

Compiling and using input-output frameworks through collaborative virtual laboratories

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Abstract – Compiling, deploying and utilising large-scale databases that integrate environmental and economic data has traditionally been a labour and cost intensive process, hindered by the large amount of disparate and mis-aligned data that must be collected and harmonised. The Australian Industrial Ecology Virtual Laboratory (IELab) is a novel, collaborative approach to the compilation of large-scale environmentally extended multi-region input-output (MRIO) models.

The utility of the IELab product is greatly enhanced by avoiding the need to lock in an MRIO structure at the time the MRIO system was developed. The IELab advances the idea of the "mother-daughter" construction principle, whereby a regionally and sectorally very detailed "mother" table is set up, from which "daughter" tables are derived to suit specific research questions. By introducing a third tier – the "root classification", IELab users are able to define their own mother-MRIO configuration, at no additional cost in terms of data handling. Customised mother-MRIOs can then be built, maximising the level of disaggregation in aspects that are useful to a family of research questions.

The second innovation in the IELab system was to provide a highly automated collaborative research platform in a cloud-computing environment, greatly expediting workflows and making these computational benefits accessible to all users.

Combining these two approaches realises many benefits. The collaborative nature of the IELab development project allows significant savings in resources. Timely deployment is possible by coupling automation procedures with the comprehensive input from multiple teams. User-defined MRIO tables, coupled with high performance computing, mean that MRIO analysis will be useful and accessible for a great many more research applications than would otherwise be possible. And finally, by ensuring that a common set of analytical tools is adopted, the IELab will facilitate the harmonisation of fragmented, dispersed and mis-aligned raw data, to the benefit of all interested parties.

Keywords: multi-region input-output tables; virtual laboratories; collaboration; Life-Cycle Assessment; Australia ; electronic research infrastructure

1. Introduction and overview

A meaningful and close integration of data from the natural environment and the economy is vitally essential for multidisciplinary studies on the total environment. Environmentally extended input-output (EEIO) analysis is widely used to provide insight on the linkages between environmental impacts and economic activity. EEIO is applied at scales ranging from individual consumption to world trade, and used in a variety of contexts such as consumption-based accounting, life-cycle assessments (LCA) and supply chain analysis of resource use and pollution ([Suh 2009](#)). A number of multi-region input-output (MRIO) databases have been constructed at global^{A1} and national^{A2} scales.

Each MRIO database construction typically focuses on a specific (set of) research question(s), requiring a good sectoral and regional resolution in those parts of the MRIO table that are most relevant to addressing those particular questions. For example, land use impact studies will require high detail in agricultural sectors; water resources studies might also require high detail in water-stressed regions; employment analysis requires high detail in service sectors; while studies on biodiversity might require high regional detail specifically for developing countries.

More generalised use of MRIO tables for meaningful environmental footprint and LCA applications would require a more consistent approach to sectoral and regional disaggregation; however this remains a substantial challenge for the EEIO research community. The conventional approach for compiling high-resolution MRIO tables is prohibitively arduous, labour- and cost-intensive, because regional economic data and environmental data are notoriously scarce and misaligned. Often a compromise has to be reached between the number of sectors and the number of regions in the model to keep resource and computational requirements at bay.

Because of these difficulties, only a handful of research groups around the world have taken on the task of compiling high-resolution international or sub-national multi-region input-output (MRIO) databases. Even fewer have done so in a way that can directly take information about individual products and/or processes into account ([Schoer et al. 2012](#); [Tukker and Dietzenbacher 2013](#)). More widespread MRIO development has been impeded by limitations in the financial and human resources that can be committed to the task. As a result, it is typical for only a subset of all potentially suitable raw data to be located and collected during the construction of an MRIO table. It is also common practice to constrain the MRIO layout and resolution to match a set of readily available data. A related shortfall of past MRIO construction efforts is that different teams have mostly worked in isolation from each other, and hence missed opportunities to leverage off each other's efforts.

Existing global MRIO databases are highly sophisticated, and have supported high-quality analysis on specific questions. However, they can fall short of the detail necessary to address a wider spectrum of research questions. Furthermore, the resource-intensive approach taken to data compilation means that many MRIO frameworks are not easy to update as the global economy changes over time. MRIO constructions can therefore be at risk of losing relevance over time, as their data currency wanes and/or the nature of priority research problems tends to change.

In this paper we describe a new approach that overcomes some of the limitations listed above. The accessibility and utility of the MRIO product is increased, by building an MRIO framework that can address a wide range of research questions by a wide range of researchers.

Section 2 introduces a new MRIO construction concept that avoids the need to impose aggregation on the input data and allows multiple versions of MRIO tables to be constructed. The philosophy here is to minimise the effect that data and resource limitations can have on the utility of the final product. This is achieved using a three-tiered *root-mother-daughter* structure that allows for maximum flexibility in the provision and use of disaggregated data, without compromising the transparency and utility of the overall MRIO analysis.

The base tier is a fixed *root* classification – this represents the maximum sectoral and spatial detail that might be attainable if highly disaggregated data were universally available. This root classification is so detailed that no actual MRIO system could be built from it because it would exceed current computer storage limits (compare [Wittwer and Horridge 2008](#)). However, its purpose is to provide a common architecture (set of classifications) against which all input datasets can be mapped. Imposing this fixed reference point means that any number of *mother* MRIO tables – the second tier – can be derived, without requiring any manual rehandling of data. *Mother* tables aggregate the *root* classification to a point that the MRIO can actually be constructed with available computing resources. The sectoral and regional classification of any particular *mother* MRIO would be designed to suit a particular family of research questions. The third tier is the *daughter* table, which has two roles. Firstly it allows simplification of any mother table components that are unnecessary for analysing a single, specific research problem. Secondly, it provides a mechanism for including any problem-specific information that is not already captured in the root.¹

Section 3 describes a computational infrastructure, known as a *Virtual Laboratory*, that makes MRIO analysis more accessible to a greater number of users, and will encourage participation in collaborative research. The *Virtual Laboratory* allows users to operate a highly automated construction pipeline to build their own MRIO tables as required to suit their research purposes. It also facilitates timely, transparent, cost-effective updating of MRIO tables as new data are released, and allows sharing of resources and tools across multiple research teams.

Section 3 also presents the workings of a real Virtual Laboratory – the *Industrial Ecology Lab (IELab)* – set up in Australia to provide sub-national MRIO analysis of its highly heterogeneous regional economic structures, climates, natural environments, and resource endowments.²

¹ The mother-daughter idea goes back to Wittwer and Horridge's (2008) large-scale TERM database that serves as a master for the flexible aggregation into small-scale input-output cores for CGE simulations with high regional and sectoral detail ([Wittwer and Horridge 2010](#); [Horridge 2011](#)).

² The construction and publication of sub-national MRIO tables is not part of the mandate of the Australian Bureau of Statistics.

Section 4 presents outcomes from the IELab collaboration to date. Achievements include the harmonisation of a wide variety of fragmented, dispersed and mis-aligned economic and environmental data – something long overdue in Australia. At the time of writing, the IELab is providing its users with analytical capabilities for a variety of economic and environmental, single-year or time-series applications. It also meets the requirements for constructing MRIO cores for dynamic economic forecasting models that are frequently used in Australia to support government decision-making.

Section 5 provides some reflections from the process of developing, and implementing, this novel approach to constructing MRIO tables.

2. The root-mother-daughter approach to compiling large-scale MRIO databases

The innovation proposed in this work is to move beyond Wittwer and Horridge’s fixed master table idea, and allow many *mother* tables to be derived from an “impossibly large”, detailed, regional and sectoral *root* classification. In a Virtual Laboratory setting this is achieved through a flexible, automated MRIO construction pipeline that includes data pooling, constraint writing, and reconciliation steps. An example of this is provided in Section 4.)

The flexibility is made possible by allowing users to build their own mother MRIO table, whose specific regional and sectoral table structure is defined as a subset of a fixed root classification. The root classification itself is too large to ever be used for a fully populated mother table (see Appendix 1). Instead, its role is to provide a consistent structure against which all input data is mapped. This means that existing data streams can be used as is, even when a new mother-MRIO classification is chosen. All that is required to make use of the existing data is to define a set of concordances between the root and mother classifications, specific to that particular mother-MRIO table. For the data-to-root mapping to be possible, there must exist at least one vector of primary data expressed directly in the root classification. For any dataset where no better information exists, this vector can be used as a proxy for generating the data-to-root classification maps.

A second innovation is to allow *daughter* tables to be derived, whereby users combine a conventional mother table with their own bottom-up data that is not captured by the root classification. Such bottom-up data could relate to particular specialised technologies, industrial processes, or products, for example. This functionality is useful when users wish to disaggregate specific sectors beyond the limitations imposed by the root classification. In practice, hybrid LCA can be carried out by inserting application-specific data in additional rows and columns into the mother table (augmentation)^{A4}, and/or aggregating certain parts of the mother table that are not important for the LCA application.

In light of these innovations, we will use the following terms in the remainder of this paper:

- A *root classification* is a very detailed, regional and sectoral classification that is in itself too large to serve as the basis of a computable MRIO table, but from which a large variety of classifications can be derived by aggregation.

- A *mother table* is a fully populated and memory-storable MRIO table, generated by an MRIO construction pipeline, derived flexibly from the impossibly large root classification for a certain family of research questions, but not necessarily meant to be used in concrete applications and analytical procedures.
- A *daughter table* is not generated by an MRIO construction pipeline, but derived from a mother table by aggregation and/or hybridisation, and is used for specific analytical tasks such as Life-Cycle Assessment (LCA) or Computable General Equilibrium (CGE) modelling.

The implementation of a root-mother-daughter approach for large-scale MRIO construction is associated with a range of challenges. Generally speaking, constructing an MRIO table involves (a) building an initial estimate and a set of constraints; and then (b) combining these in a mathematical optimisation operation to yield a final MRIO table that satisfies the conditions posed by the constraints in an optimal way ([Temurshoev et al. 2011](#)). The strategy in Wittwer and Horridge’s TERM approach is to generate CGE simulation tables – *post-optimisation* – from a fixed mother (master) table. However, this strategy faces size restrictions because the mother table needs to exist as a fully populated matrix that fits into computer memory. Since we keep mother tables flexible in order to suit many users’ needs, we need to introduce a design decision point *pre-optimisation*, during the construction of the initial estimate from the root classification. This means that both the initial estimate construction and the construction of the constraints for the optimisation need to be user-specific and therefore flexible.

In our approach we first ask the user to select a subset of the root classification for building the classification of a specific mother table. This selection process results in a concordance matrix between the root classification and the user’s specific mother classification. This concordance table is then used to aggregate the root-classified proxy vector into a mother-classified proxy vector, which in turn is used to set up an initial estimate based on one of many well-known non-survey methods for regional input-output table construction. Thus, the initial estimate construction is handled in a flexible way for a wide range of user choices. A further problem arises of how to express the constraints imposed on the optimisation operation by external data, in a way that works for each and every possible mother MRIO variant. It is impractical, if not impossible, to write these constraints in terms of every conceivable mother classification, because there are just too many combinatorial classification subsets contained in the root classification. In our approach, constraints are only ever written once, using the root classification, and then stored. Once a user has selected their mother classification from the root classification, all constraints are adjusted in a way that they fit the particular mother MRIO table structure, instead of the (impossible) root MRIO structure. Once again, the root-to-mother concordance resulting from the user’s selection is used in this adjustment procedure. Thus, the constraint writing is also handled in a flexible way for a wide range of user choices. In unison, flexible initial estimate construction and constraint writing enable flexible, user-specific optimisation and mother table construction. Here we have kept the description of the procedure for creating flexible mothers brief and qualitative. A more detailed technical description is provided in Appendix 1.

A final challenge is that in practice, mother tables are likely to be very large-scale, requiring large amounts of input data, processing and storage ([Lenzen et al. 2012](#)). The new approach taken here therefore exploits a) advanced means of computation, b) a high degree of procedural automation ([Yu et al. 2009](#)), and c) highly efficient organisational collaboration. For a world MRIO compilation, constructing a mother table would require a) purpose-built, multi-core cluster hardware running parallelised algorithms using in the order of 1 Terabyte shared RAM; b) a meta-language for addressing large amounts of raw data and variable spaces ([Geschke et al. 2011](#)) as well as constrained optimisation techniques for data reconciliation ([Yu et al. 2011](#)). To best take advantage of such computational power requires the Virtual Laboratory architecture, designed to allow a large number of data providers and analysts to work on one and the same platform without costly and inefficient human communication overheads. In Section 3 we will therefore first describe general features of a Virtual Laboratory, and explain why it would lend itself to MRIO compilation. We then describe a particular case study – the Australian Industrial Ecology Lab.

3. MRIO compilation in a Virtual Laboratory – the Australian IELab

A Virtual Laboratory (VL) is a novel concept aimed at improving digital connectivity by connecting researchers to existing and new research facilities, data repositories and computational tools. The objective is to streamline research workflows and enable new opportunities for research innovation, research collaboration, and improved research efficiencies. In Australia, VLs are created and administered under the lead of the University of Melbourne’s NeCTAR project (www.nectar.org.au), and financed by the Australian Government’s Education Investment Fund. NeCTAR Virtual Laboratories seek to support and engage major research communities in Australia by enabling collaboration across multiple research disciplines and problem-oriented research domains.

The aim of a Virtual Laboratory is to provide researchers with desk-top or bench-top access to digitally enabled data, analytical and modelling resources, specifically relevant to their research. Each VL integrates existing and new investments in research infrastructure, including data storage, data collections, high performance computing resources, domain-oriented computational analysis and simulation tools, remote access to research facilities and laboratories, online collaborative research environments, real-time communications technologies, and automated research workflow tools. Because of the ability to link a large number of researchers, a NeCTAR VL provides a suitable environment for collaboratively compiling MRIO systems.

The Industrial Ecology Lab is one of NeCTAR’s Virtual Laboratories that targets a well-described, significant research challenge: in this case the compilation and use of a time series of Australian sub-national MRIO tables, set up within the University of Melbourne’s NeCTAR Research Cloud. The structure and information flows in the Australian Industrial Ecology Virtual Laboratory (IELab) are summarised in Figure 1. For each dataset to be

used, the researcher submits to the VL: a) the raw data specific to their research question, and the information used to align this raw data with the root classification. Raw data sources that are regularly updated in a standard format may be linked into the VL using automated data feeds. The raw data feeds created by different users are coordinated using Application Programming Interfaces, so that changes in data standards, naming conventions, or MRIO structure never have to be changed separately by all users.

The three datafeed-specific raw ingredients are then gathered in a reconciliation engine ([Geschke et al. 2011](#)) that uploads the resultant mother MRIO tables into a designated repository. The reconciliation step can involve any of the procedures commonly applied, such as the construction of an initial estimate and a balancing algorithm^{A5}.

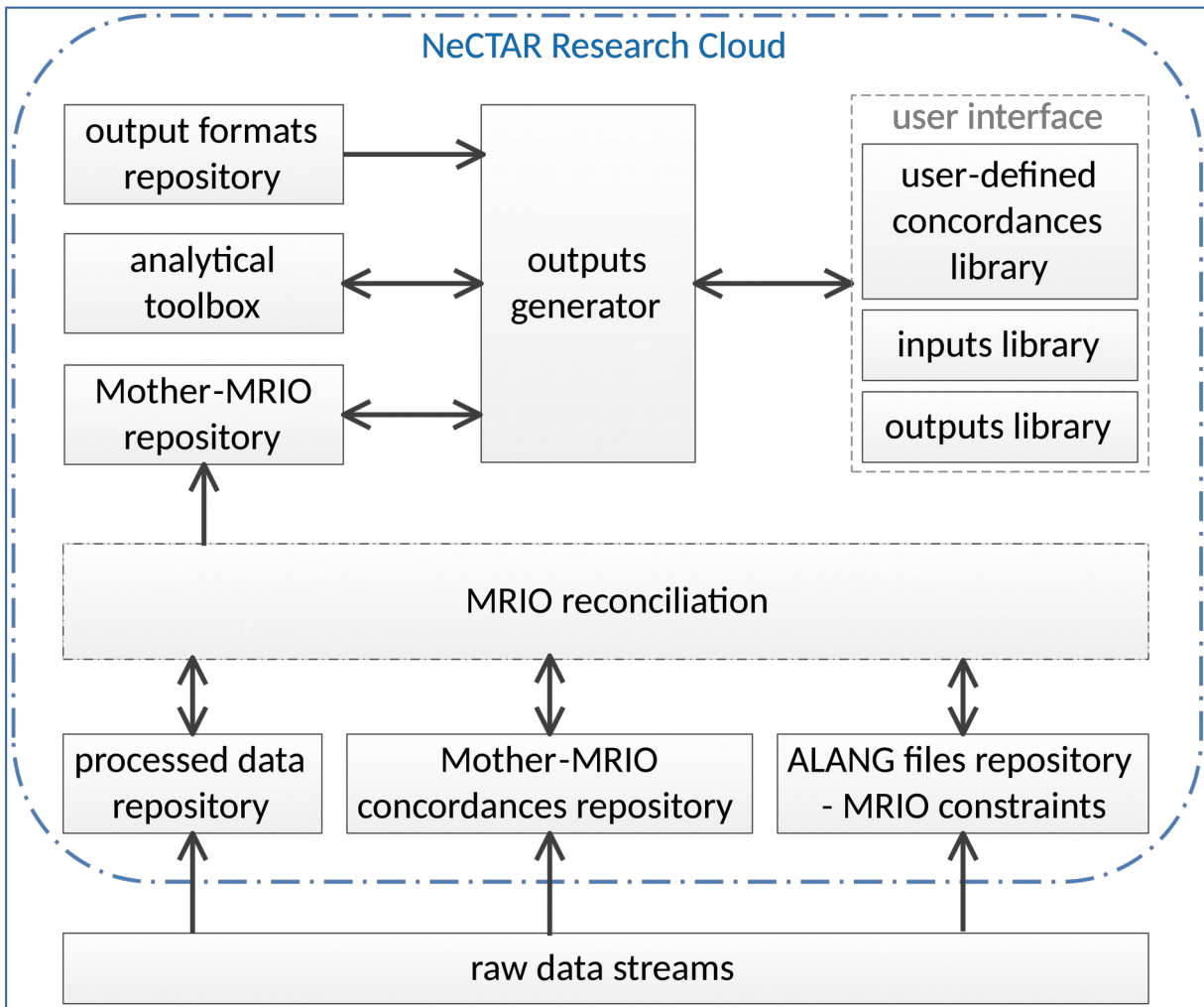


Figure 1: Schematic of structure and functionality of the Industrial Ecology Lab.

The VL is equipped with an analytical toolbox that allows users to calculate derived quantities such as Leontief inverses, multipliers and environmental footprints; and a facility to interrogate outputs and extract them in various formats. Finally, a user interface

comprises a) a library of user-defined concordance matrices that can be used to transform the mother MRIO tables into any user-defined daughter format, and b) libraries for storing user-defined inputs and outputs, enabling multiple users to work simultaneously on various individual MRIO projects that may differ by which input data and/or reconciliation method is used.

The entire workflow is handled within a cloud computing setting with nodes all around Australia.³ Each Virtual Laboratory within the research cloud is allocated resources and software on a so-called *virtual machine*, with the appearance of a stand-alone Linux system. Researchers affiliated with a certain Virtual Laboratory can remotely access this virtual machine using standard protocols such as secure shell. The IELab received the biggest possible allocation within the NeCTAR research cloud comprising two computing cores, 64GB of fully-shared memory and 5 TB of hard-disc space.

3.1 Raw data feeds

The raw data streams of the IELab are realised as pieces of computer code operating automatic feeds of information stored in standard formats. In the IELab, raw data streams process for example the Australian national input-output tables ([ABS 2012c](#)), but also state ([ABS 2012a](#)) and regional ([OGS 2004](#)) economic data, the Census ([ABS 2012d](#)), and industry-specific reports from government (eg [ABS 2008](#); [2010b](#)) and private-sector (eg [WFA 2011](#); [AAC 2012](#); [DA 2012](#); [WSAA 2012](#)) sources.

For each raw data stream, three tasks are necessary to create the constraints information required for the MRIO table reconciliation:

- a) Convert information obtained from data providers (e.g. Excel files) into .csv files cleaned of strings, blanks, tab stops, line breaks, headers and other peripheral information. The data is saved with standardised file names into the processed data repository.
- b) Generates a binary concordance table relating the classification of the raw data source to the root classification; saving these concordance tables as .csv files with standardised file names into the concordances repository.
- c) Formulate constraints using *ALANG* commands as well as the standardised names of the processed data and concordance files – thus linking the raw data to the MRIO structure (see [Geschke et al. 2011](#)). The constraint commands are saved in.txt files into the *ALANG* files repository.

Two additional tasks are involved in creating the initial estimate information required for the MRIO table reconciliation:

- d) Using the data-specific source-to-root concordance, and the user-defined root-to-mother concordance, the raw data is converted into *mother-classified* blocks of cleaned, processed data. The transformation of monetary data for the MRIO initial estimate utilises existing non-survey methods to map the data against the root

³ See <http://nectar.org.au/research-cloud>.

classification ([Bonfiglio and Chelli 2008](#); [Sargento et al. 2012](#)). The transformed data is then saved with standardised file names into the processed data repository.

- e) ALANG commands are used to identify the file location of the initial estimates data available for each section of the mother MRIO table. The initial estimate ALANG commands are saved in .txt files into the ALANG files repository.

These two tasks are necessary

Note that the constraints information refers to the root classification whilst the initial estimate information refers to the mother classification. The reason for this difference is as follows: First, as mentioned previously, a root-classified initial estimate cannot be constructed because it is too large to fit into computer storage. Initial estimate construction must await therefore user selection of a mother classification before being able to proceed. The raw data feeds could in principle also first await the user selection of a mother classification and then generating mother-classified ALANG commands and concordances. However, raw data feeds involve the reading and processing of multiple misaligned and machine-unfriendly files, thus requiring relatively long runtimes. The VL development showed that it was far more advantageous to operate the slow raw data feeds only once, let these feeds generate root-classified ALANG commands and concordances as fast-readable .txt and .csv files, which would then relatively quickly be picked up and root-to-mother converted for the creation of a mother table.

3.2 Processed data, concordance and ALANG file pre-processing

For the creation of a mother MRIO table, three sets of information are required (compare with Figure 1): a) processed, mother-classified initial estimate data and processed constraint data, b) source-to-root concordances matching the processed constraints data as well as a user-defined root-to-mother concordance, and c) ALANG command files defining the initial estimate in the mother MRIO classification, and the constraints in the root classification.

When a user activates a Graphical User Interface in order to create a mother table, these three ingredients are packaged into a standard folder/file structure and deposited into an export repository from where they await being posted as a job into the queue of the reconciliation engine. Before packaging, the ALANG command files describing the constraints as well as their respective source-to-root concordances are converted and re-written so that they refer to the mother classification rather than the root classification. Packaging and root-to-mother conversion are carried out using tailored and automated pre-processing scripts, requiring no manual intervention.

The root-to-mother conversion is the critical innovation that enabled the IELab to move from the fixed mother/master concept in the TERM project to a flexible-mother concept. Root-to-mother conversion is described in detail in Appendix A.

3.3 Table reconciliation

To prepare for table reconciliation, the raw data streams are machine-read, *ALANG* command files are pooled, and a constrained optimisation problem is conditioned. Following, the optimisation problem is solved, and the solution stored in the mother repository by the MRIO reconciliation engine. Current solvers include tailor-made, large-scale, parallelised Barrier-Penalty ([Huang *et al.* 2008](#)), GRAS ([Junius and Oosterhaven 2003](#)), KRAS ([Lenzen *et al.* 2009](#)) and Cimmino ([Censor and Zenios 1997](#)) algorithms. One of the constraints imposed during optimisation is that all MRIO elements must be positive with the exception of changes in inventories and subsidies.

The KRAS and Cimmino optimisation routines are designed to operate in parallel in order to make efficient use of available computing hardware. The basic idea of any parallelised optimisation routine is to split the reconciliation problem into several, ideally independent parts, and distribute the work that is required to solve the different parts onto different computing cores.

Whilst the computational requirements for the raw data feeds can be handled by the resources assigned to the virtual machine of the IELab, the reconciliation requires more RAM and more computing cores than are available in the IELab allocation on the research cloud. Additionally, the IE Lab's virtual machine must not be occupied by resource-intensive tasks such as the reconciliation process, as this could impede availability of the virtual machine to the participating researchers. Therefore, the reconciliation of the mother tables is carried out on separate high-performance computers located at different advanced-computation centres. The necessary file transfers and communication across the different computing systems are fully automated and handled by tailored scripts operating on the cloud.

3.4 Analytical toolbox and user interface

The analytical toolbox offers various tools for aggregating or hybridising any mother MRIO table into daughter tables to be used for subsequent analysis^{A6}, and for generating output data consistent with standard environmental accounting and assessment frameworks^{A7}. The toolbox is designed with the integration of VL outputs into Life-Cycle Assessment (LCA) databases and software packages^{A8} in mind. The combination of LCA process data and the IELab's MRIO tables will thus enable the implementation of hybrid LCA methodologies that utilise the best aspects of both process and input-output methodologies to deliver cutting-edge LCA research ([Suh and Nakamura 2007](#)), and facilitate the usage of the VL outputs by a large number and diverse range of users who are already familiar with existing LCA databases and/or software packages. In addition to IO and LCA tools, the toolbox also

contains a range of diagnostic⁴ and analytical⁵ visualisation options. Similar to the raw data feeds, the routines contained in the analysis toolbox are housed and executed within the virtual machine on the research cloud.

The creation of daughter tables is currently a post-optimisation step in the IELab. If the user chooses to insert more specific data than the root classification then the resulting daughter tables will not be balanced. In most cases, process data inserted that way refer to products, processes or companies that are so small that a re-balancing of the entire table is not necessary, because the insertion does not cause a significant economic imbalance. However, it is planned to implement a daughter reconciliation capability in the next stages of IELab development.

The user interface for the analytical toolbox has two main purposes: First, it accesses a concordances repository holding user-defined concordance tables that map the mother MRIO classifications into daughter classifications matching users' individual research needs. Users have the option of making their own concordance tables available to others, so that particular analytical approaches can be easily shared and replicated. Second, the user interface contains a repository for storing analytical outputs, and for sharing those outputs in one workspace with selected users.

3.5 Collaboration in the Industrial Ecology Lab

The IELab was developed by a consortium of seven Australian research institutions. Each partner provided a set of resources and expertise that maximised the utility of the final product.

3.5.1 Functionality and architecture

The *University of Sydney* (USyd) is primarily responsible for developing the root-mother-daughter approach and the functional architecture used for the MRIO construction and analytical use. This is based largely on its previous experiences in developing a global MRIO ([Lenzen et al. 2012](#); see also www.worldmrio.com), prototype state level MRIO development ([Gallego and Lenzen 2009](#); [Yu et al. 2009](#); [Yu et al. 2011](#)) and case study applications ([Lenzen 2009](#); [Lenzen and Peters 2010](#)). USyd contributions also include automation procedures, the *ALANG* meta-language, and the parallelised optimiser suite.

The *University of Ballarat's* Centre for Informatics and Applied Optimisation (CIAO) is contributing to the IELab functionality by accelerating the constrained optimisation routines and by integrating text mining techniques into data feeds exploring grey literature sources and industry reports, with a focus on environmentally significance sectors and supply chains.

4 See <http://www.worldmrio.com>.

5 See [Wiedmann et al. 2009](#).

3.5.2 Data feeds

During the initial IELab development, the integration of economic data via data feeds (see Section 3.1) was the domain of USyd (national data), *UNSW Australia* (UNSW – state-level data), and *Griffith University* (GU – substate-level data). The synergies in combining their relative expertise at all three scales enabled rapid progress towards the development of detailed, high quality sub-national MRIO tables for Australia.

Almost all institutions contributed data feeds for the satellite accounts. This component of the initial IELab development is being led by the *Commonwealth Scientific and Industrial Research Organisation* (CSIRO – material flow), the *University of Queensland* (UQ – water use, greenhouse gas emissions, toxic emissions), GU (energy use), UNSW (peripheral pollution data), USyd (waste), and the *University of South Australia* (UniSA – waste). These contributions reflect the data expertise and prior experience of the various contributors^{A9}, and their interests in applying MRIO analysis to economic and environmental research questions.

The project is run in close collaboration with the Australian Bureau of Statistics (ABS), which has legislated responsibility for the compilation and dissemination of the Australian national input-output tables. The ABS also produces a variety of national environmental accounts that are aligned with the UN's System of National Accounts (SNA, [UN 2009](#)) and the System of Environmental and Economic Accounts (SEEA, [UNSD 2003](#)). The ABS is strongly supportive of the project objectives, given its interest in ensuring that major Australian input-output applications adhere to the SNA and SEEA. The ABS is providing basic and enhanced raw datasets to the IELab development team, along with technical guidance on the development of the IELab framework.

4. Results - the first collaborative Australian MRIO table

At the end of 2013 (the conclusion of the development phase of the IELab) the collaboration of the partner institutions had established a complete Australian MRIO table. In addition, a number of projects were already underway using the table for technology and policy applications. The partners involved in the development phase have a variety of research interests for which the IELab will be used, ensuring it will continue to be tested and improved in subsequent years.

4.1 The root and mother classifications

The root classification of the IELab is based on the most detailed regional and sectoral classification for which economic and physical data are available in Australia. For spatial classification we adopt the new Australian Statistical Geography Standard (ASGS) published by the Australian Bureau of Statistics (ABS) which includes a Statistical Area Level 2 (SA2) subdivision of the Australian continent into more than 2200 geographical entities ([ABS](#)

[2010a](#)). The spatial root classification is visualised in the map provided in Appendix A4. For sectoral classification we use the Input-Output Product Categories (IOPC) from the ABS which distinguishes 1284 product groups ([ABS 2012b](#)).

A fully disaggregated table at root detail would have dimensions of 2.8 million by 2.8 million, therefore requiring ~ 8 trillion data cells. Reconciliation of such a large matrix is beyond the capacity of existing computer power, and therefore requires the building of a mother table with smaller dimensions. The benefit of using such a detailed root classification is that enables a high degree of user flexibility in defining a Mother table that best meets the needs of any particular analytical application. The SA2 classification for example allows the construction of an MRIO for political as well as for physical (watershed/catchment) boundaries (see Appendix 4).

4.2 Table structure and data sources

The first Australian mother MRIO table is a multi-region supply-use table (MR-SUT) distinguishing 19 regions (see Figure 1). These are six States and Territories (Victoria, Australian Capital Territory, Tasmania, South Australia, Northern Territory, and Western Australia), the Illawarra region and the remainder of New South Wales, the state of Queensland broken down into ten regions, and finally a group called 'Other territories' (including offshore Christmas and Cocos/Keeling Islands). This disaggregation was largely driven by the availability of state accounts for all eight states and territories ([ABS 2012a](#)) and input-output data for the Illawarra and Queensland sub-state regions ([OGS 2004](#); [Masouman 2013](#)) and the offshore territory of Norfolk Island ([ACIL Tasman 2012](#)). A visualisation of the transaction values in the MR-SUT is provided in the form of a 'heat map' in Figure 1.

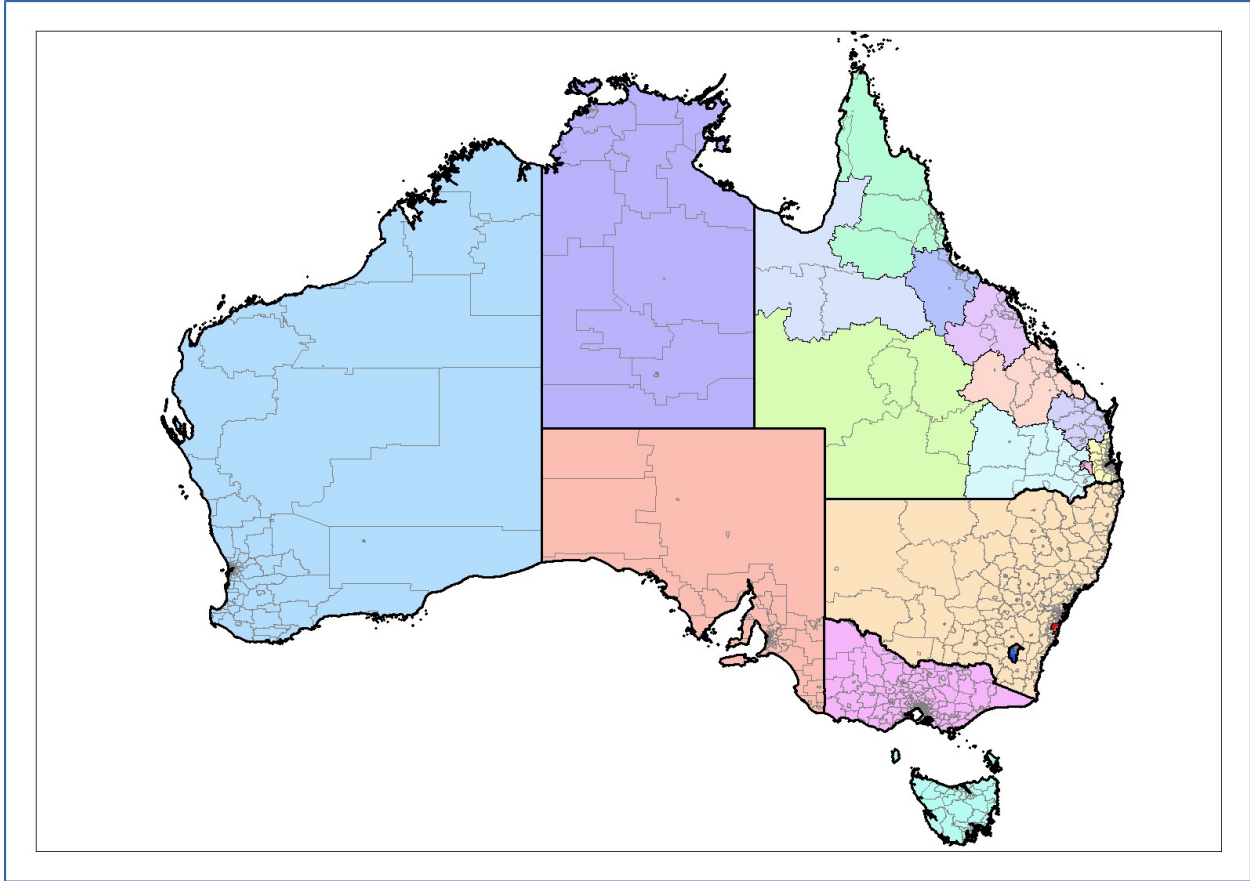


Figure 1: Map of regions in the first Australian mother MRIO table. Each coloured region is a separate mother classification, bounded by thin black lines. Heavy black lines are boundaries for state governments. Thin grey lines are boundaries for the SA2 regions.

A 344-industry and -product subset of the IOPC classification called ISAPC ([Kanemoto and Moran 2013](#)) was chosen for the mother MR-SUT sectoral classification, again based on availability of detailed supply-use data ([ABS 2012b](#); [2013a](#)). Value added and final demand are included in their 5- and 6-component representations as in the original supply-use tables published by the ABS. Similarly, the mother MR-SUT distinguishes 18 valuations (margins, taxes, subsidies etc) as in the published tables. As a result, an MR-SUT for one

year contains $\underbrace{19}_{reg} \times \underbrace{18}_{valu} \times \left(\underbrace{344^2}_{use} + \underbrace{344^2}_{supply} + \underbrace{344 \times 6}_{fin.dem} + \underbrace{344 \times 5}_{val.add} \right) = 82,235,952$ transactions.

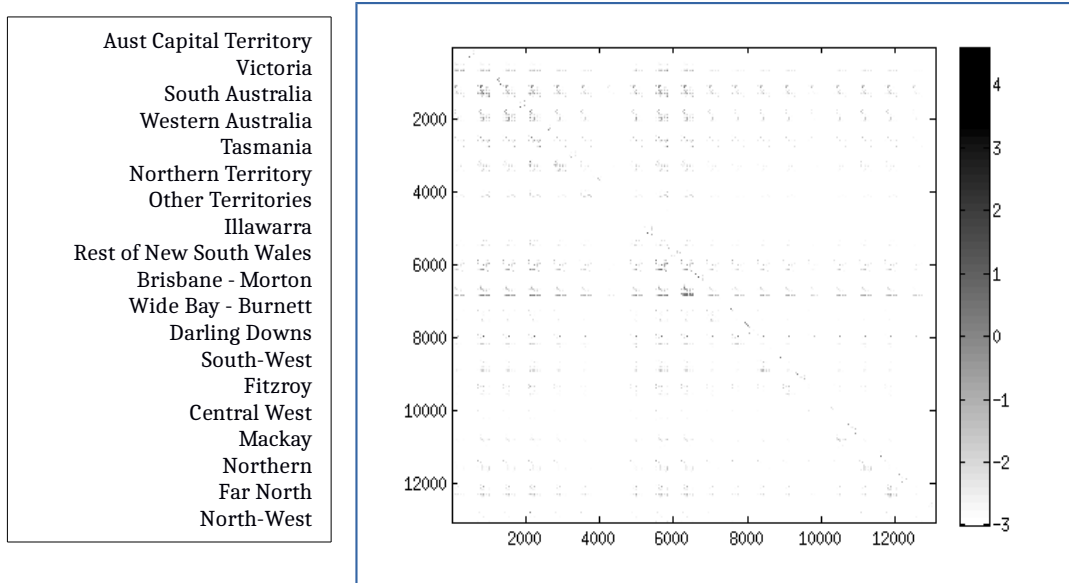


Figure 1: 'Heat map' of the Australian MR-SUT, depicting transaction values. The shading of cells indicates the \log_{10} of transaction values in millions of AU\$, ie a value of 0 means AU\$1m, and a value of 3 means AU\$1bn.

The initial estimate for the MR-SUT was constructed based on Flegg's adjusted location quotient ([Flegg and Webber 2000](#)) with a δ parameter of 0.3 ([Kowalewski 2012](#)), and utilising Census data ([ABS 2012d](#), compare [Wittwer and Horridge 2010](#)). In the subsequent reconciliation, the table was constrained by input-output data ([OGS 2004](#); [ABS 2012b](#); [c](#); [ACIL Tasman 2012](#); [Masouman 2013](#)), the business register ([ABS 2013b](#)), the household expenditure survey ([ABS 2011](#)), state accounts ([ABS 2012a](#)) and by a multitude of detailed industry data (see Appendix 5, and also [Gallego and Lenzen 2009](#); [Lenzen 2009](#)).

The Australian MR-SUT is accompanied by matching satellite accounts for greenhouse gas emissions by gas and source ([AEGIS 2013](#)), pollutant emissions by pollutant and receiving medium ([NPI 2013](#)), water by type ([ABS 2012e](#)), energy by fuel ([BREE 2013](#)), material flow by material type ([CSIRO and UNEP 2012](#)) and waste flow by waste type and treatment method ([ABS 2013c](#)).

4.3 Current uses of mother and daughter tables

Given the existence of both energy and water satellites, a major opportunity for using the Australian MR-SUT exists in understanding and harnessing the significant indirect influence of water management on energy use. Especially in the populous and water-stressed state of Queensland, energy use related to the provision and use of water is estimated at 13% of state electricity use and 18% of state natural gas use ([Kenway et al. 2011](#)). Despite the significance, relatively little is understood about the nature of

interactions in the water-energy nexus. Thanks to the disaggregation of Queensland into ten regions, the mother MR-SUT will be used by UQ and GU partners for developing strategic tools to help create a water-, energy- and emissions-smart region whilst enabling economic growth and regional prosperity. One aspect of this work will be to identify sectors of the Queensland economy that are vulnerable to future trajectories of higher water and energy costs, and sectors that produce higher economic return with efficient and sustainable use and impacts regarding water, energy, emissions and other environmental resources (for example food, concrete and other construction materials). In turn, this work can be coupled with analysis of impacts on economic activity diversity, estimating intensity in terms of other social impacts in the regions of Queensland, such as additional employment created or wages paid (such as in [Foran et al. 2005](#)). For industries that have suffered in the financial crisis, such as manufacturing or construction this leads to a better understanding and mapping of local economic structure and identifying risk of transmission of negative (or positive) effects. Potential extensions of the work are to estimate the metabolism of a highly urbanized region (Southeast Queensland is comprised of the Greater Capital Area of Brisbane and agricultural areas) Such analysis could help answer questions such as: Which sectors or regions are most dependent on “hidden” flows of water and energy (for example as virtual or embodied flows) in addition to their direct water requirements?, How does the water, energy or carbon intensity compare across the different industries and regions?, and What are the likely effects of relevant potential policy for South East Queensland, Queensland and Australia on water and energy consumption.

The main objective of UNSW in using the MR-SUT is to conduct state-of-art environmental footprinting and sustainability assessments in applied research projects. This includes the development of tailored decision-support tools for government and industry partners based on life cycle methodology. One example is UNSW-led research under the Australian Cooperative Research Centre for Low Carbon Living⁶ which uses the hybrid LCA functionality of the IELab to evaluate new ‘low-carbon’ technologies and projects. Economy-wide, comparable and life-cycle-based carbon metrics for the built environment can be derived from the IELab, ranging from individual building materials over buildings and precincts to whole cities. Future work will include the evaluation of different ‘low carbon living’ scenarios and potential policy intervention points, based on stakeholder consultation ([Wiedmann et al. 2013a](#)). Hybrid LCA projects have also been undertaken in environmental engineering projects related water and wastewater treatment technologies ([Alvarez-Gaitan et al. 2013](#)).

The CSIRO will use the IELab to provide ongoing support to decision makers regarding sustainable consumption and production policies, supply-chain initiatives and life-cycle assessments. CSIRO has established expertise in direct water, energy and material flows accounting ([Baynes et al. 2011](#); [Wiedmann et al. 2013b](#)) and the IELab not only makes good use of this but also permits the production of complementary carbon/energy/water footprinting and social indicators (for example employment) to enable more complete sustainability reporting. The IELab also provides the structure and basis for integrated assessment projects that incorporate other modelling forms: CGE, physical stocks and flows

⁶ <http://www.lowcarbonlivingcrc.com.au>.

and scenario analysis. Notably, there is a rare opportunity for investigating material stocks and flows in detail using the combination of CSIRO's domestic extraction data and waste flows as they are both available in the IELab.

The University of South Australia is already using the MR-SUT to populate a Waste-Input-Output model ([Lenzen and Reynolds 2013](#)). This Waste-Input-Output model includes the highest detail food waste data ever created for Australia ([Reynolds et al. 2013](#)). Future research using the MR-SUT is planned to focus upon examining the geographic, social and economic impacts of diet and waste.

Finally, already during its development phase, the IELab supported a number of postgraduate projects, for example studies on the impacts of a potential biofuels industry in Australia, on the changing economy of Norfolk Island, on carbon footprint accounting of cities, on industrial symbiosis and material efficiency, and on waste metal flows in the Australian economy. Another interesting collaboration emerged with the Jolliet Lab at the School of Public Health of the University of Michigan, on modeling the environmental health effects of Australian consumption, by combining an economic MRIO model with a multi-scale fate and exposure model of pollution. Some of these projects use tailored daughter tables that are derived from the mother MR-SUT described above. For example, [Malik et al. 2013](#) collect detailed process information about potential future production recipes for sugar-cane-based ethanol and gasoalcohol vehicle fuel blends, and simulate their introduction into the Australian economy by augmenting the MR-SUT with new rows and columns representing the new biorefining industries. The augmented table is an example for a tailored daughter table.

4.4 Potential future uses of the IELab

A fundamental objective of the IELab is to provide a system that is accessible and usable by a research community much larger than just those involved in the development phase. The flexible mother-daughter framework has been designed specifically with this in mind, allowing for future implementations of the IELab that might not have been envisaged by the initial project partners. A broader user engagement will be critical to the incorporation of comprehensive high-quality data specific to certain sectors and/or regions within Australia, and to realising the full benefits of the mother-daughter concept.

Corporate sustainability analysis and reporting applications can be addressed by the IELab, building on the experience of the University of Sydney in developing an input-output approach to triple bottom line reporting ([Foran et al. 2005](#)). Particularly for the calculation of corporate and product Scope-3 emissions (see [WBCSD and WRI 2013](#)), the regional detail of the IELab will bring significant enhancements in reporting accuracy.

Policy applications of the IELab are expected to vary widely, providing assessment of issues such as the triple-bottom-line performance of the Australian economy; regional impacts of the mining boom; effects of region-specific infrastructure projects; effects of alternative

regional forestry policies; effects of different policies to reduce CO₂ emissions; or the economic impacts of drought (Foran et al., 2005; Horridge et al., 2005).

The IELab has already increased the engagement between the IO and LCA research groups involved. The engagement of a wider and more diverse range of potential users and stakeholders has been formalised through the inclusion of key industry and government representatives in the IELab's User Group, which directly informs the project's Steering Committee. Apart from the IELab developers this group currently comprises about 70 members from the wider research community, government departments and authorities, NGOs as well as private sector consultants and analysts with an according diverse range of applications. As a result of the User Group, we expect that the IELab will enhance and create links amongst and between government agencies and industry groups. Last but not least, researchers from other countries have expressed an interest in using the IELab technology for the compilation of sub-national MRIO databases and virtual labs in their home country.

5. Conclusions and outlook

The Commonwealth-funded Australian Industrial Ecology Virtual Laboratory (IELab) is being developed by a consortium of seven different research institutions on NeCTAR cloud-computing resources. The IELab will provide widespread research access to a time series of Australian sub-national MRIO tables that can be rapidly updated over time as new data becomes available. It elegantly integrates detailed data from the atmosphere, hydrosphere, biosphere, lithosphere, and anthroposphere. In addition, it provides harmonisation of previously fragmented, dispersed and mis-aligned raw data, and a suite of common IO and LCA analytical tools that allow consistency of research outputs.

Unlike MRIO tables constructed using more conventional approaches, the IELab no longer imposes the limitation that all users must make do with the same version of the MRIO table. With the IELab, each user may construct a different mother MRIO version, depending on their preference for data sources and MRIO classification structure; their tolerance for data uncertainty; and their need for computational simplicity. Comparisons and trade-offs between different user MRIO versions are facilitated by standard deviation tables that accompany each and every set of results. Users can reduce the mathematical uncertainty by opting for a high degree of aggregation and conservative data selection, if they feel that coarse analytical results are sufficient. Conversely, the user can increase the resolution of the analysis, if they feel this is sufficiently beneficial to outweigh any increased uncertainty in the results. In addition, users will be able to reduce uncertainty in the areas that matter most to them, by introducing superior data to build tailored daughter tables. This flexibility is made possible by the collaborative and unsupervised Virtual Laboratory approach.

In a sense, the difference between our approach and the conventional approach is comparable to the difference between a printed, published encyclopaedia and a Wikipedia site. Rather than having one organisation responsible for data, procedures and quality

assurance, our approach is driven by multiple users uploading their own data onto a cloud environment. The main advantage of the unsupervised approach is that it provides for an effective way to share resources for what has traditionally been a quite labour- and time-intensive task, leading to enhanced timeliness of published results. The strategy to minimise downsides of this 'wiki' approach to MRIO construction includes two key components. Firstly, the IELab will encourage the largest possible number of users to test and critique its data quality. To this end, a diverse set of stakeholders participated in the initial development phase, providing them with a motive for ongoing engagement with the product. More generally, the IELab product is designed to be as easy as possible to use, by the widest possible set of researchers, for the widest possible range of applications. Secondly, the IELab will be strict in requiring that all datafeeds are accompanied by uncertainty information, and a minimum level of documentation. This latter aspect ensures that all users will be able to test and compare the uncertainties associated with any particular customisation of the IELab MRIO tables.

In summary, the IELab in the Virtual Laboratory infrastructure promises: (a) significant savings in terms of human and financial resources, thanks to the collaborative nature of the project; (b) timely deployment, thanks to the automation procedures; and (c) flexibility in future choices about sectoral and spatial representation, thanks to the flexible root-mother-daughter concept.

The IELab development process has been remarkably successful at facilitating collaboration across the large and diverse group of research participants involved. The attraction and power of the IELab concept is that it delivers a product that is more than could be achieved by each individual participant. Enhancing cost-effectiveness, automating data compilation, and providing global stewardship and governance have been identified as key requirements for the advancement of global MRIO compilation and application ([Tukker et al. 2009](#); [Wiedmann et al. 2011](#); [Tukker and Dietzenbacher 2013](#)). We therefore view the Australian IE Lab project as a test bed for a global application of the Virtual Laboratory and flexible root-mother-daughter approach to MRIO compilation.

Implementation of the IELab will significantly advance the analytical capacity of environmental and sustainability science in Australia. This will encourage a rapid expansion of national research efforts required to address the challenges of economic development, occurring in the face of environmental constraints that are growing in number and in urgency.

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Compiling and using input-output frameworks through collaborative virtual laboratories

- Appendices -

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1 Appendix 1: Creating flexible mothers

1.1 A1.1 Background and motivation

The creators of the TERM input-output database chose a master table comprising 206 regions with 172 sectors each, being restricted by available computing power ([Wittwer and Horridge 2010](#)). Indeed, a 206 172-sized square table includes 1.26 billion elements, requiring 10 gigabytes of storage. Similarly, computing power was the limiting factor for choosing the regional and sectoral breakdown for the Eora global Multi-Region Input-Output (MRIO) database. The Eora MRIO tables distinguish transactions between 15,909 sectors expressed in five valuations, including 1.27 billion elements, also requiring 10 gigabytes of storage ([Lenzen et al. 2012](#)).

One disadvantage of the TERM and Eora strategies is that a regional and sectoral table classification of the mother (master) table is fixed, and the choice of this classification limits the set of problems that can be investigated using the mother table or any derived daughter tables. It would be beneficial if daughters could be derived from mothers that incorporated the most detailed regional and sectoral classification possible. The new Australian Statistical Geography Standard (ASGS) published by the Australian Bureau of Statistics includes a Statistical Area Level 2 (SA2) subdivision of the Australian continent into more than 2000 geographical entities ([ABS 2010](#), see a map in Appendix 4). The Australian Input-Output Product Classification (IOPC) distinguishes at its most detailed 4-digit level 1284 industries ([ABS 2012d](#), see a list in Appendix 5). Building a fully populated MRIO mother at this detail would clearly be impossible since processing the required square 2.8million 2.8million-sized matrix would exceed current computational capacities. However, the flexibility of deriving a large variety of daughter tables can be achieved *before* actually building a mother table, by building flexibility into the *mother's* construction algorithms.

Generally speaking, constructing an MRIO table (“MRIO” in short) involves building an initial estimate (IE) and a set of constraints, which are then combined in a mathematical optimisation operation to yield a final MRIO table that satisfies the conditions posed by the constraints in an optimal way ([Temurshoev et al. 2011](#)). In essence, the TERM strategy is to generate CGE simulation tables from a mother table *post*-optimisation. However, as seen earlier, this strategy faces size restrictions. A more advantageous strategy is therefore to introduce another design decision point *pre*-optimisation, during the construction of the IE. Fortunately, such a strategy is feasible because the IEs of MRIOs are generally estimated using non-survey approaches that are characterised by relatively low raw data requirements ([Bonfiglio and Chelli 2008](#); [Sargento et al. 2012](#)). In most non-survey approaches MRIO table IEs can be generated as a function of some regional (r) and sectoral (i) proxy weights w_i^r . Using the above example of a SA2/IOPC combination, this proxy vector would count about 2.8 million elements. One would first need to select a regional and sectoral representation of the MRIO mother suited to the broad family of research

problems at hand, and then simply aggregate the proxy weights *prior to* IE construction, and construct the IE using the aggregated weights. Once a regional and sectoral classification is chosen, the corresponding version of the mother table would then be built and reconciled, and used to derive daughters for subsequent tailored analyses of even more specialised research questions.

1.2 A1.2 Theory and approach

Let $T^{RS} = \{T_{ij}^{od}\} = f(w^{RS}, x)$ represent an $(R * S) \times (R * S)$ -sized non-survey MRIO-IE, with $o=1, \dots, R$ regions and $i = 1, \dots, S$ sectors of origin, and $d=1, \dots, R$ regions and $j=1, \dots, S$ sector of destinations, respectively, and let this IE be a function of $R \times S$ proxy weights $w^{RS} = \{w_i^o\}$ and some national totals x (specific to each non-survey method, see [Gallego and Lenzen 2009](#)). Let M^{RP} be a $R \times P$ -sized row-map (ie a row-normalised $R \times P$ -sized binary concordance C^{RP} , see [Lenzen et al. 2012](#), SI S4.2) that can be used to aggregate any variable in R regions into the same variable in $P < R$ regions, and let M^{SQ} be a $S \times Q$ -sized row-map for aggregating variables from S sectors into $Q < S$ sectors. The P regions and Q sectors are assumed to be chosen by a user to suit to a certain broad family of research problems, and these regions and sectors will therefore be represented in the mother MRIO table. The R regions and S sectors are the classification feedstock, or *root*, from which the problem-specific P regions and Q sectors are being derived. To calculate an IE for the mother MRIO table, aggregated $P \times Q$ proxy weights are first derived from root ($R \times S$ proxy weights via $w^{PQ} = (M^{RP})^t w^{RS} M^{SQ}$, where the superscript t denotes matrix transposition. An aggregated $(P * Q) \times (P * Q)$ -sized non-survey MRIO-IE is then simply $T^{PQ} = \{T_{ij}^{od}\} = f(w^{PQ}, x)$. For example, if a user needed to undertake state-level analysis, worked off the root classification $R \approx 2000$ (SA2 geographical classification) and $S \approx 1200$ (IOPC sector classification), and chose $P = 8$ (Australian States and Territories), and $Q = S \approx 1200$, the aggregated MRIO-IE would measure about $(8 * 1200) \times (8 * 1200)$, and would therefore have about 92 million elements, occupying a feasible 9.2 GB of RAM.

In a flexible Virtual Laboratory (VL) setting, a user first chooses a region and sector representation that is appropriate for a broad area of research problems, then constructs the root-to-mother maps M^{RP} and M^{SQ} , and then uses these maps to construct the $(P * Q) \times (P * Q)$ -sized mother MRIO-IE. This IE can then be used as an input into the mathematical optimisation to yield a final $(P * Q) \times (P * Q)$ -sized mother MRIO table. However, there is one more problem: As described in the main text, a virtual laboratory environment has multiple collaborators writing constraint data feeds containing concordances and *A-LANG* commands, and these concordances and commands need to be constructed for a particular mother MRIO structure and size. If this structure and size are to be kept flexible, then the problem arises of how to configure all users' constraint sets so that they work for each and every possible mother MRIO variant. It is impractical, if not impossible, to write constraints defining the optimisation problem in terms of every conceivable mother MRIO classification $\{p,q\}$, because there are just too many combinatorial classification subsets $\{p,q\}$ contained in the root classification $\{r,s\}$. As a

result, constraints are only ever written once by the virtual laboratory participants, and they are always expressed using the root classification $\{r,s\}$. Once a user has derived a mother classification from the root classification, all constraints need to be adjusted in order to address the selected $(P*Q)\times(P*Q)$ -sized mother MRIO table structure, instead of the $(R*S)\times(R*S)$ -sized root MRIO structure.

1.3 A1.3 Root-to-mother conversion of constraint commands

Assume therefore that collaborators only write constraints containing concordances and *A-LANG* commands that address MRIO entries in the root classification $\{r,s\}$. The root-matching, $\{r,s\}$ -referenced *A-LANG* radicals $[a,b]$, $[a:b]$, $[a;b]$, $[a-b]$, or combinations thereof, can then be converted into $\{p,q\}$ -referenced mother-matching radicals as follows. Without loss of generalisation, consider the $\{r,s\}$ -referenced *A-LANG* radical $[a:b]$, and assume it describes a range of regions. Then, $1^R([a:b])M^{RP}$ is the equivalent $1\times P$ -sized $\{p,q\}$ -referenced radical describing the same regions in the aggregated classification. Here, $1^R([a:b])$ is an $1\times R$ -sized vector with $1^R(x)=1\forall x\in[a,b]$, and 0 elsewhere, and M^{RP} translates from the R -sized MRIO variable root classification to the P -sized aggregated mother classification.

Whenever raw data refer to some sub-aggregate of the MRIO table, the corresponding *A-LANG* command involves a concordance matrix that aggregates the variable spaces addressed in the full MRIO ([Lenzen and Geschke 2013](#)).⁹ Since the columns of this concordance matrix \mathbf{C} refer to the R -sized MRIO variable root classification, they have to be mapped into the P -sized aggregated mother classification. This can be accomplished by post-multiplication of \mathbf{C} with the M^{RP} map.¹⁰

Indeed, a sequence of post-multiplications with a map \mathbf{M} is all that is required to change the reference of an entire constraints set from the root classification to some chosen aggregate mother classification suited to investigate a certain broad family of research problems. It is therefore feasible to establish a system where a large variety of mother initial estimates and MRIO tables can be built from one and the same very detailed raw data, constraints and concordances set, without the need for forever fixing the classification of the mother MRIO.

One note of caution: Depending on the nature of the source data and the mother classification there could occur a number of unwanted effects. These are best described using concrete examples, which follow in the Sections below.

⁹ For example, assume that a particular constraint incorporated two data points referring to a) the total across the Australian Capital Territory (ACT, region 1) and New South Wales (NSW, region 2), and b) Victoria (region 7 out of 8). Assume that all States are broken down into 500 SA4 statistical areas. Then the concordance matrix \mathbf{C} would measure 2×2000 elements, with $C(1,1:999)=1$, $C(2,3000:3499)=1$, and $C=0$ elsewhere.

¹⁰ If $P=8$ and $R=2000$, and \mathbf{C} as in footnote 5, then $\mathbf{C}M^{RP}$ is sized 2×8 , with $C(1,1:2)=1$, $C(2,7)=1$, and $C=0$ elsewhere.

1.4 A1.4 An illustrative example referring to sectors

Without loss of generality, assume that $P = R = 1$, $S = 10$, and $Q = 6$. Hence, $T^S = \{T_{ij}^S\} = f(w^S, x)$ is a $S \times S$ -sized single-region IO-IE, and a function of $1 \times S$ proxy weights $w^S = \{w_i^S\}$ and some national totals x . M^{SQ} is a row-normalised 10×6 -sized map for aggregating variables from $S = 10$ sectors into $Q = 6$ sectors. Aggregated $1 \times Q$ proxy weights are then calculated via $w^Q = w^S M^{SQ}$. The aggregated $Q \times Q$ -sized IO-IE is then $T^Q = \{T_{ij}^Q\} = f(w^Q, x)$.

Assume now that four raw data points are available on sectoral water use (for Agriculture, Mining, Manufacturing, Services, and a combined Mining & Manufacturing data point), and that the matrices C and C^{SQ} take the following specific forms:

	Sheep	Beef	Wheat	Coal	Gas	Man	Util	Trans	Fin	Oth
$C =$	Agriculture	1	1	1						
	Mining			1	1					
	Manufacturing					1				
	Services						1	1	1	1

and

	Agr	Min&Manuf	Elec&Gas	Water	Trans&Fin	Oth
$C^{SQ} =$	Sheep	1				
	Beef	1				
	Wheat	1				
	Coal		1			
	Gas		1			
	Manufacturing		1			
	Utilities			1	1	
	Transport					1
	Finance					1
	Other services					1

The root classification includes the sectors Sheep, Beef, Wheat, Coal, Gas, Manufacturing, Utilities, Transport, Finance, and Other services. The mother classification chosen by the user includes Agriculture, a combined Mining&Manufacturing sector, Utilities split into Electricity&Gas and Water, a combined Transport&Finance sector, and Other services. The user's concordance matrix is a column map, as can be seen by the unitary column sums (see Appendix 2 for definitions). Therefore the root-to-mother concordance also needs to be a column map. As explained in Appendix 2, this is only achievable if C is a row map and

M^{SQ} a column map. Assume that weights $w^S = \{20,70,10,60,40,100,15,25,35,105\}$ on sectoral employment are available to convert C^{SQ} into the following column map (see [Lenzen et al. 2012](#), SI S4.2 on the construction of maps)

	Agr	Min&Manuf	Elec&Gas	Water	Trans&Fin	Oth
Sheep	0.2					
Beef	0.7					
Wheat	0.1					
Coal		0.3				
Gas		0.2				
Manufacturing		0.5				
Utilities			1	1		
Transport					0.42	
Finance					0.58	
Other services						1

The matrix product $C M^{SQ}$ is then a column map as required, and this column map can be used as the new concordance matrix accompanying the constraint file.

	Agr	Min&Manu f	Elec&Gas	Water	Trans&Fin	Oth
Agriculture	1					
Mining		0.5				
Manufacturing		0.5				
Services			1	1	1	1

Examining this product shows that the raw data sector Agriculture is correctly mapped to the mother sector Agriculture. Similarly, the raw data sector Services is correctly mapped to the mother sectors Electricity&Gas, Water, the combined Transport&Finance sector, and Other services. However, the individual raw data sectors Mining and Manufacturing are both mapped against the combined 'Mining&Manufacturing' mother sector, each with a factor of 0.5 derived from the proxy employment weights.

The problem that arises here is that the individual data items 'Mining' and 'Manufacturing' are not useable in the mother classification, because those items are combined there. This becomes evident when the terms $1^S(a)M^{SQ}$ are evaluated for the radicals a of the constraint lines in \mathbf{C} . The radicals a are [1-3], [4-5], [6], and [7-10]. Cast as S -sized rows $1^S(a)$, these radicals are nothing but the rows of the concordance matrix \mathbf{C} . For example, $1^S(a_1) = 1^S([1-3]) = C_{1,:}$, where the subscript notation 1,: denotes the entire first row of \mathbf{C} . We see that $1^S([4-5])M^{SQ} = 1^S([6])M^{SQ} = \{0,0.5,0,0,0,0\}$. If one used these constraints in the balancing of the mother IO table, then exactly half of the water use of the combined 'Mining and Manufacturing' mother sector would be constrained twice, once each to the

individual water use values of Mining and Manufacturing.¹¹ This is unlikely to be a realistic constraint, since the 50% weighting was derived from an employment proxy (in this example), and not from a water use proxy.

Solution #1 would be to exclude such constraints. In these cases we encounter elements $1^R(a)M^{RP} < 1$. This criterion can be used to filter out all constraints that are based on data that are too detailed to be used constrain the aggregated mother MRIO. Only in cases where the mother classification is sufficiently detailed to represent the raw data point, the corresponding constraint will be effective in the optimisation process. However, the filtering would render raw data items 2 and 3 unusable even though in unison they could inform the mother table.

Such an undesirable situation can be avoided using solution #2: deliberately including sub-totals into the raw data set. Adding a fifth raw data item shows that the sum of Mining and Manufacturing water use would be correctly mapped into the combined mother sector.

	S	B	W	C	G	M	U	T	F	O
A										
g										
r										
i										
c										
u	1	1	1							
l										
t										
u										
r										
e										
M										
i										
n										
C										
i										
n										
g										
M										
a										
n										
u										
f										
a										
c										
t										
u										
r										
i										

¹¹ Mathematically: 0.5 Min&Manuf = Mining; 0.5 Min&Manuf = Manufacturing.

n g S e r v i c e s M i n i n g & M a n u f a c t u r i n g	11 11
	1 1 1

	Agr	Min&Manu f	Elec&Ga s	Water	Trans&Fin	Oth
$CM^{(5)SQ} =$ Agriculture	1					
Mining		0.5				
Manufact		0.5				
Services			1	1	1	1
Mining & Manufact		1				

One would still apply solution #1 but then retain the subtotal constraint. The problem with this solution is however that depending on the nature of the root-to-mother concordance, one would have to add all sorts of subtotals. For example imagine another user wanted to combine Agriculture and Mining, and keep Manufacturing separate in the mother

classification. Then another subtotal Agriculture&Mining would be required to preserve the information in the first two raw data items. Ultimately, no one could guess what possible subtotals to add in order to cater for all possible mother configurations.

Fortunately there is another solution (#3) available for dealing with this problem. Instead of only adjusting the concordances of the *A-LANG* radicals, one could also apply a mapping operation to the source data. For this purpose we decompose CM^{SQ} into one row map to accompany the source data, and one column map for addressing the MRIO variable space in the mother classification.

$$M_1 = \begin{matrix} & \text{Agriculture} & & & & & \\ & \text{Mining} & & & & & \\ & \text{Manufacturing} & & & & & \\ & \text{Services} & & & & & \end{matrix} \begin{bmatrix} 1 & & & & & & \\ & & 1 & & & & \\ & & 1 & & & & \\ & & & & & & 1 \end{bmatrix}$$

$$M_2 = \begin{matrix} & \text{Agr} & \text{Min\&Manu} & \text{Elec\&Ga} & \text{Water} & \text{Trans\&Fin} & \text{Oth} \\ & & \text{f} & \text{s} & & & \end{matrix} \begin{bmatrix} 1 & & & & & & \\ & & 1 & & & & \\ & & & 1 & & & \\ & & & & 1 & & \\ & & & & & 1 & \\ & & & & & & 1 \end{bmatrix}$$

M_1 aggregates the four data items into three items, combining items 2 and 3. M_2 relates these to the mother classification. This means that only three pieces of information are usable, not four. The column dimensions of M_1 show that the combined Mining and Manufacturing sector has become sector #2 of 3. The second column of M_2 links directly to the combined Mining&Manufacturing mother sector. This split of a given user concordance into a source data map and a remainder concordance is handled in *A-LANG* by the ‘t’ command ([Lenzen and Geschke 2013](#)).

1.5 A1.5 An illustrative example referring to regions

We now illustrate a situation where source data points refer to particular subsets of statistical areas that do not coincide with the chosen mother classification. Without loss of generality, assume that $R = 10$, $P = 6$, and $S = Q = 1$. Hence, $T^R = [T_{ij}^R] = f(w^R, x)$ is a $R \times R$ -sized single-sector MRIO-IE, and a function of $1 \times R$ proxy weights $w^R = [w_{\square}^R]$ and some national totals x . M^{RP} is a normalised 10×6 -sized map for aggregating variables from $R = 10$ regions into $P = 6$ regions. Aggregated $1 \times P$ proxy weights are then calculated via $w^P = (M^{RP})^t w^R$. The aggregated $P \times P$ -sized MRIO-IE is then $T^P = [T_{\square}^{od}] = f(w^P, x)$.

Assume now that five raw data points are available on regional water use (for New South Wales, Victoria, South Australia, Queensland, and the Australian Capital Territory), and that the matrices \mathbf{C} and M^{RP} take the following specific forms:

	SA1	SA2	SA3	SA4	SA5	SA6	SA7	SA8	SA9	SA10
NSW	1	1	1							
Vic				1	1	1				
SA							1	1		
Qld									1	
ACT										1

and

	C1	C2	C3	C4	C5	C6
SA1	0.2					
SA2	0.8					
SA3		0.3				
SA4		0.2				
SA5		0.5				
SA6			0.6			
SA7			0.1			
SA8			0.3			
SA9				1		
SA10					1	1

where SA1-SA10 are ten detailed statistical areas, and the C1-C6 are six river catchments that do not necessarily align geographically with State and Territory boundaries. The fractions in M^{RP} appear because of the proxy weight vector w^R is assumed to be sectoral employment $w^R = \{20, 80, 30, 20, 50, 120, 20, 60, 35, 105\}$. The root classification includes the statistical areas, whilst the mother classification chosen by the user includes catchments, and the raw data are for States and Territories. The problem that arises here is that the catchment boundaries do not align with the State/Territory boundaries except for Queensland. This becomes evident again in the matrix product CM^{RP} .

	C1	C2	C3	C4	C5	C6
NSW	1	0.3				
Vic		0.7	0.6			
SA			0.4			
Qld				1	1	1
ACT						

Examining this product shows that the State of Queensland is correctly mapped to the Catchments 4-6. Similarly, the Australian Capital Territory is correctly not mapped at all. However, water use from New South Wales (NSW), Victoria (Vic) and South Australia (SA) is equated with sums of various fractions of the water use in Catchments 1-4.¹² These are unlikely to be realistic constraints, since these fractions were derived from an employment proxy (in this example), and not from a water use proxy.

Applying solution #3 to this situation yields

$M_1 =$	i	<table style="border-collapse: collapse; width: 100%; text-align: center;"> <tr><td style="padding: 2px 10px;">NSW</td><td style="padding: 2px 10px;">1</td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td></tr> <tr><td style="padding: 2px 10px;">Vic</td><td style="padding: 2px 10px;">1</td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td></tr> <tr><td style="padding: 2px 10px;">SA</td><td style="padding: 2px 10px;">1</td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td></tr> <tr><td style="padding: 2px 10px;">Qld</td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;">1</td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td></tr> <tr><td style="padding: 2px 10px;">ACT</td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td></tr> </table>	NSW	1					Vic	1					SA	1					Qld			1			ACT					
NSW	1																															
Vic	1																															
SA	1																															
Qld			1																													
ACT																																

and

$M_2 =$	i	<table style="border-collapse: collapse; width: 100%; text-align: center;"> <tr><td style="padding: 2px 10px;">C1</td><td style="padding: 2px 10px;">C2</td><td style="padding: 2px 10px;">C3</td><td style="padding: 2px 10px;">C4</td><td style="padding: 2px 10px;">C5</td><td style="padding: 2px 10px;">C6</td></tr> <tr><td style="padding: 2px 10px;">1</td><td style="padding: 2px 10px;">1</td><td style="padding: 2px 10px;">1</td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td></tr> <tr><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;"></td><td style="padding: 2px 10px;">1</td><td style="padding: 2px 10px;">1</td><td style="padding: 2px 10px;">1</td></tr> </table>	C1	C2	C3	C4	C5	C6	1	1	1							1	1	1
C1	C2	C3	C4	C5	C6															
1	1	1																		
			1	1	1															

M_1 aggregates the five data items into two items, combining States 1, 2 and 3. M_2 relates these to the mother (catchment) classification. This means that only two pieces of information out of five are usable. The column dimensions of M_1 show that the combined NSW, Vic and SA regions have become region #1 of 2. The first row of M_2 links these to the first three catchments. Once again, this split of a given user concordance into a source data map and a remainder concordance is handled in *A-LANG* by the ‘t’ command ([Lenzen and Geschke 2013](#)).

Due to the overlap of three states with three catchments, quite a large percentage of valuable source information has been lost. Moreover, there is no explicit individual information on the first three catchments. There is in principle no remedy to this situation, since economic and physical data are often only collected for entities defined by political boundaries, and not watersheds ([ABS 2012a](#); [e](#)). However, one more option (#4) exists where the user may choose to accept the proxy weighting in the absence of more specific data. In this case C and C^{RP} would be conditioned to generate a row map CM^{RP} . As explained in Appendix 2, this is achievable if C is turned into a column map,

SA1	SA2	SA3	SA4	SA5	SA6	SA7	SA8	SA9	SA10
-----	-----	-----	-----	-----	-----	-----	-----	-----	------

¹² Mathematically: $0.3 C_2 + C_1 = \text{NSW}$; $0.6 C_3 + 0.7 C_2 = \text{Vic}$; $0.4 C_3 = \text{SA}$.

$C =$	NSW	0.15	0.62	0.23					
	Vic				0.11	0.26	0.63		
	SA							0.25	0.75
	Qld								
	ACT							0.25	0.75

and C^{RP} into a row map

$M^{RP} =$		C1	C2	C3	C4	C5	C6
	SA1	1					
	SA2	1					
	SA3		1				
	SA4		1				
	SA5		1				
	SA6			1			
	SA7			1			
	SA8			1			
	SA9				1		
SA10					0.6	0.4	

The row map

$CM^{RP} =$		C1	C2	C3	C4	C5	C6
	NSW	0.77	0.23				
	Vic		0.37	0.63			
	SA			1			
	Qld				0.25	0.45	0.30
ACT							

can then be used to convert the five source data points directly into the mother classification, with no further MRIO variable space concordance needed. Within *A-LANG*, this is handled by the pre-map or post-map commands ([Lenzen and Geschke 2013](#)). This mapping has generated information for individual catchments, but note once again that this was done on the basis of regional employment weights, which may not appropriately reflect regional water use shares.

1.6 A1.6 Root-to-mother conversion log in a Matlab implementation

```
*****
ROOT-TO-MOTHER CONVERSION LOG
-- Region aggregator --
```

1

-- Sector aggregator --

```

0.8000  0  0
0.2000  0  0
  0 0.6000  0
  0 0.4000  0
  0  0 0.7000
  0  0 0.3000

```

-- A-LANG commands --

Command name	On/off switch	Numbering	#parts	RHS or IE flags	Value pre-map	Value post-map	RHS SD or Equation	SD pre-map	SD post-map	Constraint coefficients	Year	Valuation	Or region	Or entity	Or sector	De reg
Root2MotherTest	Y	1	1	I			E MX0.03; MN1;			A /IE.csv	1	1	1	1	1:e	1
Root2MotherTest	Y	2	1	/C1.csv			E MX0.03; MN1;			1	1	1	1	1	1:6 t1 /C1conc.csv	1
Root2MotherTest	Y	3	1	/C2.csv			E MX0.03; MN1;			1	1	1	1	1	2:4 t1 /C2rconc.csv	1
Root2MotherTest	Y	4	1	/C3.csv			E MX0.03; MN1;			1	1	1	1	1	2:5 a /C3rconc.csv	1
Root2MotherTest	Y	5	1	/C4.csv			E MX0.03; MN1;			1	1	1	1	1	2:5	1
Root2MotherTest	Y	6	1	/C5.csv			E MX0.03; MN1;			1	1	1	1	1	2-5	1
Root2MotherTest	Y	7	1	/C6.csv			E MX0.03; MN1;			1	1	1	1	1	5	1

*** Constraint 2, Dimension 5: sector of origin ***

Command concordance before conversion

```

1  0  0  0  0  0
1  0  0  0  0  0
0  1  0  0  0  0
0  1  0  0  0  0
0  0  1  0  0  0
0  0  1  0  0  0
0  0  0  1  0  0
0  0  0  0  1  0
0  0  0  0  0  1

```

A-LANG command before conversion

1:6 t1 /C1conc.csv

Command concordance after conversion

```

0.8000  0  0
0.8000  0  0
0.2000  0  0
0.2000  0  0
  0 0.6000  0
  0 0.6000  0
  0 0.4000  0
  0  0 0.7000
  0  0 0.3000

```

A-LANG command after conversion

1:3 t1 /C1conc_motherAdjusted.csv

*** Constraint 2, Dimension 8: sector of destination ***

Command concordance before conversion

```

1  0  0  0  0  0
1  0  0  0  0  0
0  1  0  0  0  0
0  1  0  0  0  0
0  0  1  0  0  0
0  0  1  0  0  0
0  0  0  1  0  0
0  0  0  0  1  0
0  0  0  0  0  1

```

A-LANG command before conversion

1:6 t2 /C1conc.csv

Command concordance after conversion

```

0.8000  0  0
0.8000  0  0
0.2000  0  0

```

```

0.2000 0 0
0 0.6000 0
0 0.6000 0
0 0.4000 0
0 0 0.7000
0 0 0.3000

A-LANG command after conversion
1:3 t2 /C1conc_motherAdjusted.csv

*****

*** Constraint 3, Dimension 5: sector of origin ***

Command concordance before conversion

0 1 0 0
0 0 1 1

A-LANG command before conversion
2:4 t1 /C2rconc.csv

Command concordance after conversion
0.2000 0 0
0 1.0000 0

A-LANG command after conversion
1:3 t1 /C2rconc_motherAdjusted.csv

*****

*** Constraint 3, Dimension 8: sector of destination ***

Command concordance before conversion

0 0 1 0 0 0
0 0 1 0 0 0
0 0 0 1 1 1

A-LANG command before conversion
3:6 t2 /C2cconc.csv

Command concordance after conversion
0 0.6000 0
0 0.6000 0
0 0.4000 1.0000

A-LANG command after conversion
1:3 t2 /C2cconc_motherAdjusted.csv

*****

*** Constraint 4, Dimension 5: sector of origin ***

Command concordance before conversion

0 1 0 0 0
0 0 1 0 0
0 0 0 1 0
0 0 0 1 0
0 0 0 0 1

A-LANG command before conversion
2:5 a /C3rconc.csv

Command concordance after conversion
0.2000 0 0
0 0.6000 0
0 0.4000 0
0 0.4000 0
0 0 0.7000

A-LANG command after conversion
1:3 t1 /C3rconc_motherAdjusted.csv

*****

*** Constraint 4, Dimension 8: sector of destination ***

Command concordance before conversion

0 0 1
0 1 0
1 0 0
1 0 0

A-LANG command before conversion
1:3 a /C3cconc.csv

Command concordance after conversion
0 0.6000 0

```

```
0.2000 0 0
0.8000 0 0
0.8000 0 0
```

```
A-LANG command after conversion
1:3 t2 /C3cconc_motherAdjusted.csv
```

```
*****
```

```
*** Constraint 5, Dimension 5: sector of origin ***
```

```
Command concordance before conversion
```

```
0 0 0 0 0
0 1 0 0 0
0 0 1 0 0
0 0 0 1 0
0 0 0 0 1
```

```
A-LANG command before conversion
```

```
2:5
```

```
Command concordance after conversion
```

```
0.2000 0 0
0 0.6000 0
0 0.4000 0
0 0 0.7000
```

```
A-LANG command after conversion
```

```
1:3 t1 20130123_NeCTARIELab_AUSMRIO_001_Concordance-2009_001_SectorR2M.txt
```

```
*****
```

```
*** Constraint 5, Dimension 8: sector of destination ***
```

```
Command concordance before conversion
```

```
1 0 0
0 0 0
0 0 1
```

```
A-LANG command before conversion
```

```
1;3
```

```
Command concordance after conversion
```

```
0.8000 0 0
0 0.6000 0
```

```
A-LANG command after conversion
```

```
1:3 t2 20130123_NeCTARIELab_AUSMRIO_001_Concordance-2009_001_SectorR2M.txt
```

```
*****
```

```
*** Constraint 6, Dimension 5: sector of origin ***
```

```
Command concordance before conversion
```

```
0 1 1 1 1
```

```
A-LANG command before conversion
```

```
2-5
```

```
Command concordance after conversion
```

```
0.2000 1.0000 0.7000
```

```
A-LANG command after conversion
```

```
1:3 t1 20130123_NeCTARIELab_AUSMRIO_001_Concordance-2009_001_SectorR2M.txt
```

```
*****
```

```
*** Constraint 6, Dimension 8: sector of destination ***
```

```
Command concordance before conversion
```

```
1 0 1
```

```
A-LANG command before conversion
```

```
1,3
```

```
Command concordance after conversion
```

```
0.8000 0.6000 0
```

```
A-LANG command after conversion
```

```
1:3 t2 20130123_NeCTARIELab_AUSMRIO_001_Concordance-2009_001_SectorR2M.txt
```

```
*****
```

```
*** Constraint 7, Dimension 5: sector of origin ***
```

```
Command concordance before conversion
```

```

0 0 0 0 0
0 0 0 0 0
0 0 0 0 0
0 0 0 0 0
0 0 0 0 1
A-LANG command before conversion
5
Command concordance after conversion
0 0 0.7000
A-LANG command after conversion
1:3 t1 20130123_NeCTARIELab_AUSMRIO_001_Concordance-2009_001_SectorR2M.txt

*****
*** Constraint 7, Dimension 8: sector of destination ***
Command concordance before conversion
0 0 0
0 0 0
0 0 1
A-LANG command before conversion
3
Command concordance after conversion
0 0.6000 0
A-LANG command after conversion
1:3 t2 20130123_NeCTARIELab_AUSMRIO_001_Concordance-2009_001_SectorR2M.txt

```

2 Appendix 2: Concordances and maps – basic definitions

Assume two countries R and S with their classifications $r = 1, \dots, R$ and $s = 1, \dots, S$, and a root classification $h = 1, \dots, H$ and $H > \{R, S\}$. A *concordance matrix* is a binary (0-1) matrix that represents mutual belonging of classes. A concordance matrix \mathbf{C}_{HR} has dimensions $H \times R$, a concordance matrix \mathbf{C}_{RS} has dimensions $R \times S$, and so on. Concordance elements are $C_{ij} = 1$ if a either a part of class i in system R is part of class j in system S or vice versa.

A *row map* is a concordance matrix normalised so that row sums equal 1: $M_{\text{row},ij} = C_{ij} / \sum_j C_{ij}$. A *column map* is a concordance matrix normalised so that column sums equal 1: $\mathbf{M}_{\text{col},ij} = C_{ij} / \sum_i C_{ij}$. A concordance matrix that is already either a row map or a column map is called a *one-way concordance* or *unambiguous concordance*. A concordance matrix that is neither a row map nor a column map is called a *two-way concordance* or *ambiguous concordance*. A row map is used to uniquely distribute row values across columns. A column map is used to uniquely distribute column values across rows.

A concordance between the R and the S system can in principle be determined from the HR and HS concordances by $\mathbf{C}_{RS} = \mathbf{C}_{HR}' \mathbf{C}_{HS}$, where the prime denotes transposition. For example, let

$$\mathbf{C}_{HR} = \begin{matrix} & \begin{matrix} 1 & 0 & 0 & 0 \end{matrix} \\ \begin{matrix} 0 \\ 0 \\ 0 \\ 0 \end{matrix} & \begin{matrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{matrix} \end{matrix}$$

0 0 0 1

and

$$\mathbf{C}_{HS} = \begin{matrix} & \begin{matrix} 1 & 0 & 0 & 0 \end{matrix} \\ \begin{matrix} 1 \\ 1 \\ 1 \\ 0 \\ 0 \end{matrix} & \begin{matrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{matrix} \end{matrix}$$

Then,

$$\mathbf{C}_{RS} = \begin{matrix} & \begin{matrix} 1 & 0 & 0 & 0 \end{matrix} \\ \begin{matrix} 1 \\ 1 \\ 1 \\ 1 \end{matrix} & \begin{matrix} 0 \\ 0 \\ 0 \\ 1 \end{matrix} \end{matrix}$$

This shows that a product of two maps is not necessarily a map. It is also possible to show that the product of two maps does not even necessarily contain only 0s and 1s. To generate a row map for \mathbf{C}_{RS} , \mathbf{C}_{HR} has to be a column map, and \mathbf{C}_{HS} has to be a row map. The opposite applies for generating a column map for \mathbf{C}_{RS} .

Maps normalised according to their row or column sums do not necessarily reflect the correct proportions of multiple class belonging. For example, if one of the classes has only minor output, then its entry in a map should be less than its proportional share in the concordance.

How else can a concordance be normalised other than through its row or column sums? Assume that certain data \mathbf{w}_H exist in the H classification, and certain other data \mathbf{w}_R in the R classification. Then, \mathbf{C}_{HR} can be normalised to a row map using the R data as weights: $M_{row,HR,ij} = C_{HR,ij} w_{R,j} / \sum_j C_{HR,ij} w_{R,j}$, or it can be normalised to a column map using the H data as weights: $M_{col,HR,ij} = C_{HR,ij} w_{H,i} / \sum_i C_{HR,ij} w_{H,i}$.

2.1 A2.1 Example

Let

$$\mathbf{C}_{HR} = \begin{matrix} & \begin{matrix} 1 & 0 & 0 & 0 \end{matrix} \\ \begin{matrix} 1 \\ 1 \\ 0 \end{matrix} & \begin{matrix} 0 \\ 0 \\ 1 \end{matrix} \end{matrix}$$

$$\begin{matrix}
 0 & 0 & 0 & 1 \\
 0 & 0 & 0 & 1 \\
 0 & 0 & 0 & 1
 \end{matrix}$$

and

$$\mathbf{C}_{HS} = \begin{matrix}
 1 & 0 & 0 \\
 1 & 0 & 0 \\
 1 & 0 & 0 \\
 0 & 1 & 0 \\
 0 & 0 & 1
 \end{matrix}$$

To generate a column map for \mathbf{C}_{RS} , \mathbf{C}_{HR} has to be transferred into a row map, and \mathbf{C}_{HS} has to be transferred into a column map. Let the weights $\mathbf{w}_R = \{200,300,400,100\}$.

Then the row map is

$$\mathbf{M}_{HR} = \begin{matrix}
 1 & 0 & 0 & 0 \\
 1 & 0 & 0 & 0 \\
 0 & 0.43 & 0.57 & 0 \\
 0 & 0 & 0 & 1 \\
 0 & 0 & 0 & 1 \\
 0 & 0 & 0 & 1
 \end{matrix}$$

In order to transfer \mathbf{C}_{HS} into a column map, we need weights classed H . Let the weights $\mathbf{w}_H = \{5,3,6,3,2,4\}^t$.

Then the column map is

$$\mathbf{M}_{HS} = \begin{matrix}
 0.29 & 0 & 0 \\
 0.18 & 0 & 0 \\
 0.35 & 0 & 0 \\
 0.18 & 0 & 0 \\
 0 & 1 & 0 \\
 0 & 0 & 1
 \end{matrix}$$

Multiplying both maps as $\mathbf{M}_{RS} = \mathbf{M}_{HR}' \mathbf{M}_{HS}$ yields the desired column map

$$\begin{matrix}
 0.47 & 0 & 0
 \end{matrix}$$

$$\mathbf{M}_{RS} = \begin{matrix} & & 0.15 & 0 & 0 \\ & & 0.20 & 0 & 0 \\ & & 0.18 & 1 & 1 \end{matrix}$$

3 Appendix 3: Format of supply-use data published by the ABS

There exist minor conceptual differences between the published input-output data (Fig. A1 left, [ABS 2012c](#)), and recoverable from the product details data (right, [ABS 2012b](#)). The published input-output tables are expressed in the Input-Output Industry Group (IOIG) classification, whilst the product details are available for the Input-Output Product Classification (IOPC) in the product dimension. IOPC distinguishes more than 1200 products and is therefore significantly more detailed than IOIG, which counts slightly more than 100 industries; this is reflected in Fig. A1 by the different sizes of the rectangles. In both databases, margins \mathbf{m} , net taxes on products \mathbf{t}_p are provided as full matrices accompanying use and final demand, but in order not to overload the diagram these are shown here as additional rows in value added. Value added is not listed amongst the product details since it is identical to the data in the input-output tables; this is reflected by the grey variable letter.

The main conceptual difference is that in the published input-output data, imports \mathbf{M} are appended as matrices below the use block \mathbf{U} in order to facilitate the industry balance \mathbf{x}_i . In the product details data, imports \mathbf{M} are appended as one row below the supply block \mathbf{V} in order to facilitate the product balance \mathbf{x}_p . The industry balance \mathbf{x}_i is unaffected by these differences. In the published input-output data, use \mathbf{U} and final demand \mathbf{y} are published inclusive of imports (\mathbf{M} and \mathbf{M}_y , respectively), but because imports tables are provided, domestic and imported production can be separated. This is not possible for the product details data since only a row vector of imports is provided.

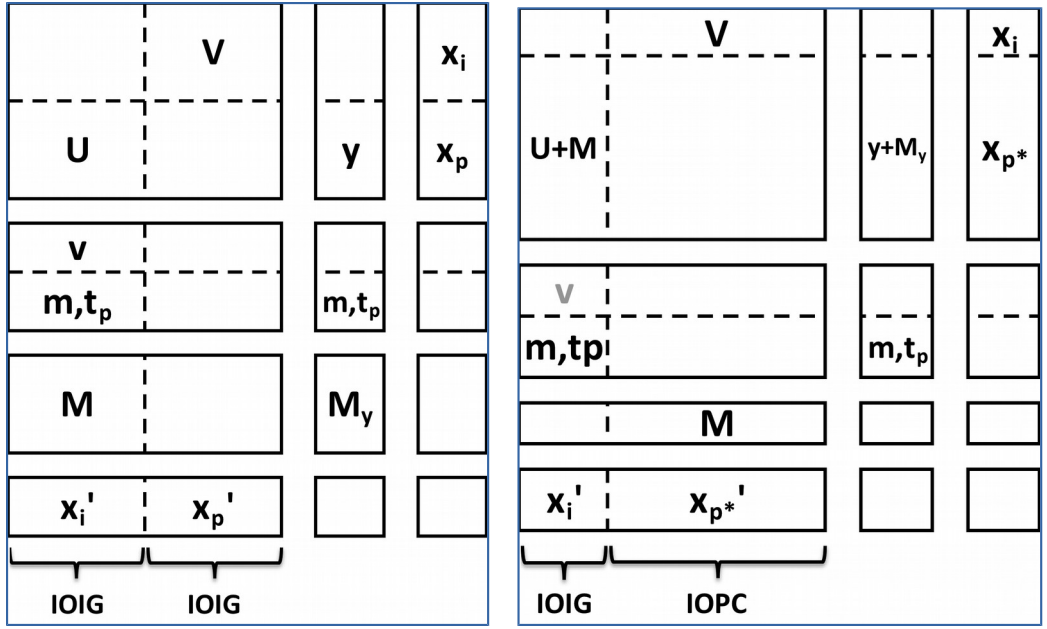


Fig. A3.1: Supply-use system in the published input-output data (left, [ABS 2012c](#)), and recoverable from the product details data (right, [ABS 2012b](#)).

4 Appendix 4: SA2 geographical root classification

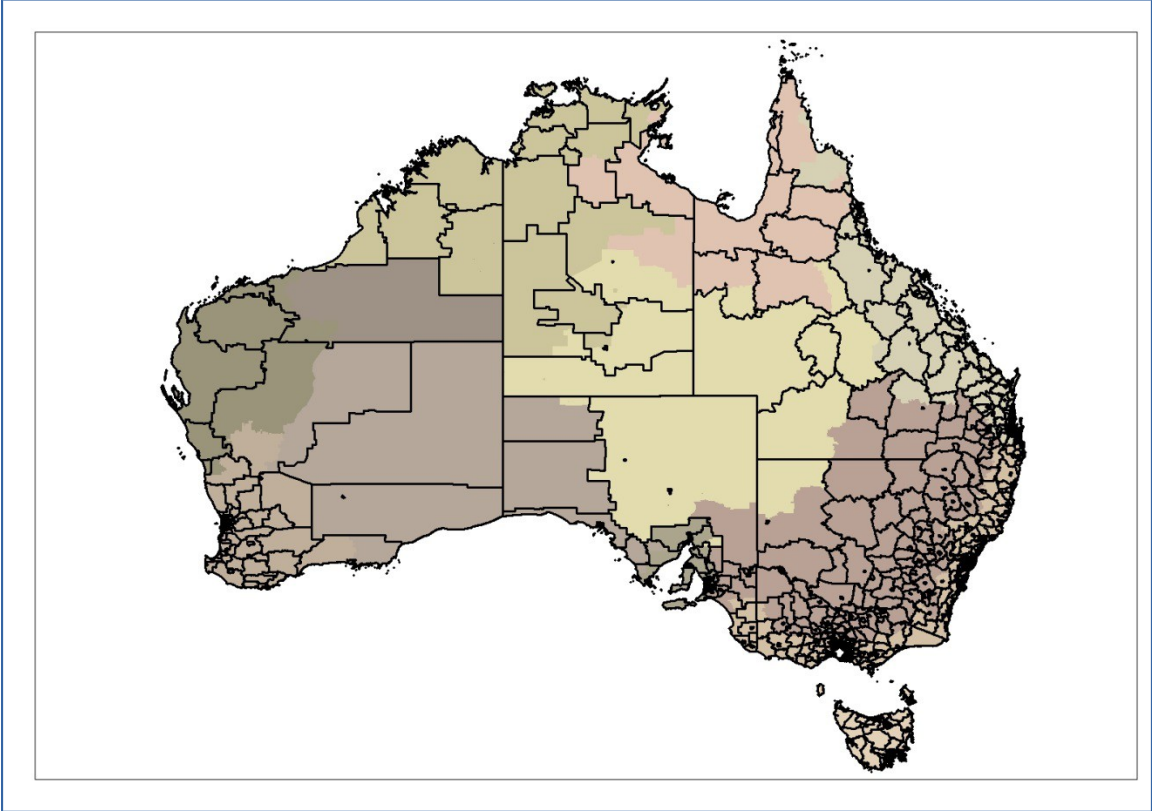


Fig. A4.1: Map of the Australian SA2 regions, which form the spatial root classification used in the Australian Industrial Ecology Lab (IELab). The individual SA2 regions ([ABS 2010](#), shown with the black boundaries) vary in size, according to varying population density and other factors. Also shown are the major Australian river basins ([ABS 2011](#), shown as shaded areas), which are aligned with the data used for the water satellite accounts in the IELab. The latter are provided as an example of how the highly disaggregated spatial root classification provides significant opportunity to better align the MRIO with real-life environmental issues of relevance.

5 Appendix 5: IOPC sectoral root classification

IOPC code	IOPC descriptor
01110010	Plants grown undercover
01120010	Plants grown outdoors
01130010	Turf
01140010	Flowers (incl cut flowers) and flower seeds grown undercover
01150010	Flowers (incl cut flowers) and flower seeds grown outdoors
01210010	Mushrooms, fresh or chilled
01210020	Mushroom spawn
01220010	Lettuces grown undercover
01220020	Tomatoes grown undercover
01220030	Other vegetables, fresh or chilled, grown undercover
01230010	Lettuces grown outdoors
01230020	Tomatoes grown outdoors
01230030	Potatoes, sweet potatoes and edible roots and tubers nec grown outdoors
01230040	Beans, french and runner; peas, green or blue grown outdoors
01230050	Cabbages, brussels sprouts, cauliflowers and headed broccoli grown outdoors
01230060	Carrots grown outdoors
01230070	Onions grown outdoors
01230080	Vegetable seeds
01230090	Other vegetables (incl. melons), fresh or chilled grown outdoors
01310010	Grapes - table
01310020	Grapes - wine
01310030	Grapes sun-dried or for drying
01320010	Kiwi fruit
01330010	Strawberries
01330020	Berries nec - fresh and sun-dried
01340010	Apples - fresh and sun-dried
01340020	Pears and quinces - fresh and sun-dried
01350010	Stone fruit - fresh and sun-dried
01360010	Citrus fruit - fresh and sun-dried
01370010	Olives - fresh and sun-dried
01390010	Bananas - fresh and sun-dried
01390020	Orchard fruit nec - fresh and sun-dried
01390030	Almonds and macadamias
01390040	Edible nuts (excluding Peanuts) nec; Other fruit nec - fresh and sun-dried
01400010	Sheep and lambs
01400020	Wool (shorn and dead)
01400030	Sheep and lamb products nec
01400040	Sheep and beef cattle agistment services

01400050 Beef cattle and calves
 01400060 Beef cattle and calves products (excluding Milk) nec
 01400070 Rice, in the husk
 01400080 Wheat (incl spelt) and meslin, unmilled
 01400090 Barley, unmilled
 01400100 Oats, unmilled
 01400110 Grain, sorghum
 01400120 Lupins (white or yellow) for grain
 01400130 Oilseeds
 01400140 Legumes for grain nec
 01400150 Cereal grains nec
 01510010 Sugar cane (for planting or crushing)
 01520010 Cotton (excl ginned)
 01590010 Forage sorghum
 01590020 Forage products nec
 01590030 Tobacco
 01590040 Beverage and spice crops
 01590050 Grass, lucerne and clover seed
 01590060 Hay, cereal grasses and fodder
 01590090 Peanuts
 01590110 Natural rubber
 01590120 Crops nec
 01600010 Whole milk, chilled but otherwise untreated
 01600020 Dairy cattle
 01710010 Poultry, for slaughtering
 01720010 Eggs
 01720020 Egg laying hens
 01800010 Deer
 01910010 Thoroughbred horses
 01910020 Horse stud and breeding services; horses nec
 01910030 Horse Agistment Services
 01920010 Pigs
 01930010 Unblended honey and beeswax
 01990010 Pet breeding and live animals nec
 01990020 Livestock products nec
 02000010 Farmed oysters (including Pearl), paua and molluscs nec
 02000020 Farmed seaweed
 02000030 Farmed fish and fish hatchery products
 02000040 Farmed prawns and crustaceans nec
 02031980 General government consumption of fixed capital (0201-0203)
 03010010 Natural gums and resins (incl oleoresins)
 03010020 Softwoods (conifers) growing
 03010030 Hardwoods, brushwoods, scrubwoods - growing
 03010040 Forest products nec
 03020010 Softwoods (conifers) logs
 03020020 Hardwoods, brushwoods, scrubwoods - logs; hewn timber and timber nec (incl firewood)
 03021980 General government consumption of fixed capital (0301-0302)
 04110010 Rock lobster and crab
 04120010 Prawns
 04130010 Fish and squid (line fishing)
 04140010 Fish (trawling or netting)
 04190010 Oysters and other aquatic invertebrates nec, live, fresh or chilled
 04190020 Coral and similar, shells of molluscs; natural animal sponges; algae, fresh or dried
 04190030 Freshwater fish and aquatic animals nec
 04200010 Skins and pieces, raw
 04200020 Wildlife culling services
 04200030 Hunting and trapping products nec
 04201980 General government consumption of fixed capital (0411-0420)
 05100010 Services to forestry nec
 05210010 Cotton (ginned), cotton seed, waste from cotton and cotton ginning services
 05220010 Sheep shearing services

05290010 Aerial agricultural services
 05290020 Services to agriculture nec
 05290030 Services to fishing nec
 05290040 Wool classing services
 05291980 General government consumption of fixed capital (0510-0529)
 06000010 Black coal (all types incl briquettes)
 06000020 Brown coal-lignite (incl briquettes)
 07000010 Crude oil (incl condensate)
 07000020 Liquefied natural gas
 07000030 Natural gas (in the gaseous state)
 07000040 Coal gas, water gas, producer gas and similar gases (excl petroleum gases and other gaseous hydrocarbons)
 08010010 Iron ore (incl treatment; excl pelletising)
 08010020 Agglomerated iron ores nec (incl iron ore pellets and sintered ores)
 08020010 Bauxite
 08030010 Copper concentrates, oxides and ores
 08040010 Gold bullion and ores
 08050010 Beneficiated ilmenite, ilmenite and leucoxene concentrates
 08050020 Rutile concentrates
 08050030 Monazite, xenotime and zircon concentrates; mineral sand ores nec
 08060010 Nickel ores and concentrates
 08070010 Lead ores and concentrates (excl silver-lead-zinc ores)
 08070020 Silver and zinc ores
 08090010 Tin, tin-copper and tin-tantalite concentrates
 08090020 Uranium concentrates
 08090030 Manganese ores
 08090040 Non-ferrous metallic ores and concentrates nec (incl tungsten)
 09110010 Gravel
 09110020 Sand
 09190010 Dimension stone
 09190020 Pebbles, broken or crushed stone, macadam, tarred macadam, granules, chippings and powder of stone
 09190030 Limestone (incl shell and coral)
 09190040 Clays nec (incl brick, pipe, tile and shale)
 09190050 Construction materials (mined) nec (incl decomposed rock, residues, etc) (excl crushed and broken stone and dimension stone)
 09900010 Salt
 09900020 Precious and semi-precious gemstones (incl garnet concentrate)
 09900030 Gypsum; anhydrite; calcareous stone of a kind used for the manufacture of lime or cement (excluding limestone)
 09900040 Silica
 09900050 Natural phosphates and Phosphate rock (unground)
 09900060 Chemical and fertilizer minerals nec
 09900070 Non-metallic minerals nec
 10110010 Petroleum exploration
 10120010 Mineral exploration
 10900010 Mining services nec
 10901980 General government consumption of fixed capital (1011-1090)
 11110010 Fresh meat, chilled or frozen (excl kangaroo or horse meat, other than for human consumption)
 11110020 Fresh kangaroo or horse meat, other than for human consumption
 11110030 Casings, bungs, weasands and runners (incl gut materials for further processing)
 11110040 Edible offals (excl poultry offals)
 11110050 Edible tallow (excl refined)
 11110060 Inedible tallow (excl refined) and other unrefined animal oils and fats
 11110070 Raw hides and skins
 11110080 Meat (excl fresh) for human consumption
 11110090 Blood meal (milled or screened dried blood) for use as stock or poultry feed
 11110100 Inedible meat or meat offal flours, meals and pellets; greaves
 11110110 Other animal products nec
 11120010 Poultry and poultry products (incl canned)
 11130010 Bacon and ham and other dried, salted or smoked pigmeat (incl canned)
 11130020 Smallgoods nec (incl crumbed lamb cutlets, cured meat (canned or uncanned), frankfurters, saveloys and salami)

11131700 Meat and meat products - commission production (1111-1113)
 11200010 Fish, canned
 11200020 Frozen whole fish, fish fillets and fish meat; fish loaf, cake, balls and paste; smoked fish; fish fingers; caviar
 11200030 Rock lobster and crayfish (incl tails), chilled or frozen (incl boiled and frozen)
 11200040 Crustaceans, molluscs & aquatic invertebrates nec (chilled, frozen, preserved or otherwise prepared)
 11200050 Inedible flours, meals, pellets & other products nec of fish, crustaceans & molluscs or other aquatic invertebrates
 11201700 Processed seafood - commission production
 11201980 General government consumption of fixed capital (1120)
 11310010 Processed liquid milk (incl whole milk and skim)
 11310020 Cream (incl thickened), not concentrated or sweetened
 11320010 Ice cream and frozen confections
 11330010 Flavoured whole milk drinks
 11330020 Sour cream, yoghurt and other cultured milk products
 11330030 Buttermilk
 11330040 Fats and oils derived from milk (incl butter oil); casein
 11330050 Butter
 11330060 Cheese and curd
 11330070 Milk based food preparations (excluding malt extracts) and dried milk based mixes
 11330080 Milk and cream, concentrated or sweetened; lactose and lactose syrup; products of natural milk constituents nec
 11331700 Dairy products - commission production (1131-1133)
 11400010 Jams
 11400020 Fruit juices, single strength or concentrated
 11400030 Dried fruit (excl sun-dried)
 11400040 Preserved fruit and fruit products nec
 11400050 Vegetables, frozen
 11400060 Vegetables, prepared or preserved (incl dried or shelled)(excl frozen); pickles and chutney
 11400070 Tomato pulp, puree and paste
 11400080 Mixed meat and vegetables, canned
 11400090 Vegetable juices (incl mixtures)(incl tomato); mixtures of vegetable and fruit juices
 11400100 Pasta products, canned
 11400110 Soup and homogenised food preparations including fruit, vegetables, meat or composites thereof
 11400120 Sauces (excl worcestershire and apple); vinegar (excl wine vinegar)
 11400130 Fresh vegetable salads, in plastic containers
 11400140 Fruit and vegetable based health, invalid or baby preparations
 11400150 Dried roots, tubers and vegetables; Flour and meal of vegetables nec.
 11401700 Fruit and vegetable products - commission production
 11500010 Crude soya bean, cotton seed, peanut, sunflower, safflower, rape seed, coconut and vegetable oils
 11500020 Refined and processed animal or vegetable oils and fats (incl tallow) (excl neatsfoot, wool grease and lanolin)
 11500030 Margarine
 11500040 Oil-cake, acid oils, cotton linters and other solid residues resulting from the extraction or refining of vegetable fats or oils
 11501700 Oils and fats - commission production
 11610010 Wheat and other cereal flours (incl self-raising)
 11610020 Flour mill products nec, for human consumption
 11610030 Wheat bran for human consumption (excl for breakfast food)
 11610040 Starch of wheat and corn
 11610050 Glucose, glucose syrup (incl dextrose) and modified starches (incl dextrans)
 11610060 Wheat gluten and tapioca
 11610070 Prepared baking powders
 11610080 Malt (excl malt extract)
 11610090 Malt extract
 11610100 Rice (husked, semi-milled or wholly milled)
 11610110 Rice groats, meals and pellets; other worked cereal grains and products nec;
 11620010 Cereal foods (incl breakfast foods)
 11620020 Mixes and doughs nec (incl custard powder) for preparation of bakers wares (excl frozen)
 11620030 Pasta
 11621700 Grain mill and cereal products - commission production (1161-1162)
 11700010 Bread and bread rolls
 11700020 Biscuits and biscuit crumbs; rusks; ice cream cones and wafers; unleavened bread

11700030 Cakes, pastries and crumpets
 11700040 Meat pies
 11700050 Biscuit and bread dough (incl frozen)
 11701700 Bakery products - commission production (1171-1174)
 11810010 Raw and refined sugar in solid form (incl brown sugar)(excl icing sugar)
 11810020 Icing sugar, molasses (incl treacle) and sugar nec
 11810030 Liquid refined sugar, golden syrup, artificial honey, starch and sugar products nec
 11820010 Chocolate confectionery (excl chocolate coated biscuits and white chocolate)
 11820020 Cocoa beans (roasted); cocoa paste, powder, butter, fat or oil
 11820030 Other food preparations containing cocoa (excl chocolate confectionery)
 11820040 Chewing gum, white chocolate and other confectionery not containing cocoa
 11820050 Crystallised, drained and glace fruit, nuts and peel
 11821700 Sugar and confectionery - commission production (1181-1182)
 11910010 Potato crisps and flakes
 11910020 Corn chips; taco, tortilla and tostada shells
 11920010 Dog and cat food (excl canned)
 11920020 Dog and cat food, canned
 11920030 Bran, sharps and other residues (excl rice, wheat and rye), for animal feed
 11920040 Prepared animal and bird feeds nec (incl poultry pellets, crumbles and mash)
 11920050 Cereal groats, meals, pellets and other cereal products nec, other than for human consumption
 11990010 Coffee and tea, including substitutes
 11990020 Yeast and yeast extracts
 11990030 Nuts, roasted
 11990040 Spices
 11990050 Mustard; worcestershire sauce; mayonnaise and salad dressing
 11990060 Flavouring essences, industrial
 11990070 Prepared meals (incl TV dinners), of meat or meat offal
 11990080 Bakers' wares nec (incl pretzels and frozen pizza) (excl bread and pies)
 11990090 Peanut butter and other nut butters, pastes and purees; jams
 11990100 Refined salt (cooking and table)
 11990110 Gelatine
 11990120 Food products nec (incl jelly crystals, meat pastes)
 11991700 Other food products - commission production (1191-1199)
 11991970 Waste from the manufacture of food, food products and beverages (excl alcohol) (1111-1211)
 11991980 General government consumption of fixed capital (1191-1199)
 12110010 Natural and artificial mineral waters and aerated waters (excl sweetened or flavoured)
 12110020 Natural water nec
 12110030 Mineral waters and aerated waters, sweetened or flavoured, canned
 12110040 Mineral waters and aerated waters, sweetened or flavoured, bottled
 12110050 Cordials and syrups; powder flavours for soft drinks; concentrated cordial extracts
 12110060 Sweetened or flavoured bulk pre-mix & post-mix concentrates for mineral & aerated waters; non-alcoholic beverages nec
 12110070 Ice
 12111700 Soft drinks, cordials and syrups - commission production
 12120010 Beer, ale and stout, bottled
 12120020 Beer, ale and stout, canned
 12120030 Beer, ale and stout, bulk
 12121700 Beer - commission production
 12130010 Whisky, brandy, rum, gin and fortified spirits; other distilled alcoholic beverages (incl liqueurs and mixed drinks)
 12130020 Vermouth and distillation wine
 12140010 Wines (incl sparkling) of grapes and other fruit (excl vermouth)
 12140020 Cider, perry, mead and wine-based mixed drinks (coolers)
 12140030 Vinegar from wine
 12141700 Wine, spirits and other alcoholic beverages - commission production (1213-1214)
 12141970 Waste from the manufacture of alcohol (1212-1214)
 12200010 Cigarettes, cigars, cheroots and tobacco
 12201700 Cigarette and tobacco products - commission production
 12201970 Waste from the manufacture of tobacco products
 13110010 Wool, scoured or carbonised (degreased but not carded or combed)
 13110020 Wool tops; noils of wool or fine animal hair

13110030 Wool grease and fatty substances derived from wool grease (incl lanolin)
 13120010 Yarn and thread (excl chenille, loop wale, elastic or elastomeric) of natural fibres (incl worsted) nec
 13120020 Chenille, loop wale yarn and thread of natural fibres
 13120030 Natural textile fibres prepared for spinning nec
 13120040 Narrow woven textile fabrics (incl tape) (excl bias binding) of natural fibres; tyre cord fabric of high tenacity yarn of natural fibres
 13120050 Woven and broadwoven pile, chenille and terry fabrics of cotton or other natural fibre (excl narrow fabrics)
 13120060 Woven and broadwoven fabrics of natural fibres, other than cotton, nec (excl pile, chenille and terry)
 13120070 Woven and broadwoven fabrics of cotton (excl pile, chenille and terry)
 13130010 Textured, high tenacity, single, elastomeric, synthetic or artificial yarns and threads nec
 13130020 Gimped yarn and strip; chenille and loop-wade yarn; woven or broadwoven fabrics of metal thread and metallised yarn nec
 13130030 Elastomeric yarn of cotton, wool or fine animal hair (containing polyurethane or similar thread, excl rubber thread)
 13130040 Yarn of glass fibre
 13130050 Woven or broadwoven fabric of artificial or synthetic filaments and fibres (excl pile or chenille)
 13130060 Woven pile fabrics and chenille fabrics (other than narrow fabrics) of man-made fibres
 13130070 Narrow woven textile fabrics (incl tape) (excl bias binding) of synthetic fibres; tyre cord fabric of high tenacity yarn of synthetic fibres
 13131700 Textiles - commission production (1311-1313)
 13200010 Leather, vegetable or chrome tanned (incl re-tanned), dressed or finished; chamois leathers
 13200020 Leather (excl dressed or finished)
 13200030 Raw hides and skins, pickled or otherwise preserved
 13200040 Tanned or dressed skins, with hair or wool retained (incl sheepskin rugs)
 13200050 Handbags, suitcases, bags, travel sets for personal toilet articles, purses, key cases, wallets and billfolds (excl paper)
 13200060 Saddlery and harness, of any material; leather articles nec
 13200070 Rucksacks of leather or leather substitute
 13201700 Tanned leather, dressed fur and leather products - commission production
 13310010 Carpets and other textile floor coverings (incl mats and matting) (excl felt and underfelt)
 13320010 Rope and cable (excl wire), cordage (excl tyre cord yarn), twine or net products
 13330010 Textile interior furnishing articles (incl blankets (excl electric), wall coverings, curtains, bed and table linen nec)
 13330020 Towels (incl tea towels) and face washers of cotton terry towelling or similar cotton terry fabrics
 13330030 Baby napkins of textile fabrics
 13330040 Textile quilted prods, hose/tubing, nonwovens, (bonded & yarn fabrics)
 13330050 Curtains in the piece (incl continuous), knitted or crocheted
 13330060 Textile tarpaulins (incl canvas), sails, tents, annexes, pneumatic mattresses and motor vehicle covers
 13330070 Blinds and awnings of textile fabrics (incl canvas) and woven textile materials (incl cotton)
 13330080 Bags, sacks and packets of textile or canvas
 13330090 Textile motor vehicle seat covers
 13330100 Pillows, cushions, bolsters, bean bags and stuffed mattress protectors (excl those of or stuffed with rubber)
 13330110 Floor-cloths, dishcloths, dusters and similar cleaning cloths
 13330120 Textile life jackets, life-belts, sleeping bags, parachutes and other cut and sewn textile products nec
 13340010 Labels and badges with printed or woven lettering or design
 13340020 Textile finishing nec
 13340030 Felt floor coverings (exclude underfelt)
 13340040 Underfelt and other felt products (excl floor coverings, headwear or clothing)
 13340050 Textile fabrics (excl rubber or plastic coated) & articles (excl bags) of a kind commonly used in machinery or plant
 13340060 Wadding, powder puffs, pads, cotton wool, gauze and bandages
 13340080 Articles of bonded fibre or yarn fabrics (excl labels & badges); tapestries, textile sutures, transmission and conveyor belts, textile articles nec
 13340090 Braids, tassels, tulle; lace or embroidery, strips or motifs
 13340100 Special fabrics nec
 13340110 Garment dyeing service
 13341700 Textile products - commission production (1331-1334)
 13341980 General government consumption of fixed capital (1331-1334)
 13400010 Hosiery (incl pantyhose, stockings, tights and socks)
 13400020 Pullovers, jumpers, sweaters and cardigans - knitted
 13400030 Knitted or crocheted pile fabrics (excl elastic or elastomeric)

13400040 Knitted or crocheted fabric nec
 13400050 Knitted products nec
 13401700 Knitted products - commission production
 13510010 Mens and boys trousers (excl suits), shorts, jeans, overalls and work shirts, dustcoats, textile (excl waterproof)
 13510020 Men's & boys' suits or uniforms (incl trousers for suits & uniforms), coats & jackets, textile (excl waterproof)
 13510030 Women's and girls' dresses, skirts, slacks, shorts, tunics, uniforms, jeans, overalls, leotards, coats, capes, suits and ensembles
 13510040 Shirts and blouses (with collars)
 13510050 T-shirts and tank tops
 13510060 Swimwear; sweatsuits, tracksuits, jogging suits, leisure suits and jumpsuits
 13510070 Foundation garments (incl brassieres, corsets and girdles)
 13510080 Underwear
 13510090 Outer nightwear (incl dressing gowns and robes) and sleepwear
 13510100 Waterproof, plastic or rubber trousers, overalls, coats and jackets
 13510110 Plastic (unsupported film) clothing other than waterproof
 13510120 Wetsuits and other rubber clothing and accessories nec (incl gloves, belts)(excl headgear)
 13510130 Fur and sheepskin clothing and clothing accessories (excl headwear, footwear, handbags, purses and toys)
 13510140 Hats and other headgear (excl safety, rubber or plastic)
 13510150 Safety headgear; textile belts for clothing; plastic clothing accessories (excl belts and disposable gloves)
 13510160 Safety eyewear (industrial or sporting)(incl goggles)
 13510170 Clothing and clothing accessories nec
 13511700 Clothing - commission production
 13520010 Footwear with uppers and outer soles of rubber or plastic (incl waterproof footwear and thongs) (excl sports footwear)
 13520020 Footwear with uppers of leather and outer soles of rubber or plastic (excl sports footwear)
 13520030 Sports footwear
 13520040 Footwear with uppers of leather and outer soles of leather or composition leather (excl sports footwear)
 13520050 Footwear nec (incl steel capped footwear)
 13520060 Soles of or cut from rubber or rubber composition and parts of footwear nec (incl plastic heels)
 13521700 Footwear - commission production
 13521970 Waste from the manufacture of textiles, clothing or footwear (1311-1352)
 14110010 Undressed sawn timber from logs sawn at same establishment (incl treated (excl impregnated sleepers or resawn)); shooks
 14110020 Treated wood in the rough (excl sawn timber, dressed or undressed); impregnated railway sleepers
 14110030 Ground bark
 14120010 Woodchips, softwood
 14120020 Woodchips, hardwood
 14130010 Resawn/seasoned timber (incl kiln dried)(excl sleepers, palings & shingles)
 14130020 Dressed timber and mouldings of a thickness up to and including 6mm
 14130030 Dressed timber and mouldings of a thickness exceeding 6mm
 14130040 Chemically preserved re-sawn or dressed timber
 14131700 Drying, impregnation or chemical treatment - commission production (1411-1413)
 14910010 Prefabricated or transportable wooden buildings
 14920010 Doors, wooden
 14920020 Roof trusses, wooden
 14920030 Wooden wall and window (incl complete with glass) frames
 14920040 Custom made built-in wooden furniture
 14920050 Other wooden builders joinery and carpentry
 14930010 Veneers (incl laminated)
 14930020 Plywood
 14930030 Glued laminated lumber
 14940010 Fibreboard (excl fibre paperboard and particle board)
 14940020 Cellular wood panels
 14940030 Particle board (incl laminated) and similar board of wood or other ligneous materials
 14940040 Laminates of timber and non-timber materials
 14940050 Other boards manufactured from wood nec (incl densified wood in block or other shape)
 14990010 Parquetry strips etc., assembled into panels; shingles and shakes
 14990020 Pallets, cases, boxes, crates, drums, casks and barrels, wooden
 14990030 Frames, wooden (incl for paintings, photographs, mirrors, etc)
 14990040 Boards & similar articles nec, of vegetable fibre agglomerated with mineral binders (excl wooden boards)
 14990050 Moulding boxes, patterns, bases; moulds for metal (excl ingot), glass, mineral materials, rubber or plastics

14990060 Wooden tools, tool bodies & handles; cork articles (incl agglomerated)(excl gaskets for motor vehicles); other products of wood nec

14991700 Other wood products - commission production (1491-1499)

15100010 Mechanical, chemical and semi-chemical wood pulp and residual lyes from wood pulp (excl tall oil)

15100020 Newsprint

15100030 Paper stock (incl toilet, facial tissue and similar paper stock used for household or sanitary purposes)

15100040 Copying paper nec

15100050 Paper and paperboard, coated, impregnated, covered, surface-coloured, surface-decorated nec

15100060 Paper and paperboard, uncoated nec

15101700 Paper - commission production

15210010 Solid and corrugated paperboard containers

15210020 Corrugated paperboard sheeting

15220010 Paper bags, packets and sacks (incl paper multiwall bags) (excl bags of composite material)

15230010 Envelopes (paper), letter & correspondence cards (excl printed or illustrated); paper wallets & writing compendiums of paper

15230020 Exercise books, registers, account books, diaries, board games and other paper stationery (excl commission printing)

15240010 Toilet, tissues, serviettes, towels & similar paper for household & sanitary purposes, in sheets or perforated rolls

15240020 Baby napkins (excl textile), sanitary towels and tampons of paper or cellulose wadding

15290010 Paper and paperboard trays, dishes, plates, cups, cones, egg containers and box files

15290020 Paper festival, carnival or other entertainment articles (incl conjuring tricks, novelties, Christmas decorations)

15290030 Adhesive paper labels (excl printed)

15290040 Other paper, paper pulp or paperboard products (incl wallpaper and liquid activated gummed or adhesive paper)

15291700 Paper products - commission production (1521-1529)

15291970 Waste from manufacture of wood and paper products (1411-1529)

15291980 General government consumption of fixed capital (1521-1529)

16110010 Books (incl atlases & touring guides), maps, charts, plans, sheet music printed but not published by this business

16110020 Newspapers, journals and periodicals printed but not published by this business once a week or more

16110030 Newspapers, journals and periodicals printed but not published by this business less than weekly

16110040 Security printed material (incl stamps, cheque books, banknotes, share documents and airline tickets)

16110050 Paper labels, printed or imprinted (but not published)

16110060 Letter and correspondence cards (printed but not published), postcards

16110070 Trade advertising material or commercial catalogues printed but not published by this business; other printed matter nec

16120010 Composed type, prepared printing plates/cylinders, lithographic stones or other impressed media for use in printing

16120020 Printing trade services nec (excluding desktop publishing)

16200010 Pre-recorded Audio and Video tapes, manufactured but not published by this business

16200020 Reproduced computer software, manufactured but not published by this business

16200030 Pre-recorded Audio CD's and DVD's, manufactured but not published by this business

16200040 Other pre-recorded media (including records), manufactured but not published by this business

16201980 General government consumption of fixed capital (1611-1620)

17010010 Automotive petrol; gasoline refining or blending; motor spirit (incl aviation spirit)

17010020 Kerosene (incl kerosene type jet fuel)

17010030 Gas oil or fuel oil (excl motor spirit and kerosene)

17010040 Petroleum bitumen; residues of petroleum oils and bituminous minerals; petroleum coke

17010050 Liquefied petroleum gas produced at refineries

17010060 Lubricating, heavy petroleum & bituminous oils; solvents; topped/enriched crude, refinery products nec

17090010 Metallurgical coke, coke breeze, retort carbon and char (excl bone char)

17090020 Pitch and pitch coke obtained from mineral tars

17090030 Mineral turpentine

17090040 Petroleum jelly; paraffin wax and other mineral waxes

17090050 Toluol, xylol, not chemically or commercially pure; benzole and benzene from petroleum

17090060 Phenol

17090070 Styrene

17090080 Chloroform and other halomethanes

17090090 Carbon tetrachloride

17090100 Brake and hydraulic fluid

17090110 Rust arresting compound
 17090120 Bituminous mixtures and other articles of asphalt
 17090130 Petroleum and coal products nec.
 17091700 Petroleum and coal products - commission production (1701-1709)
 17091970 Waste from the manufacture of Petroleum and Coal products (1701-1709)
 18110010 Acetylene gas
 18110020 Hydrogen, rare gases, nitrogen, medicinal gases (incl nitrous oxide and oxygen), carbon dioxide (incl dry ice) and carbon monoxide
 18110030 Ethylene gas
 18110040 Liquefied natural gas (other than from the well head)
 18110050 Hydrogen sulphide, Sulphur dioxide and other industrial organic and inorganic gases nec
 18120010 Carbon black
 18120020 Synthetic organic colouring agents & preparations (incl colour lakes, pigments & dyes of vegetable or animal origin)
 18120030 Hydrocarbons and derivatives (incl ethane, betane and benzole and benzene other than from petroleum and iron and steel)
 18120040 Nitrogen-function compounds (excl saccharin)
 18120050 Organo-inorganic compounds; heterocyclic compounds; nucleic acids
 18120060 Carboxylic, monocarboxylic & polycarboxylic acids and derivatives (excl pharmaceutical goods)
 18120070 Ethyl alcohol pure
 18120080 Other alcohols, phenols (excl phenol), phenol-alcohols and derivatives; fatty acids (purity less than 90%)
 18120090 Plasticiser; mixed alkylbenzenes and alkyl-naphthalenes nec; other chemical products and preparations nec
 18120100 Ethers, alcohol peroxides, ether peroxides, epoxides, acetals and hemiacetals and derivatives; organic chemicals nec
 18130010 Hydrochloric, chlorosulphuric, sulphuric (incl oleum), diphosphorous pentaoxide, phosphoric, and polyphosphoric acids
 18130020 Nitric, sulphonitric and other inorganic acids; inorganic oxygen compounds of non-metals (excl industrial gases)
 18130030 Synthetic inorganic colouring agents and preparations (incl inorganic pigments and chemical whites)
 18130040 Refined salt other than cooking or table salt
 18130050 Triammonium phosphate; ammonia (excl fertiliser); ammonium chloride & carbonates; potassium nitrate
 18130060 Prepared pigments, opacifiers, colours, glazes used in ceramic, enamel, glass industry; glass powder, granules/flakes
 18130070 Artificial graphite; colloidal or semi-colloidal graphite; preparations based on carbon in form of semi-manufactures
 18130080 Radioactive elements, nuclear reactor fuel elements, isotopes and compounds; alloys, dispersions, ceramic products and mixtures
 18130090 Other inorganic chemicals nec
 18210010 Synthetic rubber
 18210020 Polystyrene
 18210030 Polyethylene
 18210040 Polyvinyl chloride
 18210050 Polypropylene
 18210060 Polyvinyl acetate & synthetic resins nec (excl adhesives) in primary forms, not mixed/compounded (excl regranulated)
 18210070 Rosin and resin acids, and derivatives thereof, rosin spirit and rosin oils; run gums
 18210080 Plastics in primary forms, mixed/compounded with other substances; regranulated, single thermoplastic scrap material
 18290010 Cellulose fibre or filament
 18290020 Non-cellulose fibre or filament
 18290030 Synthetic fibre or filament nec
 18290040 Basic polymers nec
 18310010 Ammonia aqua or urea, fertiliser grade; ammonium sulphate
 18310020 Superphosphate and other phosphatic fertilisers
 18310030 Ammonium nitrate (excl explosive)
 18310040 Mixed fertilisers
 18310050 Ground phosphate
 18310060 Fertilisers nec
 18320010 Insecticides, pesticides, fungicides, weedkillers and pest control chemicals nec
 18321700 Basic Chemicals - commission production (1811-1832)
 18321970 Waste from the manufacture of basic chemicals (1811-1832)

18410010 Pharmaceutical goods, for human use (excl wadding, gauze, bandages and surgical sutures)
 18411700 Human Pharmaceutical and Medicinal Products - commission production
 18420010 Animal feed supplements
 18420020 Pharmaceutical goods for veterinary use
 18421700 Veterinary Pharmaceutical and Medicinal Products - commission production
 18421970 Waste from the manufacture of pharmaceutical goods for human or veterinary use (1841-1842)
 18510010 Glycerol (glycerine), glycerol waters and lyes
 18510020 Candles and tapers
 18510030 Soap and soap based products
 18510040 Toothpaste and other dentifrices
 18510050 Laundry bleach
 18510060 Disinfectants (incl phenyl)
 18510070 Anionic, cationic and other organic surface active agents (excl soap)
 18510080 Scouring preparations and abrasive cleaners
 18510090 Surface cleaning, washing and degreasing preparations nec (incl oven and stove cleaners)
 18510100 Other cleaning polishes, creams and waxes nec
 18520010 Barrier creams and toilet lanolin; suncreening preparations
 18520020 Hair shampoo, conditioner, sprays, colouring and other hairdressing preparations
 18520030 Aftershave & shaving preparations; lipstick, eye makeup; beauty cream or lotions; face lotions & powders
 18520040 Hand cream or lotions (excl barrier & medicated cream); nail polishes & other nail care preparations
 18520050 Perfume, deodorants, bath salts, depilatories, talcum powder and other preparations nec
 18521700 Cleaning Compounds and Toiletry Preparations - commission production (1851-1852)
 18521970 Waste from the manufacture of cleaning compounds and toiletry preparations (1851 -1852)
 18910010 Photographic, film, cloth, plates (sensitised), photographic chemicals and photographic paper (sensitised)
 18920010 Safety fuses, detonating fuses or caps
 18920020 Explosives and other pyrotechnic articles (incl Ammonium nitrate (explosive), nitrocellulose, gun cotton, signalling flares, fireworks and matches)
 18990010 Eucalyptus, sandalwood and Tea-tree oil
 18990020 Natural gums (processed or refined)
 18990030 Fluxes and other preparations (incl pickling preparations, powders and pastes) for soldering, brazing or welding
 18990040 Other chemical products nec
 18991700 Other Basic Chemical Products - commission production (1891-1899)
 18991970 Waste from the manufacture of other basic chemical products (1891-1899)
 18991980 General government consumption of fixed capital (1891-1899)
 19110010 Self-adhesive plastic plates, film, foil, tape, strip and other flat shapes
 19110020 Flexible plastic strip, plates, film, foil, tape and sheet (excl self-adhesive)
 19110030 Plastic-coated, pressure-sensitive, gummed or adhesive paper and paperboard
 19110040 Plastic sacks, packets and bags (incl garbage bags)
 19110050 Textile fabrics (excl tyre cord) impregnated, coated, covered or laminated with plastics
 19120010 Plastic bottles
 19120020 Plastic table and kitchenware (incl disposable cups), other household (incl buckets) and toilet articles
 19120030 Complete and assembled other domestic furniture (plastic only) not elsewhere specified
 19120040 Other complete and assembled non-domestic furniture (plastic only) nec
 19120050 Other medical, dental, surgical or veterinary furniture and parts (plastic only)
 19120060 Unassembled or partly assembled domestic furniture and parts (plastic only) nec
 19120070 Unassembled or partly assembled non-domestic furniture and parts (plastic only) nec
 19120080 Plastic pipes
 19120090 Plastic fittings for tubes, pipes and hoses (incl joints, elbows and flanges)
 19120100 Plastic taps, cocks, valves and similar attachments
 19120110 Plastic drums, drum linings, boxes, cases, crates & packaging accessories. (incl stoppers, lids, caps & seals)
 19120120 Polycarbonate sheets
 19120130 Plastic blow moulded products nec
 19120140 Other rigid or semi-rigid plastic injection moulded products (excl toys, games and fibre reinforced products)
 19120150 Rigid and semi-rigid polymer products nec (excl fibre reinforced plastic products)
 19130010 Foam and sponge plastic sheets, plates and strip (incl foam insulation and padding)
 19130020 Plastic foam products nec
 19140010 New pneumatic, rubber tyres for motor cars and motor cycles
 19140020 New pneumatic, rubber tyres for buses and lorries
 19140030 Tyres (solid rubber)
 19140040 Tyres, rubber nec (incl retreaded tyres)

19140050 Pneumatic rubber tubes
 19140060 Camel-back and unvulcanised rubber strip for retreading rubber tyres
 19150010 Adhesives (excl bituminous) and glues
 19160010 Architectural & decorative paints (incl coatings for use on buildings), enamels & clears (excl heavy duty coatings)
 19160020 Automotive paints (incl primer & undercoats), enamels, lacquers (excl heavy duty coatings & bituminous mastics)
 19160030 Industrial paints (incl primer, undercoats, finishing coats and heavy duty coats), enamels and clears
 19160040 Inks
 19160050 Filler or putty, caulking compound
 19160060 Other paints (incl marine coatings) and other allied products (incl thinners, wood stains, paint, rubbing compounds and varnish remover)
 19190010 Plastic tubes and hoses
 19190020 Plastic conveyor belting
 19190030 Plastic wall or ceiling coverings (excl tiles)
 19190040 Linoleum and other floor coverings with a textile base; plastic floor coverings (incl paper or paperboard base), wall or ceiling tiles
 19190060 Rigid fibre reinforced plastic articles (incl swimming pool shells and tanks)
 19190070 Other plastic injection moulded products nec (excl rigid or semi-rigid)
 19190080 Artificial guts (sausage casing) of hardened protein or of cellulosic materials
 19190090 Synthetic rubber products and other polymer products nec (excl rigid or semi-rigid)
 19191700 Polymer Products - commission production (1911-1919)
 19200010 Rubber gloves, mittens and mitts
 19200020 Rubber belting (incl V belts)
 19200030 Rubber tubes, pipes and hose
 19200040 Rubber sheets, strips, plates, rods, profile shapes and primary forms (excl cellular)
 19200050 Sponge and foam rubber
 19200060 Other natural rubber products nec
 19201700 Natural Rubber Products - commission production
 19201970 Waste from manufacture of polymer products, rubber, natural rubber and rubber products (1911-1920)
 20100010 Float, surface ground/polished glass, in sheets; cast & rolled glass, in sheets or profiles; but not otherwise worked
 20100020 Safety glass (incl windscreens and laminated sheet glass)
 20100030 Glass containers, bottles or jars; glass stoppers; glass inners for vacuum vessels
 20100040 Rear-view mirrors for vehicles
 20100050 Glassware nec
 20101700 Glass and glass products - commission production
 20210010 Clay bricks (excl refractory bricks)
 20290010 Refractory products (incl bricks, cement and clay)
 20290020 Ceramic roofing, flooring and wall tiles (incl terracotta) and ceramic construction goods nec
 20290030 Ceramic wash basins and permanent fixture type sanitary ware
 20290040 Tableware, ornamental pottery and domestic ware nec
 20290050 Ceramic goods nec
 20291700 Ceramic products - commission production (2021-2029)
 20310010 Cement (incl hydraulic and portland) (excl adhesive or refractory)
 20310020 Lime (incl hydraulic, quick, hydrated, slaked and agricultural)
 20320010 Plaster boards, sheets, panels, tiles, cornices and other articles of plaster (excl ornamental)
 20320020 Plasters (incl plaster of paris)(excl dental plasters)
 20330010 Ready mixed concrete and mortar (incl dry mix concrete)
 20331700 Cement, lime and ready-mixed concrete - commission production (2031, 2033)
 20340010 Concrete, cement, fibrous-cement or artificial stone pipes; concrete box culverts
 20340020 Concrete, cement and artificial stone bricks, blocks, building boards and tiles
 20340030 Concrete or predominantly concrete prefabricated and transportable buildings
 20341700 Plaster and concrete products - commission production (2032, 2034)
 20900010 Worked monumental or building stone
 20900020 Glass fibre and glass wool products
 20900030 Ground limestone
 20900040 Ground clays (excl colours); andalusite, kyanite & sillimanite; mullite; chamotte & dinas earths
 20900050 Ground mica; feldspar; leucite; nepheline ; ground natural abrasives; crushed, powdered natural steatite and talc

20900060 Ground minerals & fluorspar (excl abrasives, dust & powders of natural & synthetic precious or semi-precious stones)
 20900070 Non-refractory mortars and concretes other than ready mixed; articles of asbestos-cement and cellulose fibre-cement nec
 20900080 Other non-metallic mineral products
 20901700 Other non-metallic mineral products - commission production
 20901970 Waste from the manufacture of non-metallic mineral products (2010-2090)
 21100010 Basic iron, pig iron, sponge iron and spiegeleisen; iron or steel granules and powders
 21100020 Ferro-alloys (incl manganese, silicon or chrome)
 21100030 Iron or steel primary forms (incl ingots) and semi-finished products
 21100040 Iron or non-alloy steel flat-rolled products (excl clad, plated or coated)
 21100050 Clad, plated or coated iron or non-alloy steel flat-rolled products
 21100060 Alloy steel flat-rolled products
 21100070 Iron and steel bars, rods, angles, shapes and sections (incl sheet piling)
 21100080 Iron or steel wire for further processing (excl fencing, stranded or barbed)
 21100090 Painted, varnished or coated steel sheet, profile decking or cladding (incl steel sheeting for fencing)
 21100100 Iron or steel rails, rail fastenings or other rail accessories
 21100110 Iron or steel expanded metal
 21100120 Light oils obtained as a by-product from metallurgical coke (excl grease oils, toluole and xylene); Benzole from iron and steel manufacturing
 21100130 Crude tar
 21100140 Gas from coke works or blast furnaces
 21210010 Cast iron tubes, pipes and hollow profiles; cast iron or cast steel tube or pipe fittings
 21210020 Cast iron or cast steel steam, gas and water fittings other than domestic (incl taps, cocks and valves)
 21210030 Cast articles of iron or steel nec
 21220010 Iron or steel seamless tubes or pipes (excl cast or forged)
 21220020 Iron or steel tubes, pipes, hollow profiles and fittings (excl cast iron or seamless)
 21220030 Steel steam, gas and water fittings other than domestic (incl taps, cocks and valves)(excl cast steel)
 21221700 Iron and steel - commission production (2110-2122)
 21221970 Waste from manufacture of iron and steel (incl slag, dross, sealings and scrap steel) (2110-2122)
 21310010 Alumina
 21320010 Aluminium and aluminium alloys (excl purchased scrap)
 21320020 Aluminium secondary recovery from purchased scrap
 21320030 Aluminium castings and diecastings
 21321970 Aluminium scrap from the manufacture of alumina, aluminium and aluminium alloys (2131-2132)
 21330010 Silver primary and secondary recovery (excl from purchased scrap)
 21330020 Copper (including brass) primary and secondary recovery (excl from purchased scrap)
 21330030 Lead primary and secondary recovery (excl from purchased scrap)
 21330040 Zinc primary and secondary recovery (excl from purchased scrap)
 21330050 Silver, copper (including brass), lead and zinc recovery from purchased scrap
 21330060 Zinc alloys; copper matte; cement copper; unwrought copper and nickel
 21330070 Sulphuric acid from the smelting of copper, silver, lead and zinc.
 21390010 Platinum primary and secondary recovery (excl from purchased scrap)
 21390020 Nickel and tin primary recovery and secondary recovery from drosses, ashes or other waste materials (excl from purchased scrap)
 21390030 Nickel and tin recovery from purchased scrap
 21390040 Gold - primary and secondary (excl from purchased scrap)
 21390050 Antimony and other non-ferrous basic metals nec primary and secondary recovery
 21390060 Basic precious metals (excl silver) secondary recovery from purchased scrap
 21390070 Other non-ferrous metal alloys
 21391700 Basic non-ferrous metals - commission production (2131-2139)
 21391970 Wastes and scraps from the smelting and refining of non-ferrous metals (incl precious) (2133-2139)
 21410010 Non-ferrous metal (excl aluminium) castings and diecastings
 21420010 Aluminium and aluminium alloy bars, rods (incl wire rod) and profiles (incl decking and cladding)
 21420020 Aluminium foil
 21420030 Rolled, drawn or extruded aluminium pipes, tubes, plates, sheets, strip & wire products; aluminium powders & flakes
 21490010 Copper, copper alloy, nickel, lead, zinc and tin rolled, extruded and semi-finished products
 21490020 Silver and platinum rolled, drawn or extruded semi-finished products
 21490030 Semi-manufactures of tungsten, molybdenum, tantalum, magnesium, cobalt, cadmium, titanium, zirconium and thallium

21490040 Non-ferrous (excl aluminium) metal powders and flakes
 21491700 Basic non-ferrous metal products - commission production (2141-2149)
 21491970 Wastes and scraps from the manufacture of non-ferrous metal products (incl precious) (2141-2149)
 22100010 Iron or steel pieces roughly shaped by forging
 22100020 Forged iron or steel tyres and wheels for railway or tramway locomotives and rolling stock
 22100030 Iron or steel chain (other than articulated link chain) and other forged articles of iron or steel
 22101700 Forged iron or steel products - commission production
 22101900 Repairing and servicing (2210)
 22210010 Fabricated & prefabricated construction steel (incl scaffolding, perforated plate & ready made parts for structures)
 22210020 Reinforcing steel rods or bars
 22210030 Reinforcing welded steel mesh
 22220010 Prefabricated metal or metal framed buildings (excl aluminium) and other transportable buildings
 22220020 Aluminium or aluminium framed prefabricated buildings
 22230010 Aluminium/aluminium framed doors (incl roller/concertina) & windows (incl glass); door/window frames; roller grilles
 22230020 Aluminium fire doors
 22230030 Aluminium combined door-window units
 22230040 Architectural aluminium products (excl sheet metal), for building nec
 22230050 Aluminium roofing and guttering
 22230060 Other articles of aluminium (excl ladders) nec
 22240010 Metal roofing and guttering (excl aluminium)
 22290010 Iron or steel window-frames; metal (excl aluminium) door or door frames
 22290020 Wooden fire doors
 22290030 Iron or steel fire doors; fabricated iron or steel stairs, balustrades and other architectural products (excl Aluminium)
 22291700 Structural metal products - commission production (2221-2229)
 22291970 Waste from the manufacture of ferrous metal products nec
 22310010 Metal cylinders (incl aerosol containers) for compressed or liquified gas
 22310020 Sheet metal reservoirs, vats, tanks and similar containers of a capacity exceeding 300 litres
 22310030 Sheet metal vats and tanks of a capacity not exceeding 300 litres
 22310040 Super heated water boilers & steam generators (incl parts) (excl central heating); condensers for vapour power units
 22310050 Non-electric hot water or low pressure steam central heating boilers
 22310060 Iron, steel or aluminium vats, tanks, capacity exc. 300 litres and containers for compressed or liquefied gas
 22310070 Plate iron, steel and aluminium vats and tanks, capacity not exc. 300 litres (excl with mechanical or thermal equipment)
 22310090 Metal freight containers (excl stock crates)
 22390010 Metal containers nec
 22390020 Sheet metal milk and cream cans of a capacity not exceeding 300 litres
 22390030 Sheet metal household containers (excl sanitary ware)
 22390040 Metal vacuum flasks
 22400010 Sheet metal ducting
 22400020 Sheet metal sanitary ware
 22400030 Sheet metal stoppers, caps, lids, capsules for bottles, threaded bungs, bung covers, seals & packing accessories nec
 22400040 Sheet metal non-electric tableware, kitchenware or other household articles and parts (excl containers and sanitary ware)
 22400050 Sheet metal machine guards (not designed for use with a particular machine)
 22400060 Sheet metal products nec
 22401700 Metal container and sheet metal products - commission production (2231-2240)
 22910010 Iron or steel fencing wire (excl stranded or barbed)
 22910020 Wire stranded, cables, cordage, ropes, plaited bands and slings (excl electrically insulated slings)
 22910030 Springs (incl leaves for springs)
 22910040 Nails, tacks, staples, spiked cramps, studs, spikes & pins (incl drawing & cotter pins) (excl metallic dowel pins)
 22910050 Woven or linked wire fabric (excl mattress supports)
 22910060 Welded wire fabric (excl reinforcing)
 22910070 Iron or steel wire gates (cross-sectional dimension of wire 16mm or less)
 22910080 Iron or steel articulated link chain and parts
 22910090 Domestic metal wire products; copper cloth, grill, netting and fencing; barbed wire; other wire products
 22920010 Metal nuts, bolts (incl expansion), screws, rivets, washers, dowel pins, masonry anchors and turnbuckles

22930010 Metal coating and finishing
 22990010 Metal hand tools (incl gardening; excl power operated or pneumatic)
 22990030 Cutlery, kitchen ware and table ware (excl solid silver or gold) nec
 22990050 Knives and cutting blades for metal or wood working tools and machines
 22990060 Metal hand tool accessories & attachments (incl screwdriver & drill bits)(excl twist drills, taps, dies, chasers)
 22990070 Non-ferrous metal steam, gas and water fittings other than domestic (incl taps, cocks and valves)
 22990080 Tube or pipe fittings (excl valves) (eg couplings, elbows, sleeves), of copper or nickel (incl alloys) or aluminium
 22990090 Munitions and ammunition (incl cartridges)
 22990100 Aluminium venetian blinds (incl plastic coated)
 22990110 Metal blinds and awnings (excl aluminium venetian blinds)
 22990120 Locks (incl parts/padlocks); keys; metal fittings for windows or doors (incl hinges and hydraulic door closures)
 22990140 Firearms (incl parts)
 22990150 Fire extinguishers
 22990160 Articles of tungsten, molybdenum, tantalum, magnesium, cobalt, cadmium, titanium, zirconium and thallium (incl wrought)
 22990170 Non-electric lamps and lighting fittings (incl pressure and gas lanterns)
 22990180 Woven wire, link mesh or wire spring mattress supports (excl upholstered)
 22990190 Cigarette and other lighters
 22990200 Fabricated metal products (incl ladders) nec
 22991700 Other fabricated metal products - commission production (2291-2299)
 22991900 Repairing and servicing (2291-2299)
 23110010 Finished motor vehicles with less than 10 persons capacity
 23110020 Finished motor vehicles with 10 or more person capacity
 23110030 Finished trucks, truck type vehicles, utilities and panel vans
 23110040 Unassembled motor vehicles nec
 23110050 Chassis with engines for motor vehicles
 23110060 Engines nec, for motor vehicles or tractors
 23119000 Second hand motor vehicles
 23120010 Motor vehicle and truck bodies (coachwork)
 23120020 Caravans, camper trailers and similar vehicles
 23120030 Agricultural self loading and unloading semi-trailers (incl tippers)
 23120040 Other semi-trailers for the transport of goods & materials (incl tankers, vans, transporters, stock crates & jinkers)
 23120050 Trailers for the transport of goods and materials (incl box trailers, boat trailers and horse floats)
 23120060 Other trailers & semi-trailers nec (excl for the transport of goods & materials, & domestic type camper trailers)
 23120070 Body panels for trucks and buses
 23120080 Parts nec, for motor vehicle trailers and semi-trailers
 23130010 Vehicle electric motors of an output not exceeding 37.5W; other DC motors and DC generators
 23130020 Motor vehicle and truck air conditioners
 23130030 Motor vehicle apparatus for making, breaking, protecting & making connections to/in electrical circuits (excl wiring)
 23130040 Motor vehicle or motor cycle wiring harnesses
 23130050 Motor vehicle, tractor or motor cycle starting, heaters, demisters, windscreen wipers; lighting/signalling equipment
 23130060 Motor vehicle, tractor and motor cycle filament lamps and sealed beam lamps
 23130070 Motor vehicle & tractor gauges, revolution & production counters, speed indicators, thermostats & similar instruments
 23130080 Automotive insulated cable, wire or strip
 23190010 Motor vehicle transmission assemblies
 23190020 Cylinder blocks, pistons, connecting rods, valves
 23190030 Fuel, lubricating or cooling medium pumps
 23190040 Cranks, crank & cam shafts, gears and flywheels
 23190050 Motor vehicle, tractor and truck gaskets
 23190060 Motor vehicle body panels
 23190070 Motor vehicle and tractor parts and equipment nec
 23910010 Vessels of 50 tonnes gross and over (incl floating structures)
 23920010 Small boats (incl rowing or sail), yachts and canoes under 5 tonnes displacement (incl inflatable vessels and canoes)

23920020 Boats and other vessels for pleasure or sport (over 5 but under 50 tonnes)
 23920030 Cruise ships, ferry and excursion boats, and other vessels under 50 tonnes nec for the transport of persons and goods
 23921700 Ships and boats - commission production (2391-2392)
 23921900 Repairing and servicing (2391-2392)
 23930010 Locomotives and trams (incl underframes); railway rolling stock
 23931700 Railway rolling stock - commission production
 23931900 Repairing and servicing (2393)
 23940010 Aircraft and aircraft parts
 23941700 Aircraft - commission production
 23941900 Repairing and servicing (2394)
 23990010 Motorised tanks and other armoured fighting vehicles and parts
 23990020 Transport equipment, parts and accessories nec (incl motorcycles and motor scooters)
 23990030 Repairing and servicing - (incl factory motor vehicle engine repair or replacements) (2311-2319, 2399)
 23991700 Motor vehicles, other transport equipment and parts - commission production (2311-2319, 2399)
 24110010 Cameras, image projectors and parts
 24110020 Photographic goods nec (excl sensitised photographic film, paper, plates & chemicals)
 24110030 Objective lenses, filters and other mounted optical elements; microscopes (excl optical) and diffraction apparatus and parts nec
 24110050 Ophthalmic instruments and appliances
 24110060 Spectacle and contact lenses
 24110070 Spectacles, sunglasses and frames
 24120010 Surgical, medical equipment (excl X-ray) and appliances (incl artificial joints, limbs or eyes, pacemakers, mechanical dental chairs & needles or syringes)
 24120020 X-ray medical equipment and parts or accessories
 24120030 Hearing aids and parts or accessories
 24190010 Gas or liquid meters (incl parts and accessories)
 24190020 Parking meters, traffic signals and other signalling equipment
 24190030 Taxi meters
 24190040 Watches (incl metal watch straps), watch cases, clocks and parts
 24190050 X-ray equipment (excl medical) and parts or accessories
 24190060 Professional or scientific instruments, apparatus or models for demonstrational purposes only
 24190070 Surveying, physical or chemical analysis and other measuring, checking and testing instruments, appliances and parts
 24190080 Radio and radar equipment, navigational aids, and radio remote control equipment
 24190090 Optical fibres, fibre bundles and cables (excl insulated)
 24190100 Professional and scientific equipment nec
 24191700 Professional and scientific equipment - commission production (2411-2419)
 24191980 General government consumption of fixed capital (2411-2419)
 24210010 Mainframe and super-computers
 24210020 Computer file servers and other multiple-user computer hardware
 24210030 Laptops, notebooks, personal digital assistants and other portable computers
 24210040 Desktop computers (PCs)
 24210050 Computer peripheral devices (incl monitors, keyboards, mice, joysticks, speakers, drives and burners)
 24210060 Printers and plotters
 24210070 Other computer hardware, computer peripherals and accessories nec
 24210080 Photocopying machines and parts
 24210090 Electronic machines with a calculating device (incl cash registers, postage-franking & ticket machines) & parts
 24210100 Typewriters, word processors, addressing machines, EFTPOS machines, coin counting machines and other office machinery
 24210110 Money-changing, cigarette, food, beverage and other automatic goods vending machines (excl refrigerated vending machines)
 24210120 Office machines, parts and accessories nec
 24220010 Line telephone and telegraph equipment (excl headphones and parts)
 24220020 Radio and television studio equipment (incl cameras), transmitters, radio transceivers, mobile, cellular & car phones (excl parts)
 24220030 Satellite receivers (excl parts)
 24220040 Remote monitoring alarm systems
 24220050 Intercom equipment
 24220060 Parts for radio and television studio equipment, transmitters and radio transceivers
 24220070 Television antennae parts

24220080 Telecommunication equipment parts (incl parts for mobile phones and satellite receivers)
 24290010 Television receiving sets (excl parts)
 24290020 Radio receiving sets (incl car radios and clock radios) (excl parts)
 24290030 Sound and video recording and reproducing equipment (incl CD players, record players) (excl parts)
 24290040 Loudspeakers and audio-frequency electric amplifiers (excl hearing aids and parts)
 24290050 Electric or electronic alarm systems (excl remote monitoring alarm systems) and parts
 24290060 Video games, poker machines and other coin or disc operated games
 24290070 Prepared unrecorded media for sound or video recording (incl blank CDs, magnetic tapes)
 24290080 Other audio and video equipment and accessories (excl parts)
 24290090 Parts for television and radio receiving sets, sound and video recording and reproducing equipment, other audio and video equipment
 24290100 Electronic equipment and parts nec
 24291700 Computer and electronic equipment - commission production (2421-2429)
 24291980 General government consumption of fixed capital (2421-2429)
 24310010 Uninsulated copper and aluminium stranded wire, ropes, cables, plaited bands and slings
 24310020 Co-axial cable and other co-axial electric conductors
 24310040 Cable (excl co-axial or insulated optical fibre), wire and strip
 24310050 Insulated optical fibre cable
 24320010 Electric light or lamp bulbs or tubes (incl filament or fluorescent) (excl automotive)
 24320020 Incandescent light fittings
 24320030 Cold, discharge, arc, ultra violet, infra-red and other electric lights, torches and fittings nec
 24320050 Illuminated signs, name-plates and sign-plates having a permanently fixed light source
 24390010 Dry cell batteries
 24390020 Automotive wet cell batteries
 24390030 Batteries nec and battery components
 24390050 Transformers
 24390060 Electric motors, generators, electric generating sets and rotary converters (incl parts) (excl automotive)
 24390070 Electrical welding (incl arc) base metal wire, rods, tubes, plates and electrodes
 24390090 Relays and relay sets for radio, telephones and telegraphic equipment
 24390100 Electrical apparatus to switch, protect/connect circuits (incl boards & cabinets equipped with such)(excl inductors)
 24390120 Inductors (incl chokes, ballasts used with lighting apparatus and current limiting regulators)
 24390130 Electric soldering and welding (incl arc) irons, guns and other machines, apparatus and parts
 24390140 Industrial or laboratory electric furnaces and ovens
 24390150 Electric heating resistors (excl carbon)
 24390160 Electrical insulators nec and other electrical equipment and parts nec
 24391700 Electrical equipment - commission production (2431-2439)
 24410010 Solid fuel or gas portable barbecues
 24410020 Domestic stoves, ovens and rangehoods (incl gas, electric, solid fuel, oil or spirit fired)
 24410030 Domestic refrigerators and freezers
 24410040 Compressors for domestic refrigeration equipment
 24410050 Clothes washing machines, drying cabinets, tumble driers and dishwashing machines
 24410060 Domestic food waste disposal units
 24490010 Domestic gas, electric, solid fuel, oil, spirit fired space heaters and non-electric warm air furnaces
 24490020 Domestic soil heating apparatus
 24490030 Domestic solar hot water collectors, systems and parts (incl systems with conventional backup sources)
 24490040 Domestic gas and other non-electric water heaters and hot water systems (excl solar) and parts
 24490050 Domestic electric water heaters or hot water systems and parts
 24490060 Domestic room air conditioners and coolers (excl fans)
 24490070 Compressors for domestic air conditioning equipment
 24490080 Domestic fans (incl table, floor, wall, window, ceiling or roof)
 24490090 Electro-thermic appliances nec
 24490100 Sewing machines, vacuum cleaners, food mixers and other domestic appliances and parts (nec)
 24491700 Domestic appliances - commission production (2441-2449)
 24510010 Pumps and pumping machinery (incl petrol bowsers and air or gas compressors)
 24510020 Pump and compressor parts nec
 24520010 Complete air conditioning units nec (incl ducting etc); air conditioning compressors or parts (commercial or industrial)
 24520030 Refrigeration cabinets, coolrooms, beverage dispensing equipment (cooling), refrigerated vending machines and refrigeration equipment nec (commercial or industrial) (incl water coolers)
 24520050 Water heaters (commercial or industrial) and parts

24520060 Space heating equipment (commercial or industrial) (incl parts) nec
 24610010 Lawn mowers
 24610020 Ploughing, seeding and planting equipment and parts (excl hand tools)
 24610030 Harvesting, threshing and haymaking machinery (incl straw or fodder balers or agricultural mowers)
 24610040 Agricultural wheeled tractors (excl crawler)
 24610050 Mechanical appliances and parts for projecting, dispersing or spraying liquids or powders (excl industrial spray guns and steam blasting)
 24610070 Dairy machinery
 24610080 Agricultural and horticultural machinery and parts nec
 24620010 Construction and earthmoving wheeled tractors
 24620020 Front end shovel loaders; mechanical shovels, excavators & shovel loaders with a 360 degree revolving superstructure
 24620030 Bulldozers & other moving, grading, scraping, excavating, compacting or extracting construction machinery nec
 24620040 Buckets, shovels, grabs, grips, blades, bodies and cabs for construction vehicles and other construction and earthmoving machinery parts
 24620060 Machinery for crushing, grinding, mixing or kneading earth, stones, ores or other mineral substances in solid form
 24620070 Mineral substances sorting, screening, separating, washing, mixing or kneading machinery and parts
 24620080 Mining or drilling machinery and parts (incl coal or rock cutters, boring, sinking or tunnelling machinery)
 24630010 Gas welding and cutting equipment (excl filler welding rods)
 24630020 Hand tools, power operated (incl portable electric hand tools) nec
 24630030 Machine-tools for working materials other than metal, wood; laser machine tools; hand tools with self-contained motor
 24630040 Converters, ingot moulds and ladles, casting machines, metal-rolling mills and rolls and parts
 24630050 Machining centres & other wood & metal working machinery & parts nec (excl saw blades, metal moulds & dies)
 24630060 Saw blades
 24630070 Metal dies, die sets and moulds
 24630080 Interchangeable tools for power-operated hand tools; sintered metal plates; rock drilling and earth boring tools
 24630090 Parts for hand tools with self-contained non-electric motors
 24630100 Metal work and tool holders, heads for machine tools, and other machine tool accessories and parts
 24690010 Non-domestic cooking or heating machinery for food or drinks
 24690020 Cream separators; bakery machinery (excl ovens) and other food and beverage processing machinery and parts
 24690030 Distilling/rectifying plant; heat exchange units; centrifuges nec; gas liquefying or beverages filtering machinery
 24690040 Machinery for can and bottle washing, packing, wrapping, canning, bottling and sealing of food and drink
 24690050 Parts of machinery nec for cleaning food or drink cans or bottles, (incl parts of dishwashing machines nec), or for filling, closing, sealing, capsuling or labelling containers for food or drink
 24690060 Other food and beverage processing machinery and parts nec
 24690070 Industrial machinery and parts for textile manufacture and treatment industries (excl industrial sewing machines)
 24690080 Office type sheet fed printing machinery, accessories and parts
 24690090 Other textile, apparel and leather production machinery and parts nec (incl industrial sewing machines)
 24690100 Printing machinery and parts
 24690110 Tobacco machinery and parts; bakery and biscuit ovens; dryers for agricultural products
 24690120 Machinery and parts for paper or book-binding
 24690140 Special purpose machinery & parts nec
 24691700 Specialised machinery and equipment - commission production (2461-2469)
 24910010 Wheeled tractors (excl crawler; agricultural, construction and earthmoving)
 24910020 Powered store trucks (incl those used on railway station platforms and forklifts)
 24910030 Conveyors, continuous-action, for goods & materials
 24910040 Hoists, cranes and other lifting, loading or unloading machinery
 24910050 Elevators, continuous-action, for goods & materials; escalators & moving walkways
 24910060 Materials handling equipment and parts nec
 24990010 Hydraulic and pneumatic motors and parts
 24990020 Rubber, plastics or hot glass working machines (incl parts)
 24990030 Non-electric industrial and laboratory furnaces, ovens (other than bakery or biscuit) and incinerators and parts

24990040 Dishwashing machines other than household
 24990050 Engines nec, turbines and water wheels and parts
 24990060 Oil filters, petrol filters and air intake filters for internal combustion engines
 24990070 Bearings (incl parts)
 24990080 Parts for centrifuges (incl centrifugal dryers); parts for liquid or gas filtering or purifying machinery
 24990100 Other machinery, equipment and parts nec
 24991700 Other machinery and equipment - commission production (2451-2452, 2491-2499)
 25110010 Assembled domestic wooden chairs, upholstered seating with wooden or metal frames, wooden or predominantly wooden domestic furniture nec
 25110020 Assembled non-domestic wooden or predominantly wooden seating and furniture nec
 25110030 Unassembled or partly assembled domestic wooden chairs, upholstered seating with wooden or metal frames, wooden or predominantly wooden furniture nec
 25110040 Unassembled or partly assembled non-domestic wooden chairs, furniture and parts nec
 25110050 Wooden or predominantly wooden medical, dental, surgical or veterinary furniture
 25110060 Upholstered seats with frames of any material for transport equipment and parts of passenger transport seats
 25120010 Cabinets (Audiovisual) - Metal framed
 25120020 Assembled metal or predominantly metal domestic furniture (excl upholstered seating with metal frames)
 25120040 Metal medical, dental (excl mechanical dental chairs), surgical or veterinary furniture
 25120080 Unassembled large scale sheet metal or fabricated metal storage structures and shelving
 25120090 Unassembled or partly assembled domestic metal furniture and parts nec (excl upholstered seats with metal frames)
 25120100 Unassembled or partly assembled non-domestic metal furniture and parts nec (excl upholstered seats with metal frames)
 25120110 Metal furniture fittings
 25120120 Metal seating for entertainment and sporting venues (incl assembled and unassembled)
 25120130 Assembled metal non-domestic furniture nec (excl upholstered seating with metal frames)
 25130010 Mattresses, of, or stuffed with rubber
 25130030 Water mattresses
 25130040 Mattresses (excl water-mattresses and those of or stuffed with rubber)
 25130050 Mattress supports (excl unupholstered woven wire, link mesh, wire springs and those of or stuffed with rubber)
 25190010 Other assembled domestic furniture nec (excl wooden, metal or plastic)
 25190020 Other medical, dental, surgical or veterinary furniture (excl wooden, metal or plastic) and parts
 25190030 Other assembled non-domestic furniture nec (excl metal, wood and plastic)
 25190040 Unassembled or partly assembled domestic furniture and parts nec (excl metal, wood and plastic)
 25190050 Unassembled or partly assembled non-domestic furniture and parts nec (excl metal, wood and plastic)
 25191700 Furniture - commission production (2511-2513, 2519)
 25910010 Badges, coins and medals, sheet metal
 25910020 Jewellery and silverware
 25910030 Imitation jewellery (excl incorporating precious metal except as plating or as minor constituents)(excl watch straps)
 25920010 Toys (excl fur or leather)
 25920020 Other articles for funfair or table games (incl billiards, snooker or pool, pintables articles and accessories)
 25920030 Sporting equipment and accessories (incl fishing gear and gloves specially designed for use in sport)
 25990010 Paint brushes or rollers, accessories and parts
 25990020 Hair brushes, nail brushes, toothbrushes (excl electric) and other brushes for personal use
 25990030 Advertising signs, name-plates and sign-plates (excl electric and metal)
 25990040 Pens, pencils and refills, crayons and chalk
 25990050 Typewriter ribbons and ink pads
 25990060 Umbrellas
 25990070 Musical instruments (incl parts and accessories)
 25990090 Metal (other than precious) statuettes and other ornaments
 25990100 Articles of precious metal (incl articles for technical or laboratory use)(excl jewellery)
 25990120 Manufacturing nec (incl non-textile based sutures)
 25991700 Manufacturing products nec - commission production
 26110010 Electricity generated from fossil fuels
 26120010 Hydro-electricity
 26190010 Electricity generation nec
 26400010 Other electricity service income
 26401500 Margin - Electricity transmission, distribution and on selling (2620-2640)
 27001500 Margin - gas distribution

28100010 Water, sewerage and drainage services
 28101980 General government consumption of fixed capital (2811, 2812)
 29000010 Waste collection (incl skip and portable toilet hire), treatment disposal remediation and materials recovery services
 29221980 General government consumption of fixed capital (2911-2922)
 30100010 Residential building construction
 30109010 Second hand residential buildings
 30200010 Non-Residential building construction
 30201980 General government consumption of fixed capital (3020)
 30209010 Second hand non-residential buildings
 31010010 Road and bridge construction (excl repair and maintenance)
 31010020 Repair and maintenance - road and bridge
 31019010 Second hand roads and bridges
 31090010 Non-building construction nec
 31090020 Repair and maintenance - non-building construction nec
 31091980 General government consumption of fixed capital (3101-3109)
 31099010 Second hand non-building construction nec
 32000010 Trade services repair and maintenance
 32000020 Other construction trade services
 32001980 General government consumption of fixed capital (3211-3299)
 37000010 Non-margin - wholesaling services (excl repairing and servicing)
 37001400 Margin on reexports - wholesaling services
 37001500 Margin - wholesaling services
 38000020 Auction room operations; Electronic procurement brokering services
 38001800 Wholesale commission on sales
 38001980 General government consumption of fixed capital (3311-3800)
 43000010 Non-Margin - retailing services (excl repairing and servicing)
 43001500 Margin - retailing services
 43001800 Retail commission on sales
 43001980 General government consumption of fixed capital (3911-4320)
 44000010 Accommodation services
 45000010 Meal preparation and presentation
 45000020 Beverage serving service
 45000030 Takeaway food
 45000040 Catering services
 45000050 Net losses from gambling - Clubs, pubs, taverns and bars (Hospitality)
 45001500 Margin - food and beverage services (4511-4530)
 46100020 Non-margin - road freight transport services (incl rental or hire of trucks with driver)
 46100030 Road vehicle towing services
 46101600 Margin - road freight transport services
 46210010 Interurban or non-metropolitan bus transport services (incl long distance, charter and rural)
 46220010 Urban or metropolitan bus and tramway transport services (incl short distance, airport and school)
 46230010 Taxi transport services
 46230020 Rental or hire of passenger car with driver
 46230030 Rental or hire of passenger road vehicle nec (incl buses and coaches) with driver
 46230040 Urban road passenger transport services nec
 46230050 Interurban road passenger transport services nec
 47100020 Non-margin - railway freight transport services nec
 47101600 Margin - railway freight transport services
 47200010 Urban railway (incl monorail) passenger transport services
 47200020 Interurban railway passenger transport services
 48100020 Non-margin - ocean and inland water freight transport services
 48101600 Margin - ocean and inland water freight transport services
 48200010 Local water transport services for passengers
 48200020 Long distance water transport services for passengers
 48200030 Rental or hire of water vessel with operator
 49000020 Non-margin - air and space freight transport services
 49000030 Air passenger transport services
 49000040 Rental or hire of aircraft with operator
 49001600 Margin - air and space freight transport services
 50100010 Scenic and sightseeing transport services

50211600 Margin - pipeline transport services
 50290010 Transport services nec (incl ski lift operation)
 50291980 General government consumption of fixed capital (5010-5029)
 51010010 Postal services
 51020010 Courier pick-up and delivery services
 51021980 General government consumption of fixed capital (5101-5102)
 52100030 Non-margin - stevedoring and port handling services (5211-5219)
 52100040 Support services to water transport nec (5211-5219)
 52101400 Margin on reexports - services to water transport (5211-5219)
 52101600 Margin - services to water transport (5211-5219)
 52200010 Airport operations and other air transport support services nec
 52910010 Customs agency services
 52920010 Freight forwarding agency services
 52990010 Other transport support services nec
 52990020 Support services for road transport nec (incl taxi radio base and road vehicle driving service)
 52990030 Support services for railway transport nec (incl station and terminal operations)
 52991980 General government consumption of fixed capital (5211-5299)
 53010010 Grain storage services
 53090010 Warehousing and storage services nec
 53091980 General government consumption of fixed capital (5301-5309)
 54110010 Newspaper publishing (incl printed and published by the same business) published once a week or more
 54110020 Newspaper publishing (incl printed and published by the same business) published less than weekly
 54110030 Newspapers - advertising services
 54110040 Copyright leasing - newspapers
 54120010 Magazine and other periodical publishing (incl printed and published by the same business)
 54120030 Magazines and other periodicals - advertising services
 54120040 Copyright leasing - magazines and other periodicals
 54130010 Book publishing (incl textbooks, encyclopedias, travel guides and atlases) (incl printed and published by the same business)
 54130030 Books - advertising services
 54130040 Copyright leasing - books
 54140010 Directory, mailing list, collection or compilation publishing (incl printed and published by the same business)
 54140030 Directory, mailing list, collection or compilation - advertising services
 54190010 Other publishing nec (incl maps, greeting cards, postcards and calendars) (incl printed and published by the same business)
 54190030 Other publishing - advertising services
 54190040 Copyright leasing - other
 54200010 Software publishing services (non-customised)
 54200020 Copyright leasing - software (non-customised)
 54201980 General government consumption of fixed capital (5411-5420)
 55110010 Motion picture and video production
 55120010 Motion picture and video distribution services
 55120020 Copyright leasing - motion pictures and videos
 55130010 Motion picture theatre services
 55140010 Post-production services and other motion picture and video activities
 55210010 Music publishing nec (incl sheet music)
 55210030 Music copyrights (Acquiring, registering and selling)
 55220010 Music and other sound recording studios operation (incl pre-recorded radio programming services)
 55221980 General government consumption of fixed capital (5511-5522)
 56100010 Radio broadcasting services
 56210010 Free-to-air television broadcasting services
 56220010 Cable (Pay TV) and other subscription broadcasting services
 56221980 General government consumption of fixed capital (5610-5622)
 57000010 Internet publishing and broadcasting services (incl radio, television, books, newspapers and magazines)
 57000020 Internet publishing - advertising services
 57001980 General government consumption of fixed capital (5700)
 58010020 Wired telecommunications network services (incl International, long distance and local)
 58020010 Mobile and other telecommunication network services nec (incl wireless and satellite)
 58090010 Other telecommunications services nec
 58091980 General government consumption of fixed capital (5801-5809)
 59100010 Internet access (incl ISPs) and internet search services

59210020 Data processing and web hosting services
 59220010 Information storage and retrieval services
 59221980 General government consumption of fixed capital (5910-5922)
 60100010 Library and archive services
 60200010 Other information services (incl radio and television new collection and telephone based recorded information services)
 60201980 General government consumption of fixed capital (6010-6020)
 62000010 Bank services - Financial intermediation services indirectly measured
 62000020 Bank services nec
 62220020 Building society services nec
 62230020 Credit union services nec
 62290010 Other depository financial services (incl securitiser services) - Financial intermediation services indirectly measured
 62290030 Other depository financial services nec (incl money market and securitiser services)
 62300010 Non-depository finance services - Financial intermediation services indirectly measured
 62300020 Non-depository finance services nec
 62400010 Financial asset investors
 63100010 Life insurance provision
 63210010 Health insurance provision
 63220010 Fire and industrial special risks insurance provision
 63220020 Houseowner and household insurance provision
 63220030 Motor vehicle comprehensive and compulsory third party insurance provision
 63220040 Public liability, product liability and professional indemnity insurance provision
 63220060 Marine insurance provision (Non-margin); aviation hull/cargo insurance provision
 63220070 Employers liability insurance provision
 63220080 Insurance provision (incl travel insurance) nec.
 63221500 Marine insurance provision (Margin)
 63300010 Superannuation fund services
 63301980 General government consumption of fixed capital (6310-6330)
 64110010 Financial asset broking services
 64190010 Insurance fund management service
 64190020 Auxiliary services to finance and investment nec
 64200010 Services to insurance nec
 66110010 Passenger car rental or hire (incl cars, minibuses) - (excl financial leases)
 66190010 Other motor vehicle rental or hire (incl caravan & trailer) (excl financial leases) nec
 66190020 Transport equipment rental or hire (incl ship & boat) nec
 66200010 Farm animal and bloodstock leasing
 66310010 Heavy machinery and Scaffolding (excl erection) rental or hire (excl financial leases)
 66320010 Video and other electronic media rental or hire
 66390010 Other goods and equipment rental hire nec (incl art works, household goods and office machinery)
 66400010 Non-financial intangible assets (excl copyrights) leasing
 66401980 General government consumption of fixed capital (6611-6640)
 67110010 Ownership of dwellings
 67110020 Residential caravan park operation and residential property body corporate or strata corporation services
 67111980 General government consumption of fixed capital (6711)
 67120010 Non-residential property operator services (incl non-residential property body corporate or strata corporation services)
 67200010 Real estate agent services
 67200020 Agricultural or pastoral property broking, leasing, renting or valuing
 67201980 General government consumption of fixed capital (6712-6720)
 69000020 Architectural services
 69000030 Surveying and mapping services
 69000040 Quantity surveying services
 69000050 Engineering design and consulting services
 69000060 Commercial art and display services
 69000070 Specialised design services nec (incl fashion, interior and jewellery design)
 69000080 Scientific testing and analysis services
 69000090 Legal services
 69000100 Accounting services
 69000110 Advertising services
 69000120 Market research services

69000130 Statistical services
69000140 Corporate head office management
69000150 Management services (incl business, artists, entertainers and sporting professionals)
69000160 Management advice and consulting services nec (excl financial and computer consulting)
69000170 Veterinary services
69000180 Photography services nec (incl Video filming of Weddings etc)
69000190 Meteorology services
69000200 Interpreting and translating services
69000210 Research and development services
69000220 Own account research and development
69000230 Professional, scientific or technical services nec
69001980 General government consumption of fixed capital (6910, 6921-6950, 6961-6999)
70000010 Computer systems, hardware and software design and development services
70000030 Computer support services
70001980 General government consumption of fixed capital (7000)
72110010 Employment placement and recruitment services (incl casting agency service)
72120010 Labour supply services
72200010 Travel agency and tour arrangement services
72910010 Periodical subscription service
72910020 Office administration services nec (incl clerical, billing, record-keeping and payroll services)
72920010 Document preparation services nec (incl word processing, stenography, typing, transcription and resume writing)
72930010 Credit rating, credit investigation and collection agency services
72940010 Call centre operation
72990010 Tourist information centre operation
72990020 Theatre, concert and sport ticketing and booking services
72990030 Event management or promotion (incl sport, art or similar); fund raising services (fee based) or administration services nec
72991980 General government consumption of fixed capital (7211-7299)
73110010 Building and other industrial cleaning services nec (incl gutters, drains, roads, beaches, swimming pools and toilets)
73120010 Pest control services
73130010 Gardening services
73200010 Crating or packing services for transport
73200020 Packaging of fresh produce, groceries; bottling or rebottling services and packaging services nec
73201980 General government consumption of fixed capital (7311-7320)
75000010 Government administration and regulatory services
75400010 Judicial services
75510010 Domestic government diplomatic and consular services
75521980 General government consumption of fixed capital (7510-7552)
76000010 Defence services
76001980 General government consumption of fixed capital (7600)
77110010 Police services
77120010 Investigative and security services (incl locksmiths) (excl police)
77130010 Fire brigade services (incl forest fire fighting)
77140010 Correctional and detention centres (incl juvenile)
77190010 Public order and safety services (incl coastwatch and country border) nec
77201980 General government consumption of fixed capital (7711-7720)
80100010 Preschool education services
80200010 Primary education services
80200020 Secondary education services
80200030 Special school education services
81010010 Technical, vocational and other non-tertiary education services
81020010 Tertiary higher education services (incl undergraduate and postgraduate)
82110010 Sports or physical recreation instruction services (incl ski or snowboard) nec
82120010 Arts education services (excl vocational)
82190010 NPISH-provided adult, community and other education services
82190020 Other adult, community and other education services
82200010 Educational support services
82201980 General government consumption of fixed capital (8010-8220)
84010010 Hospital services (except Psychiatric Hospitals)

84020010 Psychiatric Hospitals services
 85110010 General practice medical services
 85120010 Specialist medical services
 85200010 Pathology and Diagnostic Imaging services
 85310010 Dental services
 85320010 Optometry and optical dispensing
 85330010 Physiotherapy services
 85340010 Chiropractic and Osteopathic Services
 85390010 NPISH-provided other allied health services
 85390020 Other allied health services n.e.c.
 85910010 Ambulance services
 85990010 Other health services nec
 85991980 General government consumption of fixed capital (8401 - 8599)
 86010010 Residential care services for the elderly (Aged care)
 86010020 Residential care services for the disabled
 86090010 Other residential care services (incl mental health illnesses or substance abuse) nec
 87100010 Child care services
 87900010 NPISH-provided other social assistance services n.e.c. (incl elderly, disabled, marriage and adoption services)
 87900020 Other social assistance services n.e.c. (incl elderly, disabled, marriage and adoption services)
 87901980 General government consumption of fixed capital (8601 - 8790)
 89100010 Museum and art gallery services
 89210010 Zoological and botanical services
 89220010 Nature reserve and conservation park services
 89221980 General government consumption of fixed capital (8910-8922)
 90010010 Performing arts operation nec (incl theatre restaurants and circuses)
 90020010 Services of independent creative artists, writers and performers
 90020020 Theatre lighting, costume design and set design services
 90030010 Performing arts venue operation
 90031980 General government consumption of fixed capital (9001-9003)
 91110010 Gymnasias or fitness centre operation
 91120010 Sports professional services
 91120020 NPISH-provided sport and physical recreation club operation
 91120030 Other sport and physical recreation club operation
 91130010 Sports grounds and similar recreational facilities operation nec (excl Gymnasias or fitness centre)
 91140010 NPISH-provided sport and physical recreation administrative services
 91140020 Other sport and physical recreation administrative services
 91210010 Horse and dog racing, administration and track operation
 91290010 racing horse or dog training and stable (kennel) operation
 91310010 Amusement parks and centres operation
 91390010 Amusement and other recreational activities nec
 91391980 General government consumption of fixed capital (9111-9139)
 92010010 Casinos operation
 92020010 Lottery operation
 92090010 Totalisator agency services
 92090020 Gambling services nec
 92091980 General government consumption of fixed capital (9201-9209)
 94110010 Automotive electrical repair or replacement services
 94110020 Automotive electrical installation services
 94120010 Car wash and cleaning services
 94120020 Automotive body, paint and interior repair services
 94190010 Other automotive repair services
 94191980 General government consumption of fixed capital (9411-9419)
 94210010 Domestic appliance repair and maintenance
 94220010 Electronic and precision equipment repair and maintenance (excl domestic appliance)
 94290010 Other machinery and equipment repair and maintenance
 94910010 Clothing and footwear repair
 94990010 Other repair and maintenance nec
 94991980 General government consumption of fixed capital (9421-9499)
 95110010 Hairdressing and beauty services (incl massage services nec)
 95200010 Funeral directing services
 95200020 Crematoria and cemetery services

95300010 Personal services nec (incl weight reduction centres and prostitution services)
 95310010 Laundry and dry-cleaning services
 95320010 Photographic film processing
 95330010 Parking services
 95391980 General government consumption of fixed capital (9511-9539)
 95400010 Religious services
 95510010 Business and professional association services
 95520010 Labour association services
 95590010 Interest groups nec (incl welfare fundraising services)
 95590020 Services to students at post-secondary institutions by their sports and student unions
 95591980 General government consumption of fixed capital (9540-9559)
 96000010 Domestic services of private household employees

6 Appendix 6: Constraint data sources

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7 Appendix 7: Main text notes

A1: [Wiedmann et al. 2007](#); [Wiedmann 2009](#); [Wiedmann et al. 2011](#); [Tukker and Dietzenbacher 2013](#).

A2: [Guan and Hubacek 2007](#); [Lenzen 2009](#); [Daniels et al. 2011](#); [Jackson and Schwarm 2011](#); [Többen and Kronenberg 2011](#); [Escobedo-Cardenoso and Oosterhaven 2012](#); [Feng et al. 2012](#); [Cazcarro et al. 2013](#).

A3: For example by hybridisation and augmentation with process- or product-specific data, as described in the hybrid-LCA literature ([Heijungs and Suh 2002](#); [Suh 2004](#); [Suh et al. 2004](#); [Suh and Huppel 2005](#), see an overview by [Suh and Nakamura 2007](#)).

A4: The insertion procedures are now standard methodology in hybrid LCA, as attested to by a number of publications see [Heijungs and Suh 2002](#); [Suh 2004](#); [Suh and Nakamura 2007](#); [Wiedmann et al. 2011](#).

A5: [Boomsma et al. 1991](#); [Van der Linden and Oosterhaven 1995](#); [Inomata 2005](#); [Okamoto et al. 2005](#); [Yamano and Ahmad 2006](#); [Bouwmeester and Oosterhaven 2008](#); [Oosterhaven](#)

[et al. 2008](#); [Rueda-Cantuche et al. 2009](#); [Temurshoev et al. 2011](#); [Timmer 2012](#); [Lenzen et al. 2013](#).

A6: For example tools for inserting process data into an IO table (see [Heijungs and Suh 2002](#); [Suh and Huppes 2005](#)), for calculating Leontief inverse, multipliers, and for undertaking a production layer decomposition and Structural Path Analysis (see [Lenzen 2002](#); [Peters 2007](#); [Suh and Heijungs 2007](#)).

A7: [ISO 1998](#); [UNSD 2003](#).

A8: For example [ISA 2012](#); [PE International 2012](#); [PRé 2012](#).

A9: For example by CSIRO: e.g. [Schandl and Turner 2009](#); [Schandl and West 2010](#); [Schandl and Capon 2012](#); [Schandl and West 2012](#); by UQ and GU: e.g. [Daniels et al. 2011](#); [Kenway et al. 2011](#); by UNSW e.g. [Peters and Lundie 2001](#); [Lundie et al. 2004](#); [Lundie and Peters 2005](#); [Rowley et al. 2009](#); [Peters et al. 2010a](#); [Peters et al. 2010b](#).

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