

EXIOPOL: towards a global Environmentally Extended Input-Output Table

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Abstract

This paper seeks to present the strategy of an EU –funded Integrated Project of various million Euros: EXIOPOL (“A New Environmental Accounting Framework Using Externality Data and Input-Output Tools for Policy Analysis”). This particularly with regard to its part on environmentally extended input output analysis. The project consists of 37 institutes, is lead by FEEM and TNO, and will run between 2006 and 2010. The project has three principal objectives:

- (a) synthesise and develop further **estimates of the external costs of key environmental impacts** for Europe;
- (b) set up an **environmentally extended (EE) Input-Output (I-O) framework** for the EU-25 in a global context which as many of these estimates as possible are included, allowing the **estimation of environmental impacts (expressed as LCA themes, material requirement indicators, ecological footprints and external costs) of different economic sector activities, final consumption activities and resource consumption** for countries in the EU;
- (c) apply the results of the external cost estimates and EE I-O analysis for the **analysis of policy questions** of importance, as well as for the **evaluation of the value and impact of past research on external costs on policy-making in the EU**.

Keywords: environmentally extended input-output analysis, EE I-O, ecological footprint, life cycle impact assessment, total material requirement, supply and use tables

1 Introduction: the goals of EXIOPOL

The Integrated Project (IP) EXIOPOL (A New Environmental Accounting Framework Using Externality Data and Input-Output Tools for Policy Analysis) has been set up by FEEM and TNO

¹ Note: this paper is part based on EXIOPOL’s report of the Scoping phase, written by a broad set of participants in EXIOPOL.

(being co-ordinator and scientific director) under the EU's 6th Framework Program. It has a budget of 5 Mio Euro and runs between December 2006 and 2010, with the following goals:

- (a) to synthesise and develop further estimates of the external costs of key environmental impacts for Europe;
- (b) to set up an environmentally extended (EE) Input-Output (I-O) framework with environmental extensions in which as many of these estimates as possible are included, allowing the estimation of environmental impacts and external costs of different economic sector activities, final consumption activities and resource consumption for countries in the EU;
- (c) to apply the results of the external cost estimates and EE I-O analysis for the analysis of policy questions of importance, as well as for the evaluation of the value and impact of past research on external costs on policy-making in the EU.

Where the concepts of external costs calculation and EE I-O are well known, a comprehensive review of external cost methodologies still lacks, and a comprehensive EE I-O database for the EU27 is absent. The IP creates hence a new, operational toolbox supportive to a great variety of EU policy fields, such as Integrated Product Policy, the Strategy on Natural Resources, the Environmental Technologies Action Plan, Sustainable Consumption and Production, the relation between sustainability and the Lisbon strategy, and impact assessment of related policies in general. Table 1.1 reviews the participants in the project. The EE I-O work in project also forces scientists that worked on rather separate fields such as IO analysis (IOA) Material Flow Analysis (MFA) and Life cycle assessment of products (LCA), to organise their approaches and data in a unified framework. Where in theory such unified frameworks have been developed (e.g. SEEA, UN et al, 2003), EXIOPOL is probably one of the first projects that integrates data on such a broad scale. In this paper we want to discuss the architecture of the project, and the results of EXIOPOL's scoping phase, that brought to the fore a number of inconsistencies in brings together This paper discusses the architecture of the proposed database, and our experiences and proposed solutions for problems related to integrating data and indicators systems that have been set up using different conventions (FEEM&TNO, 2006; Tukker et al., 2007)).

Table 1.1: Participants in the IP EXIOPOL (status: August 2006. Partners primarily involved in EE I-O marked with *)²

Participant Number	Participant name	Participant short name	Country
1	Fondazione Eni Enrico Mattei	FEEM	IT
2	The Netherlands Organisation For Applied Scientific Research*	TNO	NL
3	University of Bath	UBATH	UK
4	Leiden University, Institute of Environmental Sciences*	UL-CML	NL
5	Joint Research Centre, Institute for Prospective Technological Studies*	JRC-IPTS	ES
6	Wuppertal Institute for Climate, Environment and Energy*	WI	DE
7	National Environmental Research Institute	NERI	DK
8	Forest Technology Centre of Catalonia	CTFC	ES
9	Univerzita Karlova v Praze, Charles University Environment Center	CUEC	CZ
10	Queen's University Belfast	QUB	UK
11	Universitaet Stuttgart, Institute of Energy Economics and the Rational Use of Energy	USTUTT-IER	DE
12	Norwegian University of Science and Technology (including RPI)*	NTNU	NO
13	Nachhaltigkeitsforschungs und -Kommunikations Gmbh*	SERI	AT
14	University of Parma	UNIPR	IT
15	Ecologic Institut für Internationale und Europäische Umweltpolitik	ECOLOGIC	DE
16	University College of London	UCL	UK
17	Association pour la Recherche et le Développement des Méthodes et Processus Industriel, Ecole Nationale Supérieure de Mines	ARMINES	FR
18	Institute of Occupational Medicine	IOM	UK
19	Sweco Grøner As	SWECO	NO
20	Wageningen University	WU	NL
21	Finnish Environment Institute	SYKE	FI
22	Vrije Universiteit Amsterdam, Institute For Environmental Studies	VUA-IVM	NL
23	Chinese Academy of Social Sciences	CASS	CHN
24	European Forest Institute	EFI	FI
25	University of Padova	UNIPD	IT
27	University of Delhi, Institute of Economic Growth	UDELHI-IEG	IN
28	Institute for European Environmental Policy	IEEP	UK
29	Norwegian Institute for Water Research	NIVA	NO
30	Centre for European Economic Research	ZEW	DE
31	Warsaw University, Warsaw Ecological Economics Center	UW-WEEC	PL
32	Clean Air Action Group	CAAG	HU
33	Gesellschaft fuer Wirtschaftliche Strukturforschung	GWS	DE
34	Société pour la Promotion Internationale des Industries Aromatiques	IAP-SENTIC	FR
35	Swedish University of Agricultural Sciences	SLU	SE
36	Flemish Institute for Technological Research	VITO	BE
37	Rijksuniversiteit Groningen*	RUG	NL

² The project is being expanded with various national statistical bureaus. Furthermore, an advisory board is set up with other relevant actors, most notably EEA, EUROSTAT, and other bodies like OECD and the World Bank

2 Relevance of EE I-O and external costs in policy impact assessment

The core goal of EXIOPOL is to support cost-effectiveness and cost-benefit analysis of technologies, policies, and standard setting, at the micro, macro and meso level. This requires the coverage of a broad range of impacts and assessment of external costs (FEEM and TNO, 2006). To see the IP in this context we present the toolbox that currently is in use or ideally should be used for such assessments, and indicate the main gaps in it. This then gives the rationale on which areas our project has to focus. For this purpose, we refer to the matrix in Table 2.1. Cost-benefit analysis and cost-effectiveness analysis require insights in the following factors:

- a) Calculation of the (net) costs that implementation of a technology, standard or policy will imply.
- b) Calculation of the reduction of environmental impacts related to this implementation. The quotient of impact reduction and net costs indicates the cost-effectiveness of the measure.
- c) Calculation of the (reduction of) external costs by reduction of impacts related to this measure. Such a reduction of external costs, and (net) investment that a measure requires, allow assessing the true societal costs and benefits.

Sustainability measures can be taken at a micro (e.g. company), meso (e.g. sector) and macro (e.g. country or multi-country) level. And conversely, measures taken at one of these levels can have contrary ‘ripple effects’ or spillovers at another level. The toolbox needs to be adequately filled for each level, but maybe even more importantly, must be able to create linkages between these levels. The table shows that the main gaps in the toolbox cluster around two issues:

- a) The (market) costs and direct (market) benefits of proposed sustainability policies, technologies and standards usually can be calculated rather straightforwardly. This is not true, however, for the indirect, non-market costs or externalities. That there are still important gaps in the assessments of external costs, which need to be filled.
- b) Implications of measures at meso- and macro level, but also the ‘ripple effect’ of measures taken at micro level, can only be assessed properly when making use of a framework that covers all relations in the economic system including environmental effects, which only can be provided by environmentally extended input-output tables (EE I-O tables). Such inter-country tables are currently simply non-existent for the EU27.

Table 2.1: Tools needed for analysis of cost-effectiveness and costs/benefit assessment of sustainability options at micro, meso and macro level

Level	Example	Tools for direct cost assessment	Tools for impact assessment	Tools for benefit assessment ³	Gaps in toolbox filled in this project
Micro	Company level (e.g. technology choice), household level (e.g. consumption decisions)	Life cycle costing	Life cycle assessment, site specific tools like EIA or RA	External costs, local	- <i>Externalities</i>: for many pressures and endpoints external costs are still lacking, there is a variety of conceptual questions still to be solved, and cost data for ready use in meso- and macro accounting frameworks are not available. - <i>IO and EE I-O</i>: comprehensive, detailed, uniform and open-source IOTs with environmental extensions for the EU25, and with suitable trade links with the RoW are absent. Such a comprehensive EE I-O database can also support LCA and LCC calculations by providing the system context which allows the estimation of impacts of truncated processes entailed by LCA approaches⁴.
Meso	Sector or product group level (e.g. sector standard, tax, or ban)	IO, in combination with scenario tools (e.g. CGE)	EE I-O, in combination with scenario tools (e.g. CGE)	External costs, sectoral average	
Macro	Societal level (as per sector level)	IO, in combination with scenario tools (e.g. CGE)	EE I-O, in combination with scenario tools (e.g. CGE)	External costs, country average	

Note: EIA: Environmental Impact Analysis. LCA: Life Cycle Assessment. LCC: Life Cycle Costing. IOTs: Input-Output Tables. RA: Risk assessment

³ Note: we assume here that direct benefits can be included easily in direct (net) costs assessments, so that in here we in fact we have to focus on benefits in terms of the reduction of external costs.

⁴ As well known from literature, LCAs try to follow the full supply chain to the final functionality delivered, but due to the networked character of any economy at some point seemingly unimportant supply chains are 'cut off' and neglected in further analysis (e.g. Guinée, 2002). It has been shown that the cumulative effects of such cut offs can be up to 50% of the total impact of a product (Lenzen, 2000).

It is particularly the integration and linkage of the (EE) I-O Table with external costs data and other mainstream environmental indicators that provides additional power to the toolbox. EXIOPOL envisages inventorying those environmental extensions, needed to calculate external costs, Total Material Requirement, the Ecological Footprint and the Life cycle Impact Assessment themes for Global Warming, Acidification, Eutrophication, and Photochemical Oxidant formation. All these indicators play an important role in sustainability policy. The great advantage of linking such indicators to a Multi-regional I-O framework is that it allows calculating spillovers between sectors, countries, etc. (i.e. how a change in activity level in one sector or country may induce changes in activity levels in other sectors, and hence related emissions, external costs, etc.).

3 The EE I-O data situation today in the EU27

3.1 Introduction

Input-Output Tables (IOT) are a component of the System of National Accounts (SNA; United Nations 1993) and European System of Accounts (ESA95; European Communities 1996). These sources now generally recommend to produce Supply and Use Tables (SUT) as a first step in constructing IOTs.

In brief, the supply table shows the supply of goods and services by product and industry, distinguishing between domestic industries and imports (hence it is a product-by-industry table). The use table shows the use of goods, services and value-added by product and by type of use, such as, intermediate consumption (industry) and final consumption (hence it is a product-by-industry table). An IOT gives a detailed description of the domestic production processes and transactions within an economy. The IOT is constructed by merging the supply table and the use table into one single table and is expressed as either a product-by-product or industry-by-industry table. The central part of an IOT is thus square (it contains the same number of rows and columns) and symmetric (the items indicated by the rows and columns are the same: both are products or both are industries). The abbreviation SIOT is sometimes used to refer to a square and/or symmetric IOT. The merging of the SUT into a single table requires assumptions – hence loss of information – but the IOT is the standard framework for a detailed structural analysis of economic activity (input-output analysis, IOA). The SUT itself requires no (or fewer) assumptions, therefore it is the preferred accounting framework for SNA and ESA95. We will not discuss in detail the well-known approaches for transforming SUT into SIOT here; reference is

made to the standard literature on this matter (e.g. Miller and Blair, 1985; Ten Raa, 2005), and others (e.g. Rueda Cantouche et al., 2007)⁵.

3.2 Available data

ESA95 requires EU member states to transmit in a standardized format SUT (annually) and IOT (five yearly). On a voluntary basis, individual member states report National Account Matrices including Environmental Accounts (NAMEAs) with some 10-15 emissions to air (Eurostat, 2005). The big advantage of this material is that it is available in a harmonized sector and product classification. Sixty industry sectors and related product groups are discerned, corresponding with the NACE 1.1. and CPA 1.1 level 3.. Yet, for a variety of reasons this material cannot directly be used for environmental-economic assessments. First, the ESA95 SUT and IOT are for individual countries only and not linked via trade. Second, various studies including EIPRO (Tukker et al., 2006a, Weidema et al., 2005) showed that a much higher resolution of at least 100-150 sectors or more is essential for allocating sustainability impacts in a meaningful way to sectors, products, and final consumption activities. Third, the environmental interventions gathered via NAMEAs are just enough to analyse impacts related to global warming and maybe Acidification, but are insufficient to calculate other important sustainability indicators (e.g. external costs, Total Material Requirement, or the Ecological Footprint).

For other countries in the world, (sometimes detailed) SUT or IOT are available covering a significant part of the global economy (e.g. the US, Japan). Yet, since most National Statistical Institutes (NSIs) make own choices about sector/product detail and – classification, there is a lack of harmonization. The OECD has taken the initiative to produce a harmonized set of industry by industry IOTs. Their third edition, published in 2006, discerns 48 sectors and 39 countries responsible for over 90% of the Global GDP (Yamano and Ahmad, 2006). The Global Trade Analysis Project (GTAP) produces a multi-regional I-O table for the world economy that discerns

⁵ In brief, with usually Supply tables in basic and Use tables in purchaser prices, a set of valuation matrices has to be available or constructed to express the Use table in basic prices. Similarly, an import matrix needs to be available or constructed to separate use of domestic production and imports. Once the supply- and use table are in basic prices, one has to decide if a product by product or industry by industry IOT best serves the analytical questions posed. To transform SUT into IOT assumptions about by-products in the Supply table have to be made; the two most usual are the so-called Industry technology and the Product technology assumption.

a fair amount of sectors (about 60) and regions (about 90), and links such data also to energy use. Environmental extensions lack however (Dimaranan, 2006)..

3.3 Limitations in existing data and ambition of EXIOPOL

In sum, we see important limitations in existing data sources. Most provide SUT and IOT for single countries, without trade links. Sector and product detail is not as detailed as desirable. Usually environmental extensions lack⁶. Data across different countries is not or only partially harmonized and/or not compiled on a same, consistent basis. All this makes it difficult to solve basic questions about the sustainability performance of a specific country, let alone the world as a whole. With the advent of globalisation and quickly changing trade patterns, environmental-economic accounting systems at national level are becoming rapidly obsolete. With production of products rapidly shifting from the West to Asia, it is essential to be able to calculate ‘embodied pollution in imports’ to assess if a Western country indeed reduces greenhouse gas emissions, enhances its resource efficiency, etc. – other than due to outsourcing dirty industries abroad (cf. Peters and Hertwich., 2006; Nijdam and Wilting, 2003). Trade linked tables are also essential to analyse the effects of sustainability measures taken in Europe on Europe’s economic competitiveness.

The EE I-O work in EXIOPOL, roughly half the size of the full project, seeks to solve this problem. It is an explicit goal of the project that the database should not stay in ownership of the developers, but is handed over for structural maintenance and use to one of the relevant Commission’s services (DG JRC IPTS, the European Environment Agency, and EUROSTAT). The project aims hence at filling an essential gap in the current toolbox of environmental (and economic) accounting at the Commission’s services. This need has been recently emphasised by the Renewed Strategy for Sustainable Development adopted by the Council in June 2006. The project’s aim is really to leapfrog: it would give the EU a full-fledged, detailed, transparent, public, official global EE I-O database with externalities, allowing for numerous types of analyses for policy support (e.g. problem analysis, monitoring of e.g. causes of decoupling of impact from environmental growth and (if time series are available), and scenario development (when the EE I-O table is linked to dynamic models)).

⁶ Individual research groups sometimes combine I-O data with environmental data sources, such as in the US (cf. Suh, 2004). Japan has developed with a number of other countries bilateral I-O tables that include trade (Inomata et al., 2006).

4 The approach chosen in the project to improve the EE I-O data situation

4.1 Introduction

In sum, the EE I-O work in EXIOPOL has as main goal to develop an operational and detailed input-output table with environmental extensions for the 27 EU countries, plus a set of important non EU countries, linked via trade. The EE I-O table will be organised in such a way that it can:

- support analyses at micro-level, such as cost-benefit analysis (CBA) and LCA, via so-called hybrid LCA or EE I-O-LCA⁷; thus both improving this micro analysis and linking it to the meso and macro level
- support scenario-analysis for analysis of impacts of sustainability options at meso- and macro level. These can be done in a variety of ways. One option is to ‘force’ exogenously a technology-, emission- or demand scenario on the EE I-O table. Another option is to endogenize economic developments. For this purpose, the EE I-O table developed will be linked to existing CGE models in use with the EU and macroeconomic models. Furthermore, an alternative model (the World Trade Model; Duchin, 2005) will be expanded in this project to create a third approach to scenario analysis⁸.

Our EE I-O table covers emissions and resource uses per sector per country covered (e.g. per individual EU27 member state). Meso- and macro tools like EE I-O tables usually do not have further geographical specification⁹.

⁷ As shown by e.g. Lenzen (2000) the truncation in the process LCA approach may lead to the situation that several dozen percent of the life cycle impact of a product is neglected. Estimation of economy-wide environmental impacts of such truncated flows with EE I-O can improve LCA results tremendously. See also Heijungs and Suh (2002)

⁸ Most CGE models tend to be best suited to forecast rather ‘smooth’, incremental changes of the economic structure endogenizing a number of economic relations in the model, but are less apt to deal with scenarios involving radical, fundamental changes in the underlying economic structure. The WTM allows for imposing exogenously rather radical policy scenarios, while calculating the optimal use of factors/resources globally at a given final demand. This makes the WTM an interesting tool for analysing ‘what-if’ scenarios that aim to realise radical changes to sustainability.

⁹ In the sense that very specific locations can be taken into account in emission-effect modelling. There are of course regionalised IO tables at sub-national level in use, but beside the fact that we do not develop

4.2 Overall approach and strategic choices made

Developing the indicated EE I-O table is an ambitious task. There are four major issues at stake that need attention (see Figure 4.1 for the relation between WPs)

- First, for the countries included in the table individual IO tables have to be gathered, uniformed, and for the EU27 countries enhanced in sector detail.
- Second, for the countries included in the table various dozens of environmental extensions per sector have to be gathered.
- Third, the country tables have to be linked via trade data. This is far from trivial and actually one of the crucial issues to be solved in Cluster III¹⁰.
- Fourth, all data have to be embedded in a user-friendly general purpose database system, that can support e.g. LCA, direct scenario analysis, CGE models, etc.

In doing this work, the following strategic choices have been made:

1. To stay as close as possible to officially collected statistics. This implies e.g. using for the EU27 the ESA95 Supply and Use Tables and IOTs.
2. To use open sources only, and produce a database for the public domain
3. To give priority on building the database, since that is the unique added value of our project, rather than to give priority to model building¹¹;

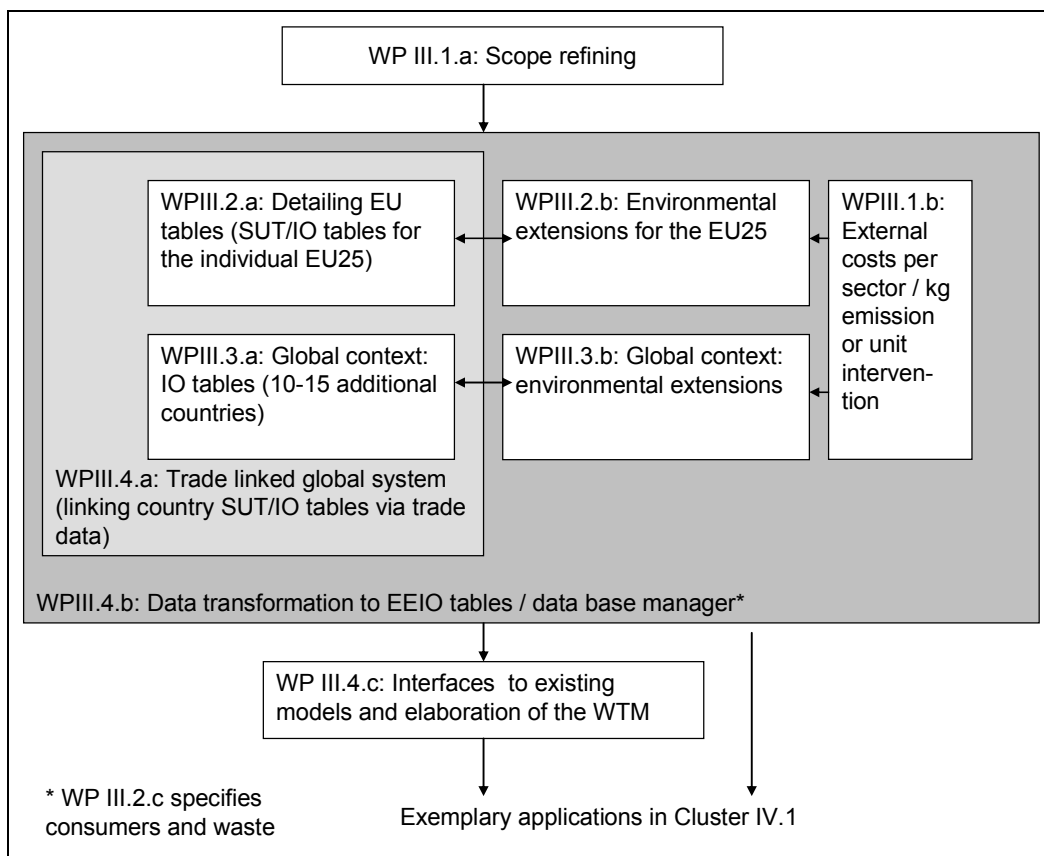
these, they are still not sufficiently detailed to allow for local effect modelling nor local externality calculations. For instance, where in the FP6 project TransTools input-output tables from GTAP are regionalized on NUTS-2 level for a CGE analysis (leading to a spatial CGE model called CGEurope), this for instance still is insufficient to do precise externality calculations for the impacts of, say, transport within cities.

¹⁰ Trade databases like COMTRADE (UN) and STAN (OECD) usually only give bilateral trade data for countries, but do not specify the sectors of import and export. Furthermore, there is a host of trivial and less trivial reasons why total import data and total export data that in theory should be identical, do not match. See for instance the thesis of van der Linden (1999), guided by Oosterhaven of RUG, for solutions of these problems.

¹¹ Particularly developing another CGE model would have much less added value, given the many already available. Our strategy is to ensure the database can be easily used in combination with existing models, particularly CEPAM-GEM-E3 as in use at IPTS, probably GINFORS (Meyer et al., 2007), etc.

4. To concentrate work in relatively large WPs and on a limited number of 9-10 partners, in order to maximize coherence and minimize communication problems¹².

Figure 4.1: Relations between main Work Packages in the EE I-O part of EXIOPOL



4.3 Gathering and detailing economic data

4.3.1 Main approach and basic architecture

The first two principles mentioned in section 4.2 imply that at this stage, the intention of the project is to build a Multi-regional EE I-O table, centred around EU27, from officially reported data. This strategy excludes using existing secondary databases¹³.

¹² As essential issue, since all data finally have to be structured into a similar format, which implies that a high degree of co-ordination of work in the different WPs is essential.

¹³ Such as GTAP and OECD data (see section 3). In the MOSUS project that used the GINFORS model OECD data were trade-linked, but at a rather low level of detail (25 product groups). The project may use these sources as fall-back positions, but only when and where primary data lack.

As follows from section 3.1, a Multi-regional EE IOT can be constructed via different routes. Most existing examples use directly country IOTs and link them via trade. An alternative is to use country SUT, link the extensions to the SUT, and produce country IOTs from there. The final approach is to use country SUT, link these to extensions, and produce from there via trade links a Multi-regional SUT. This ‘Multi Regional EE SUT’ can then be transformed into different Multi-Regional EE IOT (product by product, industry by industry, different technology assumptions).

We chose for the last route since this one provides most flexibility and needs least theoretical assumptions¹⁴. Most extensions (emissions and resource uses) need to be linked to economic data via an industry perspective: it is industries that emit. But trade links and analyses related to final demand need a product perspective. IOTs are either in products or industries, and never can deal with both requirements. SUT can, since they have product and industry dimension. Further, as indicated, from the same MR EE SUT a variety of MR EE IOT can be derived, suiting different modelling and other needs.

While it is now generally accepted that producing SUT should be the first step in building an input-output framework, in terms of data gathering this choice comes at a price. For a complete framework, for each country in the database in principle the following economic data is needed (e.g. Rueda Cantouche et al, 2007):

- supply and use table (the former usually in basic, the latter in producer prices)
- import matrix
- valuation matrices (retail, wholesale, transport, taxes and subsidies on products)

Where in the project we may be forced to use estimates due to time constraints, the added value is that a fundamentally right structure is applied in the design of the database that can be filled with better data over time or for later years.

4.3.2 Countries covered

The database will cover the EU27 and 16 non EU countries. The latter are the US, Japan, China, Canada, South Korea, Brazil, India, Mexico, Russia, Australia, Switzerland, Turkey, Taiwan, Norway, Indonesia and South Africa. These countries were selected since they cover over 90% of the global GDP and 80-90% of the trade volume by value with Europe. Our selection misses

14

many countries that are of key importance in supply of resources like oil, gas, and others. In the ‘true’ Rest of the World, we will include the most important resource extraction processes or impact-intensive sectors. Via trade data and resource production statistics the volume in such sectors can probably easily estimated. This approach ensures that the database will give a comprehensive overview of industries and products that are responsible for the total global environmental impacts and resource uses¹⁵.

For the EU27, the ESA95 tables sourced from Eurostat will be used as a basis. From other countries, primary tables as published by NSIs will be used.

4.3.3 Sector and product classification

The nomenclatures used for organising quantitative economic data are available in many variants and often different between applications and regions. We chose to use NACE rev 1.1 nomenclature and the adjoining revised ISIC nomenclature for the industry sector classification since most available SUT and IOT use this as a basis¹⁶. Product classifications, come from three domains: IO related (CPC, CPA); trade related (HS, CN) and function related (COICOP; COFOG; COPNI and COPP), all at several levels of resolution and usually with slight adaptations for specific applications. EXIOPOL will use CPA 1.1, for the very simple reason that this corresponds to NACE 1.1. and is used in most available SUT and IOT. Transformation tables relating all source classifications to the standard classes form the first main element in the data transformation structure.

Studies like EIPRO (Tukker et al., 2006a) have shown that a high level of sector detail is essential for obtaining a proper insight in how environmental pressures and interventions relate to economic activities or clusters of economic activities. This detail is particularly relevant for sectors with a high impact, or sectors related to final consumption activities with a high life cycle impact. At the same time, open sources that structure SUT and IOT data in a similar format for a number of countries (most notably the ESA95 supply and use tables for the EU27 member states) typically reach a level of detail of 60 sectors. A supplement to this paper provides the envisaged

¹⁵ This approach was inspired by the GINFORS model, that included the oil-dominated OPEC countries by just counting oil and gas production.

¹⁶ We considered using the upcoming NACE rev. 2.0, but all existing data are still in NACE 1.1 and it appeared that there is no simple transformation between the classifications possible.

sector and product classification. It basically took the 60 sectors and products at NACE 1.1. /CPA level 1.1, as a starting point, adding detail in sectors where previous studies showed high environmental impacts and in which overall sector the impacts differed significantly in type and magnitude per sub sector (Tukker et al, 2006a; Weidema et al, 2005; Hertwich, 2005). This lead to the following additional detail above that currently reached in ESA95:

- a) agriculture and food production (+20 sectors/products),
- b) energy extraction and production (+ 10 sectors/products)
- c) resource extraction and processing (+10 sectors/products),
- d) various others (transport, waste management, recycling: +5 sectors).

In total the EXIOPOL will discern about 110 sectors and products¹⁷. Detail will be realised by developing technology transfer assumptions making use of one or more of the following data sets: detailed sector data from SUT/IO tables from EU member states, using detailed sector statistics from e.g. the IEA and FAO, and others. Risks will be managed by testing the envisaged procedure on a set of 2 EU countries and 2 non EU countries first. .

4.3.4 Other dimensions: elements of value added, and elements in final demand

The database will further include the traditional elements of value added, and elements in final demand. For final demand, a differentiation will be made in consumer expenditure, government expenditure, gross fixed capital formation, and changes in inventories. EXIOPOL will use a slightly more specified division of value added elements, given demands of the World Trade Model that we intend to use in the project:

- 1) Compensation of employees: wages and salaries + employers' social contributions
- 2) Net taxes on production (production taxes paid by industry excluding non-deductible VAT and those ad valorem taxes used to derive the total supply of products in the supply matrix at basic prices; MINUS production subsidies received by industry excluding those ad valorem subsidies used to derive the supply matrix at basic prices).

¹⁷ In most cases the classification is based on a lower level of NACE/CPA 1.1. In some cases this was not possible, since the sector or product was not listed even at the most detailed level. Here, an own classification was developed. For agriculture and food production, for pragmatic reasons the GTAP classification was used to be able to link our database easily to the many GTAP based models.

3) Gross operating profit, divided into

- 3a) Consumption of fixed capital: amount of fixed assets used up during a certain year (excluding any rents on land)
- 3b) Rents on land
- 3c) Royalties on resources: 'profit transferred to the owner of the resource extracted' (inventoried for oil, gas, coal, iron, aluminium and copper)
- 3d) Remaining Net operating profit

For labor, physical data will be included for labor supply (persons), labor demand (in persons, hours, and fte), specified in low, medium and highly skilled, plus corresponding hourly wages.

4.4 Gathering environmental extensions from the EU25 and other relevant countries

The environmental extensions include the use of primary resources (including land) and emissions. As is well known from Life cycle assessment of products, there can be hundreds of such interventions and listing or analysing these is usually not a suitable input for policy making processes. Usually, more aggregated indicators (so-called impact categories) for environmental pressure are used. The project aims to inventory at least those emissions and resource uses that allow expressing environmental pressures in the following, widely used, impact categories:

- various environmental themes usually applied in Life Cycle Impact Assessment, most notably GWP, ODP, POCP, acidification, eutrophication, and where possible ecotoxicity and human toxicity (methodology available, see e.g. Guinée et al., 2002, and the explanation below)
- Total Material Requirement (methodology available, see Eurostat, 2001)
- Ecological footprint (methodology available, see Wackernagel et al., 2005)
- External costs (part available, part developed in Cluster II; to be transformed for use with EE I-O in a specific WP)¹⁸.

¹⁸ In principle, external costs can be expressed per kg emission of a substance, in relation to the full set of end-points that is affected by this substance. Hence, with the emissions in an EEIO table known, calculating full external costs would be a matter of multiplying total emissions with such unit external costs

A supplement to this paper lists the primary resource uses and emissions that we envisage to include in the database. Resources will be sourced from the (voluntary) NAMEAs on material use of Wuppertal Institute and partners for EUROSTAT, the resource use/material flow database of SERI developed in the MOSUS project¹⁹. The main challenge here is allocating resources to the right sector of primary use. For gathering emission data, two approaches were considered: using international emission inventory databases, or calculating emissions using emission factors and activity variables (for energy related emissions, often the energy database of the IEA is used). The first approach would e.g. rely on data supplied to the IPCC or LTRAP, but an important drawback is that many important countries (e.g. China, India), are not part of the related conventions and hence do not report. Further, reported emission values quite often in fact have been calculated using the 2nd approach, but it could have been that slightly different assumptions have been used. EXIOPOL will hence use the 2nd approach, applying TNO's TEAM model, ensuring that for all countries emissions will be estimated in a similar and consistent way (Pulles et al., 2007).

4.5 Linking SUT via trade

One WP has the central objective to link the SUT for EU countries and the tables of other countries/world regions developed in the other WPs via trade. This work is demanding in terms of data needs and will have to encounter a variety of practical problems, such as:

- Differences in classification systems of trade data and the SUT/IOT data at country level
- The origin of the sector from which is imported and the destination of the sector to which is exported is usually not registered in trade databases.
- At global level total imports and exports per commodity (in theory identical) usually do not match, a.o. since exports and imports are expressed in different price types

per kg emission. But as some additional complications have to be solved due to the top-down/rather time- and location independent character of EEIO and the bottom-up/location specific approach used until now in the calculation of externalities. The Life Cycle Impact Assessment (LCIA) methodology has also struggled with the question to what extent LCIA could be made more location specific, and the final solution may be to use impact categories like Disability Adjusted Life Years Lost (DALYs – Human health) or Potentially Disappeared Fractions (PDFs – Ecosystem health/biodiversity) calculated with LCIA, in combination with external costs per DALY or unit PDF (e.g. Guinée et al., 2002).

¹⁹ <http://www.materialflows.net/>, accessed 20 October 2007

Groningen University has developed a non-survey method to link IOT via trade (Oosterhaven et al., 2007). That approach is used as inspiration in our project to trade link SUT. For SUT such a methodology is not yet available, and hence has to be worked out in EXIOPOL. The first step is to disaggregate the national import use tables into bilateral import use tables that specify the country of origin. This will be done by applying import ratios obtained from an international trade database, most probably the UN's COMTRADE. The national import tables specify country of destination, the product that is imported, and the industry that uses the product as input. The trade data contain information on which product is traded and the country of origin and destination, but do not specify the buying industry. Combining these two sources of trade data will result (under some assumptions) in the four-dimensional data required for the construction of an intercountry table. It specifies both country of origin and destination, the product that is traded, and the buying industry. Finally, the resulting intercountry use table will have to be subjected to a so-called GRAS procedure in order to reach consistency of the international product flows and the supply tables (cf. Junius and Oosterhaven, 2003). A variety of options is available in applying GRAS; for instance, the explicit choice can be to retain the import and export data that are given in the national SUTs. Such choices will be settled in a later stage in the project.

4.6 Linking SUT and IOT to models

Ultimate use of the newly constructed tables is in modelling for policy support and more general decision support, often linking to models with broader behavioural mechanisms like CEPAM-GEM-E3, NEMESIS and the World Trade Model. The interfaces to these models will be constructed in a most open way for such further applications. Special attention will be paid to dynamic aspects. Within the project a set of data will be constructed for one year only. However, in due time, after the project, time series can be constructed and in a shorter time frame these may be based on partial time series as in NAMEAs. Also, in a smaller part of the project dealing with policy applications, some exemplary scenarios will be constructed to deal with dynamic changes in technologies, consumption, and trade. So the interface to broader modelling, the last workpackage in EE I-O cluster (see figure 4.1), will reckon with three levels of dynamics, each with their own requirements: as time series, in scenarios, and as endogenized technological change.

5 Reflection: combining routines and conventions from various science fields in one database

EXIOPOL is in many ways an interesting exercise, since it aims to combine data from a great variety of sources, and gathered by science groups that apply quite different routines and conventions in one, single database. The full consequences of this endeavour of course still have to become clear in the project, but some interesting findings can already be reported.

First, the project inventories various economic data from different sources that in principle should be consistent, but in are not so in practice. In some cases this has trivial backgrounds, such as trade data that are inventoried by different organisations via different estimation procedures. Yet, we also found that where official SUT and IOT for the same country should be mathematically related, in practice they are not always. What apparently happens is that first SUT is produced, and from this an IOT is constructed, but that in this step additional balancing and adjustment is necessary and that this additional insight is not used to re-adjust the SUT. This implies in practice that EXIOPOL never can be fully consistent with NSI data, since sometimes different sets of NSI data apparently are not fully consistent in themselves. Similar inconsistencies, but then between data from different NSIs, are likely to be found in the trade link procedure. EXIOPOL will cover 43 countries responsible for over 90% of global GNP. However, where individual SUT (or IOT) will be balanced, it is likely that the total imports will not match total exports (even if adjusted for pricing differences)²⁰. Where in theory the Rest of World could explain such differences, it is most likely that there is a real mismatch. Here, we may have to face the choice of keeping the original SUT untouched, or to adjust them in the GRAS procedure, thereby again producing an end result where our SUT and IOT will not correspond with those of NSIs – since we will be able to provide a consistency at a level that is impossible to realise for individual countries.

Second, several data will be inventoried in physical and economic terms. Examples are energy flows in the economic system that will be used to calculate a broad spectrum of energy-related emissions. In principle, such energy data will have to be stored as an additional layer in the SUT, using the same product and sector classification. Producing such correspondence is however not

²⁰ Such pricing differences occur e.g. since countries that export report ‘free on board’ prices, where countries that import see and report when imports reach them ‘cost, insurance, freight’ prices, i.e. costs including transport and insurance margining.

always easy. Further, in principle such physical flows should relate to the monetary flows via a price matrix. It is likely, however, that we will see again inconsistencies between such inter-industry values in economic terms and physical terms, for the trivial reason that data were gathered and processed by different institutions

Third, probably the most important issues we see that various conventions used by the different science groups in our project in practice cause conflict when one wants to construct a coherent, clearly defined database. We give two examples.

- EE IO makes a clear distinction between economy and environment. Everything that is produced in the economy forms a (monetary) flow value in the SUT or IOT; everything extracted from nature (primary resources) or discarded into nature (emissions) is an extension. In material flow analysis (MFA) one tries to analyse the total primary material use in society. Where in SUT or IOT biotic materials like crops, fodder etc. are produced in the economy, in MFA the mass of such biotic products is counted as a proxy for primary extracted materials – it simply would be too difficult to measure the amount of CO₂, water, and nutrients that are taken up by plants as the ‘true’ primary material use. The project will place the physical data on crops, fodder and the like in the same structure as the economic data in the SUT, but this decision is hardly acceptable for the MFA specialist in the project, who use such data to construct an environmental indicator and hence see such data as extensions..
- SUT and IOT also contain a review of value added components per industry: compensation for labor, compensation for capital, taxes less subsidies, and net operating profit. Yet, again, there are sometimes environmental extensions that are directly related to these value added components. Certain emissions (in the list of extensions) are taxed. Land use occupation (in the list of extension) usually comes with rents on land (in value added). Primary resources extracted (notably oil and gas; listed as extensions) are levied by the owner of a resources via a profit share, a (usually very high) tax on production, or royalties, which are all components of value added. Here, there is probably no option but to draw certain extensions into the value added block, and to include both physical as monetary values.

In sum, EXIOPOL organises data from very different sources in a similarly structured way. A logical next step, not part of the project itself, would be to do a consistency analysis across these different sources, and develop routines that adjust economic data, physical inter-industry flows,

and extensions in such a way that they become mutually consistent. It is obvious that the database will form a rich source for further analysis and improvements.

6 Discussion and conclusion: key choices for discussion

The EE I-O database we envisage to develop will be an extremely powerful support for a great variety of EU environmental and general economic policies. It will allow for analysis, monitoring and improvement assessment of issues such as the total environmental impacts and external costs per industry sector, per final consumption activity, per final product group, related to imports to and exports from the EU25 and per resource used (e.g. Femia and Moll, 2005; Tukker et al., 2006b; Tukker et al, 2005; de Haan, 2004; Suh, 2006; Giljum et al, 2006). By splitting up the total consumption into consumption patterns of different target groups, analysis of the life cycle impacts and external costs per target group, life style pattern, etc. becomes possible (Hertwich, 2005). The tool will allow for a structural path analysis and contribution analysis (i.e. which sectors or processes contribute to what extent to impacts or external costs related to products or resources used, and if these processes are located in the EU or are related to imports)²¹. It will do so in a number of widely used and inspiring indicators: external costs, ecological footprint, and various LCA impact categories. This, combined with the ambition of EXIOPOL to provide an true standard in for formal use in the EU, is important for practical application of all these indicator system. Indeed, if this admittedly ambitious goal is met, the Ecological Footprint community will not see ‘10 in 10’ (ten countries using the Ecological Footprint as key indicator in 10 years), but ‘27 in 4’ (all 27 EU countries using the Ecological Footprint as a key indicator once the EXIOPOL project is finished in 4 years).

Where this end point is very attractive, it is also clear that the road towards it is on the one hand complex and on the other hand may provide a number of unique opportunities. The *complexity* lies in our view particularly in aligning SUT tables from different sources, detailing them, and above all linking them via trade. Our strategic choices made – giving priority to the use of official ESA95 data and transparency – imply that we have to start with unlinked, individual country data with all the complexity that this gives.

²¹ We list here applications feasible with the database that we envisage to develop. When other data such as employment numbers per sector and added value are included, socio-economic analysis become possible as well.

The *opportunity* however is also clear. In many individual projects or for many individual research groups working on EE I-O, the subject of modelling imports becomes of clear importance (e.g. Peters and Hertwich, 2006; Nijdam and Wilting, 2003). On an individual basis, they usually have no option but to discern just a few main trade partners and gather specific EE I-O data for these trade partners. EXIOPOL could be a platform to link such efforts, and provide the many groups working on EE I-O and EE SUT a common structure to share results. This would maybe add another level of complexity in the project, but to forego even investigating this option would be a lost chance.

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