Executive summary - Environmentally extended input-output tables and models for Europe

Introduction

Environmentally extended input-output (EEIO) tables and models have become a powerful element in supporting information-based environmental and economic policies. Briefly stated, monetary input-output (IO) tables give insight into the value of economic transactions between different sectors in an economy, including output for exports, capital formation and final government and private consumption. They allow for calculating the added value that each sector contributes to the final output of an economy. Such monetary IO tables can be 'extended' with environment-related information for each sector, such as its emissions, primary (natural) resource use, land use and other external effects per sector. These environmental externalities may be expressed in monetary terms as well. The same framework can be used to add other information, for example related to the third pillar of sustainability, regarding social aspects, such as the number and quality of jobs per sector. And, last but not least, such EEIO tables can be integrated in broader models, such as computable general equilibrium (CGE) models.

This ensemble forms an unrivalled toolkit for information-based policy-making because EEIO tables and models are based on a comprehensive accounting framework covering all economic activities. EEIO tables bring together economic and environmental data in a consistent, related sectoral framework. EEIO models based on them allow for analysing such data via a great variety of cross-sections of the economic system, such as the product perspective, or a sector perspective. If the EEIO tables and the related data collection system are set up rightly, it can fulfil multiple goals, and hence will probably greatly reduce the effort in data gathering for analysis, ex ante impact assessment and monitoring for a variety of environmental policy fields.

Background and goals of the project

Against this background, DG JRC/IPTS set up a call for tender for a project that would cover the following main tasks:

1. to describe the state of the art of IO tables with environmental extensions in Europe and outside, and to depict their usage and limitations;
2. to assess the potential application areas of IO tables with environmental extensions in European policy-making;
3. to evaluate the feasibility of producing and using IO tables with environmental extensions in European policy-making in the short, medium and long term;
4. to propose practical steps for exploiting the potential of European policy analysis based on IO tables with environmental extensions.

Below, we describe first the result of Task 2, culminating in desired design specification for an EU-25 EEIO table, and subsequently describe the current state of the art and available information (Task 1), options for developing an EU-25 EEIO table (Task 3), culminating in conclusions and recommendations (Task 4).

Potential application areas for EEIO models

EEIO tables and models based on them can be used in three main ways in support of environmental and other policy purposes. There are the following options for application.

1) *Environmental problem analysis*
   This involves the analysis of the nature and causes of environmental problems, as related to resource use and emissions relevant for policy. The most important application of EEIO models for this purpose include analyses of:
   a) life cycle environmental impacts per consumer group (e.g. inhabitants of a city versus the rest of a country, car owners versus non-car owners, etc.);
   b) life cycle environmental impacts of consumption expenditure categories, per consumption category (e.g. the impact of food consumption at home and the impact of food consumption in restaurants);
   c) life cycle environmental impacts of product groups (e.g. cars, meat, houses, etc.);
   d) life cycle environmental impacts of products (in combination with LCA via so-called hybrid LCA-EEIO. In such hybrid LCA-EEIO, the impact of a specific product is analysed with LCA, and the impacts of process chains not included or 'cut off' in the LCA are estimated with the help of EEIO);
   e) life cycle impacts related to primary resources used (e.g. oil, copper, wood, etc.);
   f) factors that are responsible for the main contributions to life cycle impacts mentioned under the above points. Examples include the relative importance of impacts in the resource extraction, production, use and waste management stages; the relative importance of domestic impacts and impacts embodied in imports; and the sector mainly contributing to impacts of a consumer group, expenditure category, or product (group).

2) *Prospective effect analysis of policies*
   This involves the ex ante prediction of effects of policy measures and may include trend and scenario analysis. The most important application of EEIO models for this purpose include:
   a) economy-wide environmental and other implications of changes in life styles and consumption expenditure patterns, such as a shift from travelling to educational and cultural services;
   b) economy-wide environmental and other implications of incremental or radical technical change of products or processes, such as a shift to coal-based hydrogen production for large-scale fuel cell introduction, combined with carbon sequestration;
   c) economy-wide environmental and other implications of emission reduction measures, such as fine dust reduction in all combustion processes, including shifts to prevention;
   d) economy-wide environmental and other implications of price effects, such as environmental taxation and other ways to internalise external effects (or other price effects in the aforementioned scenarios).

3) *Monitoring and ex post effect analysis of policies*
   This involves the ex post analysis of impacts and effectiveness of policy measures, including time series analysis:
   a) analysis of the relation between environmental impact, be it emissions, total material requirement, or a specific impact, and economic output, via a variety of cross sections of the economy (for instance for a specific industry sector, a specific product group, a specific consumption expenditure category);
   b) in relation to the former point: monitoring of eco-efficiency ratios (impact per unit of value created);

c) decomposition analysis of observed changes in the aforementioned ratios (for instance whether decoupling between CO_2 emissions and economic growth is caused by a change in consumption patterns, change in technology structure or a change in emission factors).

Required specifications of EEIO tables

These applications pose the following demands with regard to an EEIO table. For a comprehensive coverage of the different environmental issues, it must at least contain data on primary resource use, some 20–30 emissions of substances to water, air and soil relevant for global warming, ozone depletion, eutrophication, and photochemical oxidant formation and, if possible, land use. Other demands depend more on the application.

a) For *problem analysis* purposes, a detailed sector resolution is desirable, time series less relevant, and a basic EEIO model is usually sufficient. The relevance of detail was convincingly shown in the EIPRO study, which allowed for assessment of environmental impacts of very specific product groups.
b) For *prospective effect analysis of policies*, a detailed sector resolution is, in principle, even more desirable, time series are less relevant, and it is often desirable to use the EEIO table in models that make a number of exogenous parameters endogenous ([1]). The latter point is somewhat at odds with the demand for detail as it is usually more complicated with detailed tables. But, here too, detail is important: EEIO tables with one sector for 'agriculture' will not allow analysis of a shift in expenditure from animal protein sources to vegetable protein sources, whereas a table that discerns such sectors will do so.
c) Finally, for *monitoring and ex-post effect analysis of policies*, EEIO tables of moderate sector resolution are, in most cases, sufficient and time series are essential. But, here too, detail may have advantages if monitoring of policies directed at very specific resources, sectors or product groups is at stake.

In sum, this report pleads for detailed EEIO tables with several hundred sectors, as reached in the CEDA EU-25 tool developed in the study 'Environmental impacts of products (EIPRO) performed in 2004 and 2005' ([2]). Obviously, this desire must be balanced against efforts, costs and institutional impediments. Appropriate level of detail is at least needed for consumption areas with major effects, such as food, housing and transport. Below we will discuss how such a detailed EU-25 EEIO table can be constructed.

Available information

The EU has various elements already in place that could be used to build EEIO tables. The European System of Accounts (ESA95) requires that EU Member States send Eurostat make and use tables yearly, and IO tables five yearly, both with a resolution of 60 sectors. A main problem is that sectors in different countries are connected by trade, and the information obtained via ESA95 does not link domestic sectors which import with sectors abroad which export, and vice versa. This makes it difficult to construct an EU table from Member State tables, and Eurostat has not yet done this. At national level, several countries produce IO or

([1]) Examples include the relation of consumption expenditures with the cost of labour, including price elasticities, and dynamising the model with regard to changes in capital stock and technical development as a function of expenditure on capital goods.

([2]) EIPRO was performed as a support for the EU's integrated product policy (IPP). The Comprehensive Environmental Database (CEDA) EU-25 is based on OECD IO tables for European countries with a resolution of several dozen sectors, and European totals for environmental extensions. Due to the lack of further available data at the moment, the level of detail of 500 sectors was reached by 'Europeanising' a detailed US EEIO table.

EEIO tables with up to around 100–150 sectors. The United States and Japan produce IO tables with a resolution of about 500 sectors.

Concerning environmental extensions, EU Member States each year produce voluntary NAMEA ([3])-Air tables that correspond with the ESA95 sector structure. These NAMEAs contains some 10–20 emissions to air, mainly greenhouse gases. NAMEAs on emissions to soil and water and the use of resources are still largely absent. Examples of other environmental data sources in the EU are EMEP, EPER, UNFCCC, RAINS, GAINS, and the national PRTR data ([4]). In most cases, these are built up for specific purposes and use detailed classification systems unrelated to ESA95 or UN industry sector classifications. When gathering information on NH_3 emissions, for instance, all sorts of animal stables may be distinguished, beyond any detail in standard classifications, such as the NOSE/NOSE-P process lists ([5]) which link processes to the European standard industry sector classification NACE. Lacking uniformity in classification means that representativeness of emission data for classes as distinguished in IO tables cannot be established, as the detailed data are not defined as being representative of specific standard classes.

Physical input-output tables might be established within the IO sector structure too. There are several options for specification of such flows, in terms of elements, chemical compounds, materials and total mass. Energy or exergy data can also be placed in this framework. Such material and substance flows are not recorded in any systematic way in relation to make and use tables. The measurements of flows within an economy remain limited and are hardly related to specific product specifications or to specific sectors of origin and destination. Only imports and exports are specified well and used for material flow analysis (MFA), especially in establishing domestic material consumption (DMC). Due to the use of a sound product classification system, imports and exports of product flows might be analysed systematically. When the composition is total mass, or is in terms of materials related to elements, as with aluminium and copper, mass balancing is possible, allowing for the derived computation of internal flows within countries. The currently available data sets do not fit into the IO framework, i.e. the make and use tables, nor do they link to the product classifications used in these make and use tables.

Available classification systems

A main problem in the existing situation is that data are not gathered in consistent classification systems. At statistical bureaus, much effort is currently spent on transposing sector and product data from one classification to another, rather than on gathering data themselves. Classification systems play an essential role, as actual data are always partial, with some degree of representativeness only relative to a well-defined class. Within a class, there will always be diversity. This holds both for sectors (where one pig farm system is different from the other) and for products (where one mobile phone type is different from another). The essential nature of classification systems for data gathering and modelling for analysis was recognised long ago and standardised classification systems have been set up, coordinated by the UN, and supported by the OECD. The main industry sector classification

([3]) NAMEA: National Accounting Matrices including Environmental Accounts.
([4]) EMEP: Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe.
EPER: European Pollutant Emission Register.
UNFCCC: United Nations Framework Convention on Climate Change.
RAINS: Regional Air Pollution Information and Simulation.
GAINS: Greenhouse Gas and Air Pollution Interactions and Synergies.
PRTR: Pollutant Release and Transfer Register.
([5]) NOSE-P: Nomenclature of Sources of Emission — Process List.

systems are ISIC ([6]) by the UN, the related but more differentiated and mutually incompatible NACE ([7]) and NAICS ([8]) approaches in the EU and US, and variants in almost all countries. Real progress is under way, however, as the EU and US will come up with a modernised and aligned system, comprising well over 500 sectors — here called new-NACE. It is expected that this system will become the UN standard too. It seems that any systematic data gathering in the future should adhere to this standard, with further detailing only within the classes with the highest resolution.

For products, the situation looks less bright. There are three internationally recognised systems which, at their highest resolution, are all mutually incompatible. They are:

- CPC (Central Product Classification) of the UN, which is linked to the ISIC Industry Classification. CPA (Classification of Products by Activity) with 2 608 classes is the European variant and is used in the realm of the ESA95 IO and make-use tables;
- HS (Harmonised commodity description and coding System) of the UN, with CN (Combined Nomenclature), 19 000 classes, as the European variant. They are used for classification of economic data on international trade;
- the COICOP (Classification Of Individual COnsumption by Purpose) system of the UN, slightly adapted for use in Europe, 157 classes, and a number of related final expenditure classifications.

It seems wise to gather base information on products only in relation to one system, making the other systems into derived, compatible, classification systems, not only compatible between product classifications but also linked to the make and use framework for linking to IO tables. The most detailed internationally recognised product classification system is HS, with 7 466 classes. Choosing this classification system or an improved internationally agreed-upon classification system as the base, the COICOP and CPA would have to be revised and become derived systems only. This would allow for systematic data gathering, including time series, on the composition of products, well linked to the IO framework. Such options for streamlining classification systems of course have to fit in with other main uses of the data set, as for economic and social policy purposes. There is no a priori reason why these would require different classification systems. A revision of classification systems of course requires reclassification, which implies substantial work too for these other applications.

Options for developing a detailed EU-25 EEIO table

Introduction

When setting up EEIO tables, several steps need to be distinguished: the base data gathering; their incorporation into make tables and use tables with environmental extensions, and the linkage of make tables and use tables with product flow extensions; the transformation of these into squared IO tables with environmental extensions (the EEIO tables); the construction of physical input-output tables (PIOTs), as IO-linked SFAs and MFAs.

It goes without saying that the first step in any development strategy should be to use what is there: combining the national ESA95 tables and NAMEAs, complemented with other environmental data, into an EEIO table for the EU. This would result in a 60x60 EEIO table with a few dozen environmental extensions, a great leap forward compared to the current situation. How to make the step from national to EU-25 level requires a specific

([6]) ISIC: International Standard Industrial Classification of All Economic Activities.
([7]) NACE: Statistical Classification of Economic Activities in the European Community.
([8]) NAICS: North American Industry Classification System.

methodological decision to be made. Currently, the make and use tables are transformed into input-output tables at a national level. For integration to an EU-25 table, it is preferable to aggregate national make and use tables to EU-25 make and use tables, to link environmental extensions at that level, and then make the transformation to an EU-25 EEIO table. Further detail can be elaborated from this basis, via three distinct approaches. They range from rather simple improvements relative to the current CEDA EU-25 table, through the better use of basic data as are available especially in statistical bureaus, to the improvement in basic data gathering and classification. All three options incorporate a broad set of environmental data, but differ in their sector resolution.

1. High resolution CEDA EU-25++.

The current CEDA model has been built up from US data and has been Europeanised, with a limited set of European data. The procedure could be reversed by starting from the 60x60 sector EU-25 EEIO basis described above and then bringing in detail through technology transfer assumptions, using the US data as one (but not the only) main source. The 60x60 core table would be updatable given the link to the ESA95 reporting procedures. In the future, several improvements in data and methods will be possible compared to the CEDA model. However, it will be difficult to solve the relations between several classification systems in a transparent way, and US data especially will put their mark on the outcomes. Also, the starting point will probably remain in IO tables, not in make and use tables. This is the most simple and least expensive improvement option, not in line with the method rules as specified above, as with working from make and use tables with environmental extensions instead of starting with IO tables. The procedure for creating the improved CEDA model is that of a project.

2. Medium resolution EEIO tables: IO/NAMEA++

Currently, several EU countries have data gathered which are not used in reporting to Eurostat, and sometimes are not even published. A limited level of reclassification and adjusted methods could lead to national make and use tables at a higher level of detail than in ESA95, albeit differently for different countries and not available for all EU countries. For several countries, make tables and use tables are available for 100–150 sectors. Environmental data can be linked to these make and use tables, as can the material and substance flow extensions. By technology transfer assumptions using European data, the ‘EU-content’ is maximised, with only incidental recourse to data from abroad. The advised method for producing IO tables can then be followed at the EU-25 level. Up to 150 sectors could be distinguished, depending on how far one may go with technology transfer assumptions. Using official data as a main base, the construction of time series becomes possible. The main difference with the CEDA EU-25++ model is that, while using the same base data at the 60x60 sector level, the deeper level of detail is based on transfer of EU data available from national statistical offices. The updatability of the IO/NAMEA++ tables is easier to realise than for CEDA EU-25++.

3. High resolution tables: the ‘royal route’

The central approach to this improvement option is to bring together the economic and environmental information at record level, through agreed-upon and regularly repeated procedures of statistical bureaus. Using detailed and uniformly standardised classification systems, including the new NACE classification, representativeness of data can be formally established and data quality can be strategically improved. The ESA95 system would have to be substantially upgraded. The import and export flows are linked, at least partially, to the record level, allowing for much improved regional EU-25 data and interregional data. Due to remaining data limitations, sophisticated statistical procedures also remain necessary in this option. Time series can be produced ‘automatically’ in the procedures specified. The long-term cost of this option need not be much higher than current expenditure.

Useful additional work
The result of all approaches will be a ‘basic’ EEIO table, which can be expanded in various ways. The table can be turned into a model, by making exogenous factors such as consumption, imports and capital formation endogenous. The first candidates for this seem to be imports and their embodied pollution: assuming that imports are made with domestic technology often leads to important under-estimations of environmental impacts. The ideal solution is to embed the EU-25 EEIO table in a regionalised world IO model such as the GTAP ([9]) model or MOSUS ([10]) model, with region-specific environmental extensions. If such extensions include topics such as land use, resource use and various emissions properly, by using various impact assessment methodologies the EEIO model can provide information as diverse as ecological footprints, external costs, scores on environmental themes, and the total material requirement related to consumption of products.

Conclusions and recommendations

Each of the three options has a clearly distinct character. Option 1 can be implemented in one to two years through low-key project work. Option 2 is a large three to four-year project that would require the active support of at least a number of statistical bureaus, and would also require the active cooperation of Eurostat. Option 3 requires a well-prepared political decision, related to UN alignment procedures and with input from several statistical bureaus and environmental data suppliers. The legal framework, especially ESA95, would also have to be adapted, though this might be phased to later stages. It is clear that this ‘royal route’ cannot be implemented on the short or even medium term.

The choice between option 1 and 2 is a matter of budget and taste, particularly with regard to the question of whether Europe’s EEIO model should rely on foreign data. In the view of the authors of this report, option 2 is probably the best way forward. To some extent, it prepares and tests option 3. It is somewhat more expensive than option 1, but has — as a great advantage — that, in the end, a truly European table is built.

([9]) Global Trade Analysis Project, a commercial database sold by Purdue University in the United States. An update on version 6 is due in 2006.
([10]) Modelling Sustainability in Europe, an EU FP5 project.