade data as recorded in the SUT, as they are the core of the database.

   Alternatively, a small value of trade can be inserted in the SUT. In case information is known about the certain existence of the trade flow an assessment can be made which sector most likely imported the product. If no information is known, the structure of the domestic table can be used to introduce some small amount of trade in a certain product. However, this implies changing the vector of imports, which has repercussions on other values due to the accounting framework.

In the second case (import indicator reports zero trade in a product, while the import vector from the SUT indicates a trade flow), no information is given regarding the origin of the product. The value can be shifted from the import vector (and thus the import use table) into the domestic use table, effectively setting the imports of a certain product to zero. Alternatively, the origin of the trade flow can be assigned based on the origin of products that are alike the product with zero trade, assuming a recording error has been made.

As each of these alternatives are rather invasive, the different possibilities will be discussed at the next meeting of Cluster III in December of 2008 with all partners involved in building the database. The actual extent of this zero problem will only be known after all data is gathered, but the four-country test has already shown that it is most likely to occur on a rather frequent basis. As the trade statistics are loaded into the database as ratios, it is impossible to use information regarding values of trade from the trade statistics in case the import vector from the SUT does not indicate a value.

7) The 42 vectors of import trade ratios are applied per country to the import use table of this country. This results in 42 bilateral import use tables per country.

8) The import use tables for each country are split into 42 bilateral tables representing each country of origin. Now shifting the focus to the country of origin; if all tables that refer to the same country of origin are taken together, the total trade flow should essentially be equal to the exports of this country to its 42 trade partners. The implicit export vector is obtained by summing over all import use tables that refer to the same country of origin.

9) The implicit export vector and the vector with export ratios of the 42 partners aggregated need to consistent. If the implicit export vector indicates (zero) trade in a product, the aggregated export ratio vector should indicate (zero) trade for this product.

10) In case one of the vectors records zero trade for a product, while the other indicates a trade flow, four alternatives exists. These are analogous to the solutions given in 'adjustment I'.

In case the implicit export vector indicates zero trade for a product and the aggregated export ratio vector does not, the first or the latter can be adjusted. Changing the implicit export vector implies changing the bilateral import use tables and requires shifting a value into the row for the product that has no implicit exports. This increase in value has to be deducted at another place in the column as the sum over all products and countries of origin need to stay equal to total imports. However, choosing this solution in order to accommodate the export trade ratios implies that the import trade ratios used to split up the tables were incorrect. Alternatively, the element in the aggregated export trade ratios vector regarding the problematic trade flow can be set to zero. This has no repercussions for the accounting framework.

In case the implicit export vector indicates trade and the aggregated export ratio vector does not, again either one has to be adjusted. Deciding to shift the values in the import use table implies the import trade ratios were incorrect.

Alternatively it can be decided to adjust the export ratio vectors to introduce a very small value for the trade ratio.

11) The export vectors as imported from the Use table (see note 3), show the exports of each country to the world. In order to use this vector as consistency check and constraint for the bilateral use tables, it needs to be split into an export vector of exports to the 42 trading partners and an export vector of trade with the rest of the world. This is done by applying the vectors with trade ratios to obtain vectors with bilateral exports that are then aggregated into one vector per country.

12) This vector will serve to constraint the rows of the large Use matrix.

13) This vector will serve as constraint the columns of the large Use matrix.

14) The block diagonal zero matrices are set to zero as these have the same country of origin and destination (domestic transactions), which are not considered in the trade-linking process.

15) To be able to apply the RAS algorithm, the overall total of the vector to constraint the rows needs to be equal to the overall total of the vector that constraints the columns. In order to accomplish this, the row constraint (the export vector) is rescaled to match the overall total of the column constraint. The total value of the exports (in f.o.b. prices) and the total imports (in c.i.f. prices) should not deviate very much, because the trade and transport margins included in the c.i.f prices are recorded as exports of the sectors involved in delivering these services.

16) The difference between the original export vector (as aggregated over 42 partners) and the rescaled row constraint needs to be retained as a statistical discrepancy vector in order to maintain the accounting identities. This vector is directly stored into database II

17) If no negative values are present in the large Use table, the RAS procedure can be used. This reduces memory usage.

18) RAS is a bi-proportional adjustment algorithm. It was developed for updating input-output tables by Stone (1961). In addition to regaining consistency, the bilateral import Use tables are effectively revalued into f.o.b. prices with the trade and transport margins ascribed to the sectors delivering these services. See also Bouwmeester & Oosterhaven (2008).

19) Generalized RAS can be applied to deal with negative values in the matrix while minimizing the information loss. This entails working with two matrices of the same size, one that copies only the positive values of the large Use matrix, and one that copies only the negative values of the large Use matrix. See Junius & Oosterhaven (2003) for the mathematical generalization and the development of the algorithm of the RAS procedure.

20) The consistent bilateral tables will be stored in database II. In addition to the bilateral tables, also the residual import tables (imports from the rest of the world) are saved in database II.

Export Supply tables

21) Most likely no additional information will be available to make an informed split of the domestic Supply table and the export Supply table. The information contained in the export vector of the Use table will be used to make a purely proportional split.

22) If the export vector from the Use table indicates there is (zero) trade, the export indicator, which consist of ones and zeros to show whether a country exports a product, should also indicate (zero) trade.

23) In case an inconsistency arises regarding the presence of a trade flow either the export supply table needs to be adjusted or the export ratios have to be changed.

24) Per country, the export supply tables are split into bilateral supply tables that indicate the country of destination of the export products.

25) Summing the bilateral export supply tables related to one country of destination over all industries and over countries of origin should equal the imports of this country from the 42 partners. This vector is called the implicit imports vector of the export Supply tables.

26) A zero check needs to be performed on the implicit imports vector and the sum of all import ratios related to the same country.

27) Again, several options exist of adjusting any inconsistent data.

28) Instead of applying RAS to the bilateral export supply tables, the implicit imports vector is used as row constraint for the import use table (for specifics see Bouwmeester & Oosterhaven, 2008). The implicit imports vector relates to imports from the 42 partners, therefore the import use table has to be split into a table that also relates to these 42 partners and a table for imports from the rest of the world.

29) The vector of implicit imports (the row constraint) is rescaled to match the overall total of the import Use table (for the 42 trading partners).

30) The statistical discrepancy vector is retained to maintain the accounting identities of the Supply and Use framework.

31) Instead of performing one (generalized) RAS procedure as for the large Use table, now 43 (generalized) RAS procedures have to be undertaken, one for each country.

5 Concluding remarks

This paper presents the algorithm of obtaining an international make and use table. As the ISUT forms the core of the EXIOPOL database this paper's main goal is to enhance transparency in the construction of the database. Important elements in this exposition concern the assumptions made in this construction process and the decisions that need to be made to adjust data that fails the zero checks. Several information sources are combined to construct full international Supply or Use tables although these full tables do not represent full information. The proportionality assumption is in general needed to complement the limited information available.

The decision has been made that the algorithm should run completely mechanical, possibly requiring some user input that will be pre-defined in, and requested by the program. This limits the flexibility of the choices made as each problem needs to be foreseen and each possible solution needs to be programmed in order for the user to choose. In case the solution method is pre-defined in the program through expert judgment of the EXIOPOL partners, future users will have to adjust the program code in case they will want to apply alternative adjustments.

A test has been undertaken of the algorithm of the import Use tables. The data had to be aggregated to smaller tables, as the detailing of the tables has not been completely carried out. Also the import Use tables were not finalized yet, and export Supply tables will have to be generated within the algorithm as partners will most likely not deliver these tables. Even in these aggregated tables, some zero checks proved to be important as inconsistencies arose regarding trade flows recorded in the trade data of the SUT and the trade ratios. The run the algorithm the choice was made to solve these inconsistencies by setting the trade ratio for the specific product to zero as this adaptation is least invasive. The preferred method to deal with these inconsistencies will be matter of discussion in the next meeting of Cluster III.

In addition, the data transfer format between the databases and the Matlab program code still has to be finalized. A meeting with CML (responsible for the development of the database management system) has been scheduled for the end of November.

This project is ambitious, and this ambition is also reflected by the amount of data that will be incorporated in the databases. Trade-linking of the four tables has not posed computational problems, but scaling the procedure to 43 countries may require alternative procedures and assumptions in order to be able to construct the ISUT.

List of references

Ahmad, N. & A. Wyckoff (2003). Carbon Dioxide Emissions Embodied in International Trade of Goods. DSTI/DOC(2003)15, Organisation for Economic Co-operation and Development (OECD).

Bouwmeester M.C. & J. Oosterhaven (2008), Method for trade linking described. DIII.4.a-2, Deliverable of the EXIOPOL project. See: http://www.feem-project.net/exiopol/userfiles/EXIOPOL_DIII_4_a_2_final(2).pdf

FEEM and TNO (2006) EXIOPOL – Annex I: Description of Work. FEEM, Milan/Venice, Italy. Version of 16.11.2006

Junius, T. & J. Oosterhaven (2003) The Solution of Updating or Regionalizing a Matrix with both Positive and Negative Entries. *Economic Systems Research*, 15(1), 87.

Lenzen, M., L. Pade & J. Munksgaard (2004) CO 2 Multipliers in Multi-region Input-Output Models. *Economic Systems Research*, 16(4), 391-412.

Stone, R. (1961) *Input-output and national accounts*, Organisation for European Economic Co-operation.

Tukker A. & R. Heijungs, eds. (2008), Definition study for the EE IO database, DIII.1.a-5, Deliverable of the EXIOPOL project. See: http://www.feem-project.net/exiopol/userfiles/EXIOPOL_DIII_1_a_5_final(1).pdf

Turner, K., M. Lenzen, T. Wiedmann, J. Barrett (2007) Examining the global environmental impact of regional consumption activities -- Part 1: A technical note on combining input-output and ecological footprint analysis. *Ecological Economics*, 62(1), 37-44.