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Manfred Lenzen, Daniel Moran, Keiichiro Kan

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BUILDING EORA: A GLOBAL MULTI-REGION INPUT–OUTPUT DATABASE AT HIGH COUNTRY AND SECTOR RESOLUTION

MANFRED LENZEN*, DANIEL MORAN, KEIICHIRO KANEMOTO and ARNE GESCHKE

ISA, School of Physics A28, The University of Sydney, NSW, Australia

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There are a number of initiatives aimed at compiling large-scale global multi-region input–output (MRIO) tables complemented with non-monetary information such as on resource flows and environmental burdens. Depending on purpose or application, MRIO construction and usage has been hampered by a lack of geographical and sectoral detail; at the time of writing, the most advanced initiatives opt for a breakdown into at most 129 regions and 120 sectors. Not all existing global MRIO frameworks feature continuous time series, margins and tax sheets, and information on reliability and uncertainty. Despite these potential limitations, constructing a large MRIO requires significant manual labour and many years of time. This paper describes the results from a project aimed at creating an MRIO account that represents all countries at a detailed sectoral level, allows continuous updating, provides information on data reliability, contains table sheets expressed in basic prices as well as all margins and taxes, and contains a historical time series. We achieve these goals through a high level of procedural standardisation, automation, and data organisation.

Keywords: Multi-region input–output; Constrained optimisation; Data conflict; Automation; Visualisation

1. INTRODUCTION

During the past decade, our understanding of climate change has improved, but with it, the future outlook has worsened, with research indicating that positive feedbacks may dominate negative feedbacks (Luthje et al., 2006; Walter et al., 2006), and lower estimates for the absorptive capacity of the biosphere (Schuster and Watson, 2007; Heimann and Reichstein, 2008). At the same time, global emissions have, during recent years, approximated the more pessimistic emissions scenarios of the Intergovernmental Panel on Climate Change (Nakiæenoviæ and Swart, 2000; Van Vuuren and Riahi, 2008). In summary, the problem of climate change is now perceived as more severe, more urgent, and as a result more political. The latter is reflected in increasing debates about the national responsibilities for the damages expected from climate change (Munksgaard and Pedersen, 2001; Peters, 2008; Peters and Hertwich, 2008; Peters et al., 2011a). In particular, exporters of emissions-intensive commodities now argue more strongly than ever for a consumer responsibility principle (BBC News, 2009).

In response to these recent trends, various accounting, labelling, reporting, life-cycle, and policy frameworks for consumer responsibility have been created or revived (Section

*Corresponding author. E-mail: m.lenzen@physics.usyd.edu.au

3 in Rueda-Cantuche et al., 2009), and some of these deal with international trade, such as the European EIPOT project. In order to underpin these initiatives, a comprehensive and reliable multi-region input–output (MRIO) database on emissions and international trade is necessary (Tukker et al., 2009; Wiedmann et al., 2009).[1] MRIO-based studies have recently been successful in bringing the issue of carbon embodied in international trade to wider audiences (Davis et al., 2011; Peters et al., 2011b), and in triggering debate amongst decision-makers (BBC, 2008; Lenzen et al., 2010; Wiedmann et al., 2010). Wiedmann et al. (2011) provide an overview of the policy relevance of MRIO databases and studies.

Such databases should ideally cover the entire world at high sector detail, so that emissions-intensive industries or commodities can be singled out. However, previous multi-region studies have used either sector-disaggregated models for a limited number of countries, or sector-aggregated models for the world (Wiedmann et al., 2007; Moran et al., 2009; Wiedmann, 2009b). At present, there are a number of initiatives aimed at compiling large-scale global and international MRIOs (IDE-JETRO, 2006; EXIOBASE, 2012; GRAM, 2012; GLIO, 2012; GTAP, 2012; OECD, 2012; WIOD, 2012; see a summary in Murray and Lenzen, 2013), and these are represented in this Special Issue. The MRIO databases generated by these initiatives have different purposes, and this is reflected especially in their choice of sector and country detail. Most initiatives do not provide for maximum sector disaggregation, but instead most initiatives opt for a breakdown of up to 129 regions and 120 sectors.[2] Further differences relate to whether a continuous time series is generated or not, and how many valuation sheets exist. Most databases do not publish quantitative information on reliability and uncertainty.

2. MOTIVATION

The aim of this work is to address a number of potential areas for improving MRIO compilation. Our goals are

- *Detail*: disaggregation into countries and sectors to the maximum possible level of detail, in order to assist environmental life-cycle and footprint-type assessments of international trade in the most accurate way possible;
- *Dynamics*: creation of a historical time series back to 1970, in order to allow trend and scenario analyses, and projections;
- *Flexibility*: compilation of table sheets expressed in basic prices as well as margins and taxes, and in current and constant US$, so that calculations for different purposes can be carried out;
- *Transparency*: minimisation of assumptions made during the compilation (such as ratios of purchasers to basic prices), and close adherence to the raw data;
- *Uncertainty*: provision of standard deviation estimates for all MRIO elements in order to aid comparative assessments, hypothesis testing, and decision-making;

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[1] In the following, we will refer to a MRIO database extended with physical information simply as an MRIO.
[2] GTAP 8: 57 sectors and 129 regions, extended into a full MRIO by Peters et al. (2011a); EXIOPOL: EU27 and 16 non-EU countries, and about 130 sectors; WIOD: 27 EU countries and 13 other major countries in the world; more than 30 industries and at least 60 products.

- *Reliability*: provision of data for constraint violations in order to inform expert users and statisticians about the discrepancies between the fully balanced MRIO and disparate raw data;
- *Timeliness*: continuous updating of the entire database, so that user analyses are relevant at the time;
- *Budget*: implementation of the entire compilation and updating capability using less than 12 person-years initially, and less than 2 person-years per year continually;
- *Openness*: public, free availability for research purposes, so that there is no barrier for wide dissemination.

At the time of publication, we have achieved:

- *Detail*: we disaggregate the world into 187 countries at a detail of 25–500 sector (Section 4.2 and Appendix 1);
- *Dynamics*: we created a historical time series spanning 1990–2011 (Sections 4.5 and 5.3);
- *Flexibility*: we compile table sheets in basic prices as well as two margins, taxes on products, and subsidies on products (Section 4.3) constant-price tables are the subject of ongoing work;
- *Uncertainty*: we routinely calculate standard deviation estimates for all MRIO elements (Section 5.3);
- *Reliability*: we have developed a web interface allowing the user to gauge overall adherence to raw data, and to query individual constraint violations (Section 5.4);
- *Timeliness*: we are able to continuously update the entire database with a delay of about two years (Sections 4.5 and 5.3);
- *Budget*: the creation of the Eora database and website has required 12 person-years (Section 5.3);
- *Openness*: the database is available at www.worldmrio.com.

We achieve these goals through a high level of procedural standardisation, automation, and data organisation. This article describes the realisation of our MRIO time series.

3. DATA SOURCES

We used six types of data to construct the Eora MRIO tables:

(1) input–output (I–O) tables and main aggregates data from national statistical offices (Appendix 2),
(2) I–O compendia from Eurostat (2011), IDE-JETRO (2006), and OECD (2009),
(3) the UN National Accounts Main Aggregates Database (UNSD, 2011a),
(4) the UN National Accounts Official Data (UNSD, 2011b),
(5) the UN Comtrade international trade database (UN, 2011), and
(6) the UN Servicetrade international trade database (UN, 2009).

The National Accounts Main Aggregates and Official Data compendia form the backbone of Eora's domestic country blocks. The Main Aggregates database comprises 126,152 data points for 216 countries over 38 years, expressed in current US$. There are 1,599,180

National Accounts Official Data items spanning 38 years and 216 countries. An analysis of the National Accounts Official Data shows that the standard deviations of various value-added and final-demand proportions are surprisingly small, and hence the macroeconomic aggregates are relatively stable in their structure across countries and years (Table 1). In addition to the macroeconomic aggregates in Table 1, this database contains sectoral information in terms of some two- and three-digit ISIC classes.

We were able to collect a total of 74 countries' national I–O tables from various statistical agencies (Appendix 2), and these data provide the best support for the I–O relationships of the respective countries. Finally, we utilised a small number of tailor-made data sets, such as a time series of Australian Supply-Use Tables (SUT, Wood, 2011), an extended I–O table for the UK (Wiedmann, 2010), and survey-based I–O tables for Central Asian countries (Müller, 2006; Müller and Djanibekov, 2009), and an extraction of Hong Kong's production structure from the SALTER database (Jomini et al., 1994).

Countries are represented by their ISO 3166 three-letter acronyms (ISO, 2006). Their classifications in the MRIO are represented by a classification acronym (for example, 'NACE'), or by their ISO 3166 acronym if the national SUTs or IOTs are used.[3] We stored data only expressed in their original currencies and units, and only converted to other currencies and units within the constraints writing, with the aim of making the search for constraint realisation (and violation) adhere as closely as possible to the original data, which are known to local statisticians. All raw data were warehoused using eight specifiers[4]: Year, valuation, country of origin, entity (industry or commodity) of origin, sector of origin, country of destination, entity of destination, and sector of destination (see following).

4. METHODOLOGY

In this section, we will lay out the basic elements of our MRIO time series. Characteristic, innovative features will be discussed in further detail in Section 5. Further details on our methodology that are not touched upon here are available elsewhere (Lenzen et al., 2012a).

4.1. Structure of the MRIO Database

Our MRIO features an eight-tiered hierarchy. The first tier describes the accounting year. The second tier describes the valuation of the table. The remaining tiers denote the country, entity, and sector of transaction origin (3–5), and the country, entity, and sector of transaction destination (6–8). Entities are industries, commodities, and value added/final demand (Figure 1).

We assume that the international trade of value added is zero (Figure 1). This can be weakly supported by a comparison of country statistics for the period 1970–2007, where the differences between GDP and gross national income (GNI), which is equal to net trade of value added,[5] are around or less than 1% (UNSD, 2008c, 2008d). Similarly, but by definition, inter-national supply blocks are empty.

[3] http://www.globalcarbonfootprint.com/queries/classifications.jsp.

[4] Instead of four specifiers as in Stelder and Oosterhaven (2009).

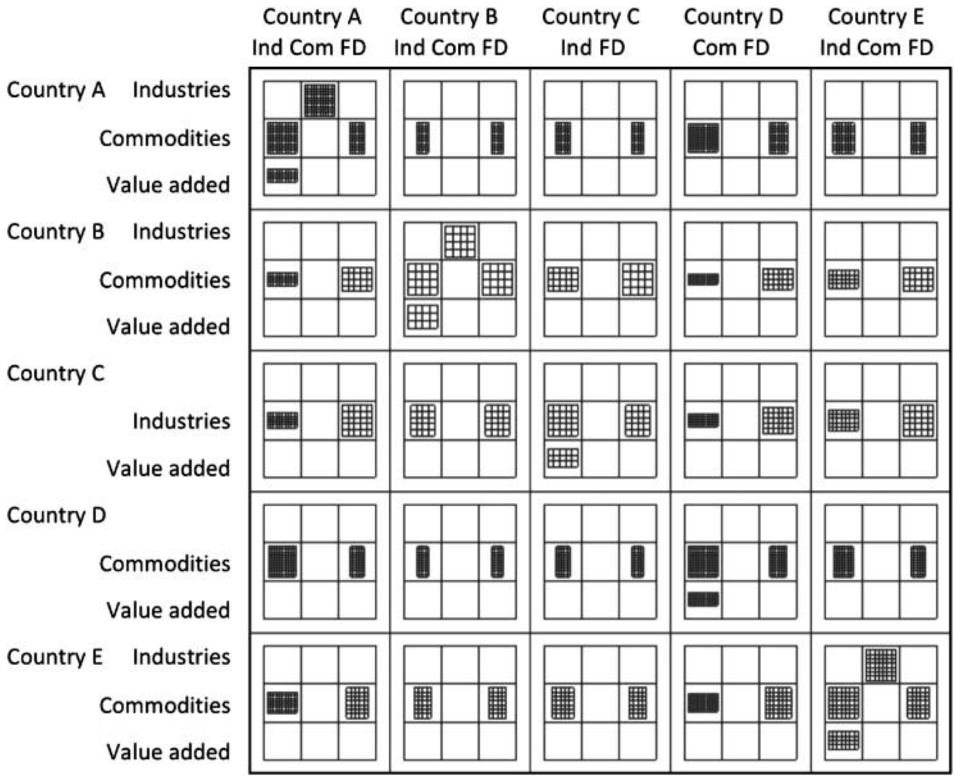
[5] Gross national income (GNI) is GDP less primary incomes (net taxes on production and imports, and compensation of employees and property income) payable to the rest of the world (non-resident units) plus the corresponding items receivable from the rest of the world.

TABLE 1. Descriptive aggregate statistics for the National Accounts Official Data (UNSD, 2011b).

	Value added	Final demand	Intermed demand	Househ'd cons'n	Gov't cons'n	NPISH cons	Capital formation	Inventories	Valuables
As a portion of	Gross output			Total final demand					
	51.3%	51.1%	49.1%	56.8%	19.1%	1.3%	21.9%	0.9%	0.1%
Standard deviation	0.7%	0.6%	0.7%	0.5%	0.4%	0.1%	0.4%	0.2%	0.0%
No. of observations	1327	453	1338	482	482	482	482	482	482
	Comp. of employees	Taxes on products	Taxes on prod'n	Subsidies on products	Subsidies on prod'n	Net gross surplus	Net mixed income	Capital cons'n	
As a portion of	Total value added at purchasers' prices (GDP)								
Standard deviation	40.4%	11.0%	1.4%	−0.5%	−0.6%	25.9%	10.0%	12.5%	
	0.7%	0.3%	0.1%	0.0%	0.1%	1.3%	0.5%	0.6%	
No. of observations	62	62	62	62	62	62	62	62	

Note: Based on 62 component breakdowns of value added, 482 breakdowns of final demand, 453 simultaneous observations of total final demand and gross output, and more than 1,300 simultaneous observations of gross output, and either value added and intermediate demand.

FIGURE 1. Mixed supply-use/I–O MRIO structure (Ind = industries, Com = commodities, FD = final demand).



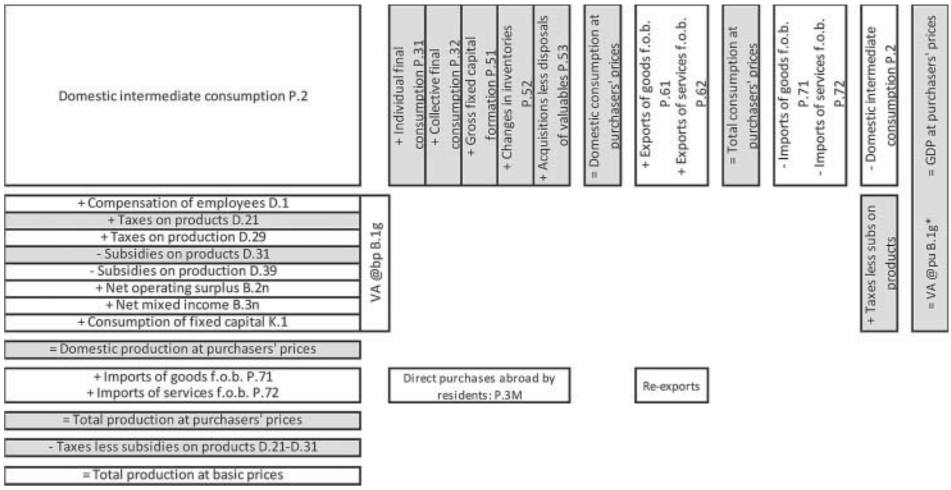
Notes: The well-known supply-use blocks contain national supply and use matrices, **V** and **U**. Country C has only industry-by-industry I–O tables, country D only commodity-by-commodity I–O tables. Off-diagonal trade blocks exist only as use matrices and final demand.

4.2. Sector and Country Classification

The 187 countries covered in the MRIO database and their currencies are listed in Appendix 1. We consider this coverage of the world practically complete[6] and hence do not explicitly construct a 'Rest-of-the-World' region. After the table has been compiled (as described below under Compilation process), we create a Rest-of-the-World region to contain any remaining residuals in the event that the compiled table is not 100% balanced. New countries and their precursors were treated as different entities coming in and out of life over time. National sectoral classifications were adopted, except where I–O data were unavailable or where national sectoral classifications were less detailed than a common ISIC-type classification spanning 25 sectors (Appendix 3). The latter tended to be the case for most of the countries; this group will be referred as the 'common-classed' countries, as opposed to

[6] The UN SNA Main Aggregates and Official Country databases list 252 geographical entities. Amongst the 65 entities excluded in our MRIO are small nations (Vatican, Monaco, Niue, Tokelau, and Nauru), disputed territories (Western Sahara), and small dependencies (Mayotte, American Samoa, Guam, and Gibraltar).

FIGURE 2. Basic structure of UN data for common-classed countries, including SNA93 item descriptors (UNSD 2009).[7]



the detailed 'separately-classed' countries. These countries were represented by industry-by-industry IOTs, with data taken from the United Nations' SNA National Accounts Main Aggregates Database (UNSD, 2011a) and National Accounts Official Data (UNSD, 2011b), and the classification for value added and final demand of those common-classed countries is based on SNA93 definitions (Figure 2).

For many of the common-classed countries, the choice of a 25-sector classification means that a majority of available raw data will be more aggregated than 25 sectors. These aggregated data were used in constraints spanning several MRIO elements (Section 4.5). Our strategy is contrary to some prior work where researchers sometimes aggregated a small, detailed part of some raw data into the largest classification common to all data sets, with a resulting loss of valuable information. A common view is that disaggregation is not desirable, especially when there is no sound information basis on which to construct disaggregation weights. However, disaggregating aggregated raw data in order to match available detailed data is a superior strategy for I–O multiplier calculation. This is true even if detailed data points are few, and weights for disaggregating do not exist (Lenzen, 2011), hence our decision for a disaggregated classification for all countries.

4.3. Valuation

Attempts at constructing MRIO databases are generally hampered by raw data being expressed in different valuations, for example at basic prices, or including various combinations of margins and taxes. This is true for data on domestic transactions as well as international trade (Van der Linden and Oosterhaven, 1995; Lenzen et al., 2004; Oosterhaven et al., 2008). We construct our MRIO at all levels of valuation, distinguishing margins

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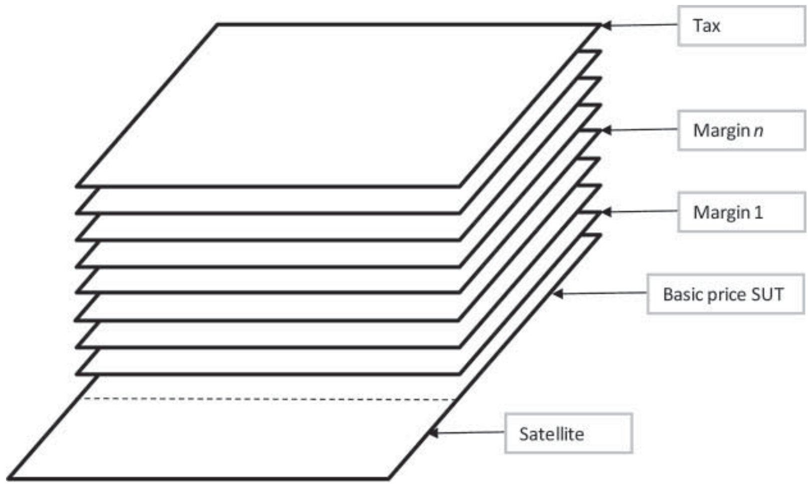
[7] In essence, this implies a one-to-one correspondence between industries and commodities wherever UN data refer to commodities.

FIGURE 3. Stack of MRIO tables expressed in different valuations. The physical satellite accounts exist only as extensions to the basic price table.



and taxes from basic prices (Figure 3). This way, all kinds of raw data can be used as constraints on the table without further conversion, and also the table can be used for different purposes.[8]

In our work, we separate from the basic price sheet, two margins (trade and transpose), and taxes on products and subsidies on products. The various sheets are constructed based on a mix of basic-price and purchasers'-price data, and a detailed initial estimate based on explicit data on all valuations (detailed information can be found is Section S3.1 of Lenzen et al., 2012a). In addition, trade transactions are often valued 'free on board' (f.o.b.) and 'cost, insurance, freight' (c.i.f.). Oosterhaven et al. (2008) (Figure 2) present an overview of how f.o.b. and c.i.f. differ from basic and purchasers' prices.

4.4. Currencies

Whilst national data as well as UN National Accounts Official Data are expressed in national currencies (Appendix 3), other data such as the UN National Accounts Main Aggregates are expressed in current US$. We constructed our base MRIO in current US$, mainly so that we could apply balancing constraints across the entire MRIO, but also so that countries could be compared against each other. For the conversion of national currencies into current US$, we used exchange rates based on International Monetary Fund (IMF) Official Exchange Rates. Whenever International Monetary Fund (IMF) data were not available for certain countries and years, we used price adjusted rates of exchange, and UN Operational Rates (UNSD, 2008a, 2008b).

[8] For example, one may want to undertake a life-cycle or footprint analysis for a multi-national company, using Leontief's quantity I–O model for a classical demand-pull exercise. It is likely that the expenditure vector of that company exists only in terms of purchasers' prices. Having all margins matrices at hand, such an expenditure vector can readily be converted into basic prices without requiring further assumptions and data.

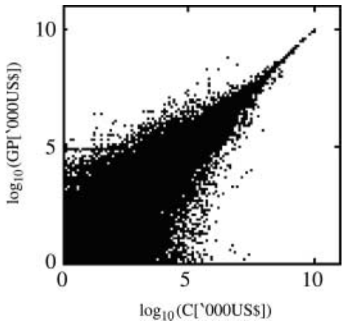
4.5. Compilation Process

The time series is constructed iteratively, by setting up a year 2000 initial estimate of the entire MRIO, reconciling this with all the year 2000 constraints, and taking the solution as the initial estimate for a subsequent year. A unique feature of our approach is that both forecasting and backcasting can proceed simultaneously (Lenzen et al., 2012c). A balanced table for one year will be an inappropriate initial estimate for the subsequent year if significant economic change has occurred during the prior year. Therefore, we have constructed initial estimates by scaling all prior solutions with inter-year ratios $\beta^{rs}_{\mathrm{T,y,v,V}}$ specific to transactions (use $\mathbf{T}^{rr}$, trade $\mathbf{T}^{rs}$,), final demand $\mathbf{y}^{rr}$ and $\mathbf{y}^{rs}$ within countries r and between countries r and s, and value added , and supply tables of countries r. These ratios were derived from country time series data on GDP, exports, imports, and value added (UNSD, 2011a).

MRIO tables were obtained by applying large-scale optimisation approaches to each set of initial estimate and constraints data. Balanced tables were created using either a quadratic programming approach (Van der Ploeg, 1988), or a non-sign-preserving KRAS variant of the RAS method.[9] These methods were chosen because of the considerable conflict in the raw data,[10] as well as sign-changing raw data. Both are problems that pose unsurmountable convergence problems to the conventional widespread RAS method (Lenzen et al., 2009; Lenzen, 2012). Vectorising our MRIO into a $N \times 1$ column vector $\mathbf{P}$, and arranging our raw data into a $M \times 1$ column vector $\mathbf{c}$, we were able to formulate a system of linear equations $\mathbf{GP} = \mathbf{c}$, and a set of box constraints $\mathbf{l} \le \mathbf{P} \le \mathbf{u}$, to be met as much as possible by the MRIO solution $\mathbf{P}$. The quantification of the criterion 'as much as possible' depends on the optimisation method chosen, and in particular on the type of objective function. The $M \times N$ matrix $\mathbf{G}$ holds constraints coefficients connecting raw data to elements of the MRIO. Balancing rules are also incorporated in $\mathbf{G}$, for example as differences between row and column sums, with elements of $\mathbf{c}$ set to zero. Elements of the lower and upper bound vectors $\mathbf{l}$ and $\mathbf{u}$ were set so that all MRIO elements were strictly positive, except values for changes in inventories, and subsidies. In addition to the raw data $\mathbf{c}$, and a prior matrix $\mathbf{P}_0$, optimisation techniques that are capable of dealing with conflicting constraints need some information on the reliability, or uncertainty, of the entries in $\mathbf{c}$ and $\mathbf{P}_0$, for example standard deviations σ_c and σ_P. Constraints posed by raw data $\mathbf{c}$ are usually violated by the constraint realisations $\mathbf{GP}$, and more so for smaller constraints than for larger constraints (Figure 4). This feature will be revisited in Section 5.2. Standard deviations $\sigma_{F,j}$ of MRIO table entries P_j were determined post-optimisation from the standard deviations $\sigma_{c,i}$ of the raw data, by propagating errors of $\mathbf{c} = \mathbf{GP}$ according to $\sigma_{c,i} = \sqrt{\sum_j (G_{ij}\sigma_{P,j})^2}\forall i$. The $\sigma_{P,j}$ are severely underdetermined by the $\sigma_{c,i}$ (M«N), and therefore needs to be solved using a method that can deal with underdetermination, such as RAS. Since the problem is generally RAS feasible, we modified a standard RAS method so that, instead of reconciling $\mathbf{GP} = \mathbf{c}$, it reconciled the error propagation above. The initial estimate $\sigma^0_{P,j}$ was taken as the shift that the MRIO elements experience during the table balancing run: $\sigma^0_{P,j} = P_j - P_{0,j}\forall j$. This means

[9] A mathematical formalisation as well as intuitive introduction of these optimization methods is given in Section S2 of Lenzen et al. (2012a).
[10] On conflict between balancing rules and raw data, see McDougall (2006) and Wiebe et al. (2012). On conflict within the UN Comtrade database, see Lenzen et al. (2012a) and Bouwmeester and Oosterhaven (2008).

FIGURE 4. A ‘rocket graph’ showing adherences of constraints **c** to constraint realisations **GP** in absolute US$ terms.



Notes: Because the externally fixed raw data represented by the constraints **c** conflict, the optimiser can generally not find a solution **P** where the realisations **GP** perfectly match all constraints **c**. Constraints on large values are better obeyed (top right) than constraints on small values (lower left). If the MRIO table perfectly satisfied all constraints this plot would be a 45° line.

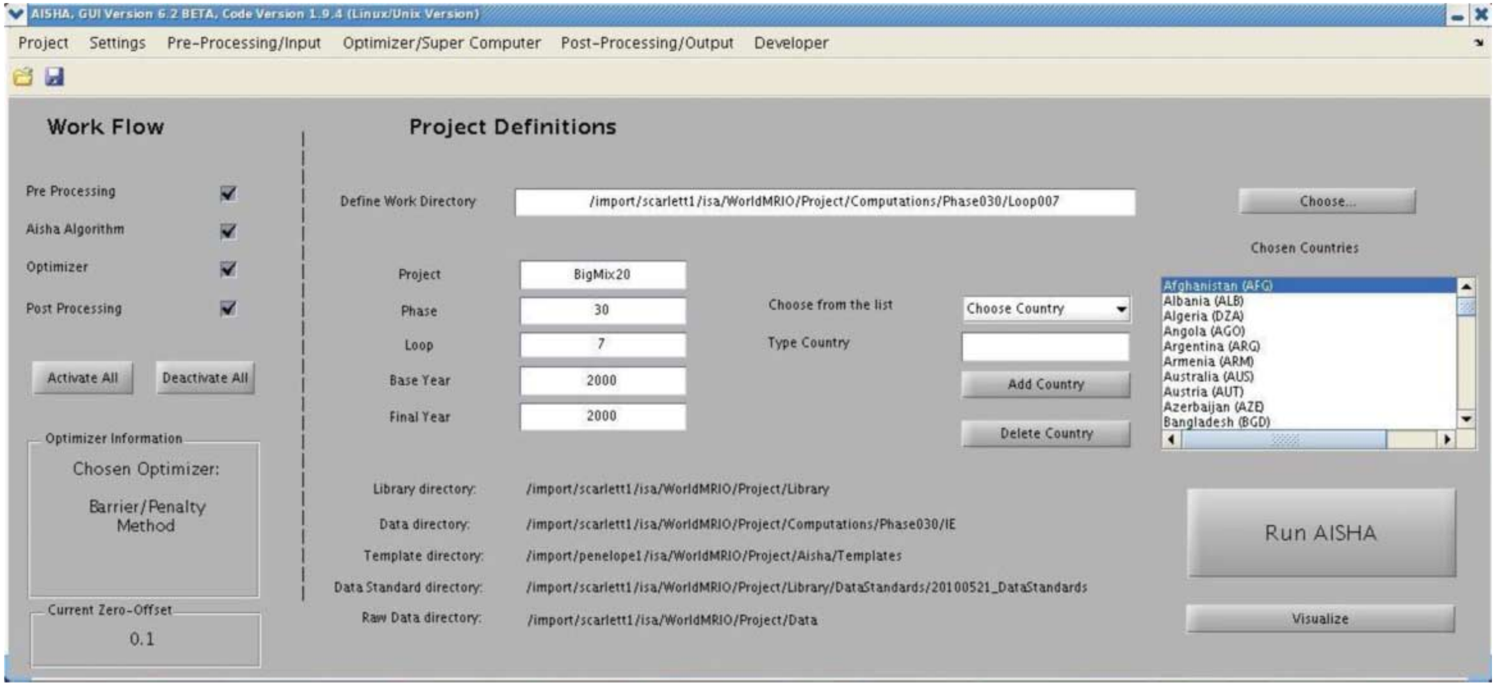
that the problem of finding a solution to the underdetermined error propagation formula is exactly the same as finding a solution to the underdetermined I–O table construction problem $\mathbf{GP} = \mathbf{c}$. Constraints were sorted according to descending $\sigma_{c,i}$, so that the more reliable c_i are always dealt with by RAS after the less reliable c_i, and hence the $\sigma_{P,j}$ are determined on the basis of the best information available. For further details on the method, see Wiedmann et al. (2008) and Lenzen et al. (2010). In general, the reliability of a balanced table increases with the quality and amount of superior data used for balancing (Lenzen et al., 2006; Oosterhaven et al., 2008).

At the time of publication, the Eora tables measured $N \approx 1.2 \times 10^9$, supported by $M \approx 5 \times 10^6$ data points. Handling optimisation at such dimensions requires a combination of parallel programming and advanced computational resources. First, we utilised a purpose-built cluster with 72 cores and 600 GB of RAM. Second, since commercial solvers are unable to deal with optimisation problems at this scale, we needed to develop new mathematical approaches and algorithms, and to tailor hardware to these algorithms.

In order to manipulate and integrate a large number of different data sets we created a custom data processing language (AISHA, Geschke et al., 2011). This language contains commands for locating specific sections of the MRIO table time series and is linked to a library of concordance matrices that assist with the aggregation, disaggregation, and reclassification steps necessary to align disparate data. Conceptually, this language is the reverse of a database query language: instead of selecting and aggregating portions of a multidimensional data set, we want to populate it. For each input data source (national I–O table, UN database, etc.), AISHA reads the processing script and uses it to insert the raw data into the MRIO as constraints or as a portion of the initial estimate.

In order to handle data assembly, constraint writing, optimisation, visualisation, and quality assurance procedures with minimum labour, we developed a graphical user interface (GUI, Figure 5) that enables rapid variation of MRIO run configurations such as country selection, time series span, sector detail, and path for file storage. The GUI was crucial in terms of keeping an overview of test runs during the development of the Eora tables.

FIGURE 5. GUI for controlling Eora runs.



5. CHARACTERISTIC FEATURES

In this section, we will focus only on those aspects of the Eora tables that are innovative in the sense that they differ from features of existing global MRIO databases. Since the Eora tables were only launched in 2012, only one application has been published at the time of writing (Lenzen et al., 2012b). Further applications and their policy relevance in general has been described in detail by Wiedmann et al. (2011), who provide an overview of the role of MRIO frameworks for decision- and policy-making. One of the better known concepts that utilise these frameworks are carbon footprints (Minx et al., 2009; Wiedmann, 2009a).

5.1. Technology Assumptions and Table Formats

In contrast to existing MRIO databases, Eora retains the technology assumptions[11] chosen by the providers of raw data. We combine a mix of SUT, as well as industry-by-industry (IIOT) or commodity-by-commodity tables (CIOT), linked into one compound MRIO. This strategy was pursued in accordance with one of Eora's guiding principles – avoiding transformations of the original raw data as much as possible for the sake of transparency.

There are a number of theoretical and empirical advantages in using SUTs instead of IOTs for analytical modelling (Rueda-Cantuche, 2011; Lenzen and Rueda-Cantuche, 2012).[12] However, supply and use matrices are only available for a limited number of countries, and also in various cases, statistical offices produce IOTs based on superior knowledge and technology assumptions. Such issues with data availability and consistency may result in empirical advantages of IOTs over SUTs. Therefore, and once again for the sake of transparency, rather than opting for one particular table format, we retained the formats chosen by the providers of raw data.

5.2. Reliability

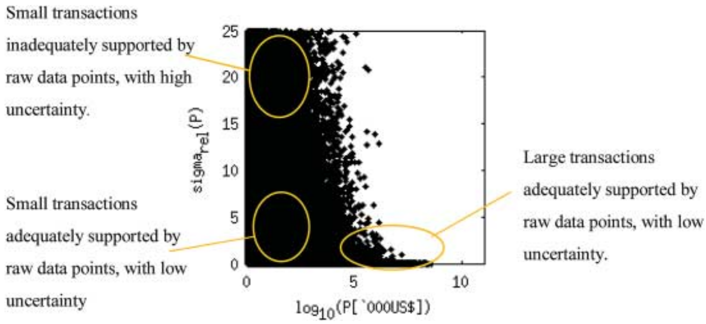
A centrepiece of Eora's approach is the simultaneous estimation of information on data reliability. Users of the Eora tables are being asked to view all quantitative information in light of its varying degree of reliability, and make use of the information provided only within the bounds of its statistical significance. For example, analysts may choose to aggregate the Eora database into a format that is more suitable for their purposes, and in this case Eora's accompanying standard deviation matrices provide the input necessary for calculating the standard deviations of any aggregated table, using standard error propagation.

The method used in the Eora tables for determining MRIO standard deviations is described in Lenzen et al. (2010 compare with Weber, 2008 and Wilting, 2012). In essence, this method fits an error propagation formula to the standard deviations of raw data . These standard deviations can in most cases only be estimated, since very little information is available on the uncertainty of macroeconomic and I–O data. Hence, the standard deviations of raw data, and as a consequence also the standard deviations of the MRIO table elements, are based on

[11] I–O and SUT can be compiled according to a range of technology assumptions, with the commodity and industry technology assumptions being the most widespread amongst data sets provided by Statistical Offices around the world (Ten Raa and Rueda-Cantuche, 2007). Each assumption has its drawbacks, and there is no definite overall advantage of one over the other assumptions (Kop Jansen and Ten Raa, 1990).

[12] Supply-use frameworks were suggested previously for use in Life-Cycle Assessment (Heijungs and Suh, 2002; Suh et al., 2010).

FIGURE 6. Hillside graph' of relative standard deviations $\sigma_{\rho\varepsilon\lambda sP} = \sigma_P/P$ of MRIO elements.



Note: Large elements have a relatively small relative standard deviation as they are relatively well constrained compared to smaller transactions.

assumptions, or *choices*. Furthermore, the uncertainties that we have estimated are stochastic (i.e. only data uncertainty is covered) and not systematic (for example, omissions, lack in coverage, misclassification, underreporting). Note that this approach does not preclude the omission of raw data as an input into the MRIO table compilation. The unsupervised, automated optimisation approach chosen here can readily be complemented with more in-depth manual raw data probing, and selective manual exclusion based for example on data provider interviews. The (variable) degree to which the unsupervised approach is refined by manual interrogation and intervention in the raw data streams would simply depend on the amount of time, and human and financial resources available for the task at hand.

The Eora tables as published at the time of publication were estimated assuming that national I–O tables were most reliable, with the narrowest standard deviation settings, followed by UN Main Aggregates and Official Country data (UNSD, 2011a, 2011b; for years where national I–O data do not exist), and then followed by UN Comtrade data (UN, 2011). The latter were considered least reliable, partly because of severe conflict and errors (Oosterhaven et al., 2008). As a result, a set of Eora tables should be viewed as *based on a particular world view of uncertainty, or reliability*. For other world views, one could re-specify standard deviations, and re-run the Eora construction routines. One would then obtain a different set of tables. Hence, *there is no one unique set of MRIO tables*.

The Eora MRIO tables contain many elements that are small and/or highly fluctuating between years. One might ask: What is the reliability and significance of such elements? To understand this feature, let us recall that the estimation of any large MRIO table is an underdetermined problem. This means that the number M of raw data items c_i that can serve as support points for the MRIO matrices is much smaller than the number N of matrix elements P_j (Section 4.5).

During the optimisation, or matrix *balancing* process, elements that are supported by only few raw data, and hence restricted by only few constraints, can be subject to large adjustments, and hence their reliability is low. On the other hand, for large and important I–O table elements, there usually exist supporting raw data, so that the adjustment of these elements is usually minimal, and hence their reliability is high. This circumstance is reflected in Eora's online 'hillside' graphs (Figure 6).

5.2.1. Mechanisms Generating Unreliable Elements

Large balancing adjustments, and as a result unreliable MRIO elements, are the consequence of the interplay between data conflict and lack of information. Conflicting data create 'tensions' in the set of constraints, whilst lacking support data creates 'dustbins'. Understanding the workings of these tensions and dustbins is critical to achieving a realistic MRIO table. This can be illustrated using a well-known example of conflicting information. Data on country-wise total exports and imports fundamentally conflict with global trade balances. One cannot achieve a balanced global MRIO table whilst at the same time respecting data on exports and imports. This means that in a real MRIO table, either balancing conditions must be violated or raw data misrepresented (compare with Wiebe et al., 2012). The current Eora tables have been constructed with emphasis on (1) representing large data items and (2) fulfilling balancing conditions for large countries. For most countries, exports and imports are smaller than GDP, and the tensions in the constraints force those exports and imports to deviate somewhat from raw data given in the UN's Main Aggregate database (UNSD, 2011a). For some countries, such as Singapore and Hong Kong, exports and imports are larger than GDP, and for these countries, the GDP estimates tend to deviate from raw data.

Tensions in raw data and balancing conditions in one part of the MRIO table can create undesirable outcomes in such parts that are not well constrained by available information. Faced with irreconcilable conflicts in the basic price sheet, optimisation algorithms attempt to accommodate tensions between raw data and balancing conditions through (sometimes large) compensatory adjustments of loosely constrained MRIO elements elsewhere (such as the margins, tax, and subsidies sheets of international trade blocks). Such loosely constrained parts of the table are known amongst MRIO compilers as 'dustbins'. The intermediate demand matrices of any country-year pair where specific I–O data are not available are the most obvious dustbins (sectoral value added and final demand are always constrained by UN SNA data). Further dustbin effects found in the Eora tables are a minority of negative international trade blocks, notably due to overall negative margins sheets or excessively negative subsidies sheets, as well as margins columns that do not sum to zero.

A further but less pronounced source of conflict is constituted by unresolvable differences in definitions between the raw data and the MRIO table. For example, most raw intermediate transactions data exclude re-exports (entrepôt trade) of the respective commodity, but some include them. In order to cater for the majority of circumstances, we disaggregated total re-exports as a one separate sector in our MRIO classification. The national I–O data of 38 countries[13] contain explicit data on re-exports. Whenever such data were not available, re-exports were set to zero.

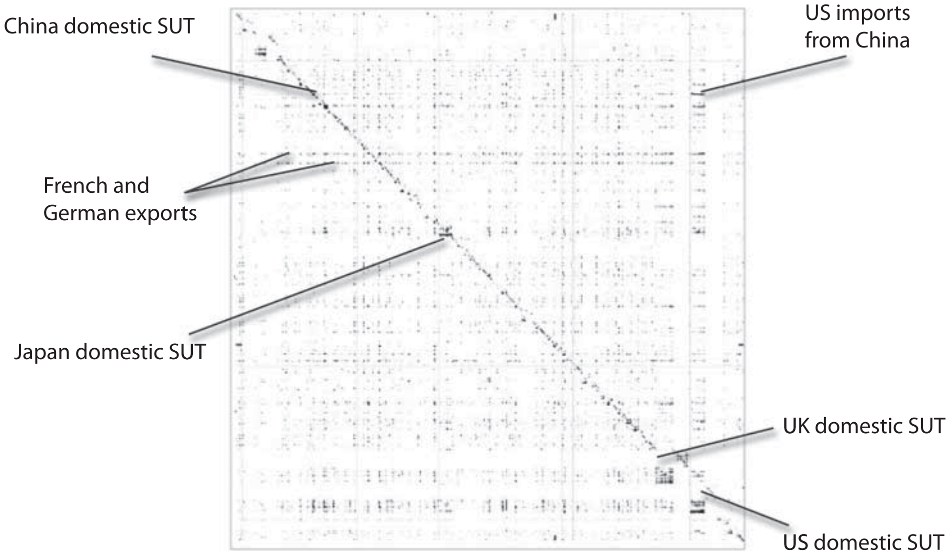
5.2.2. Resolution versus Reliability, and Holistic versus Table Accuracy

Confronted with lack and conflict of data, researchers have asked the following questions:

(1) Does it make sense to construct (MR)IO tables at high detail if many of the ensuing elements are insufficiently supported by raw data, and may become prohibitively unreliable?

[13] Aus, Aut, Bel, Bra, Can, Che, Chl, Cze, Deu, Dnk, Esp, Est, Fin, Fra, Gbr, Grc, Grl, Hun, Irl, Ita, Ltu, Lva, Mkd, Mys, Nld, Nor, Nzl, Per, Pol, Prt, Rou, Svk, Svn, Swe, Tur, Twn, Ven, and Zaf.

FIGURE 7. Visualisation of the basic price sheet of the 2009 Eora world MRIO. Diagonal blocks are domestic tables, and off diagonal blocks contain international trade transactions. French and German exports are discernible as dark grey rows, and US imports as a dark grey column. Domestic transactions are usually more important in monetary terms than international trade.



(2) Will the large number of small and unreliable elements lead to low-quality results for multipliers, footprints, and other impact measures?

With respect to the first question, one can show via the Monte Carlo simulation that it is always beneficial for I–O table construction to use as much information as possible. Choosing not to modify the table's sector classification even when only one disaggregated raw data item was available would mean losing information. Also, even if one were only interested in an aggregated final table, it would be better to construct a disaggregated table first, undertake the multiplier or footprint analysis, and then aggregate the results (Lenzen, 2011).

Regarding the second question, Jensen (1980) has demonstrated that a large number of small elements can be perturbed without significantly changing estimates for multipliers or footprints. Jensen and West (1980) report that a surprisingly large number of smaller elements in an I–O table can even be removed before multipliers show a significant change, because the value of these elements is often negligible compared to the combined value of a few large elements. Since Jensen's pioneering work, this phenomenon has become to be known as *holistic accuracy*. While table accuracy represents the conventional understanding of the accuracy of single matrix elements, holistic accuracy is concerned with the representativeness of a table of the synergistic characteristics of an economy. In this perspective, the accuracy of single elements may be unimportant, as long as the results of modelling exercises yield a realistic picture for the purpose of the analyst or decision-maker. In other words, unless the research focus is on single table elements, it does not matter to have a large number of small and unreliable elements in an I–O table.

5.3. Continuity, Timeliness, and Cost

The Eora tables currently exist as a time series spanning the period 1990–2011. The utilisation of automated data handling systems (Yu et al., 2009) and advanced hardware (Section 4.5) has enabled the reduction of construction cost to around 0.5 US$m initially, and 0.25 US$m on a continuing basis. In addition, we were able to reduce publication delays of a continuous series of tables to no more than about two years. It must be noted however that the resulting MRIO for the most recent two years is mainly based on a forecasted initial estimate that is two years old, and a limited set of recent national accounts data on macroeconomic summary measures and some timely original IOTs, because for the overwhelming majority of countries, original SUT and IOT are typically published four years or more after the year that they refer to. The implication is that if one reconstructed the MRIO at a later stage with more original SUT and IOT for those recent years available, one would obtain a different outcome.

5.4. Visualisation and Diagnostics

Eora is deployed on-line (http://www.worldmrio.com), and at the time of publication, provided a 1990–2011 time series of global MRIO tables, distinguishing 187 countries (Appendix 1) represented by more than 10,000 sectors.[14] The basic price sheet is complemented by four additional sheets in the same format, containing trade and transport margins, as well as taxes and subsidies on products. The entire set of tables is accompanied by an equal-sized set of tables containing the standard deviations of all MRIO elements. Information is available for the entire table, as well as for each country separately. The monetary tables are complemented by satellite accounts containing a number of environmental and resource use indicators such as greenhouse gas emissions, energy use, and emissions to air.

5.4.1. Heat Maps

Accompanying the numerical data are a number of visualisations, which during the development of the Eora database played a crucial role. One such tool is a topographical map, or heat map, which shade-codes the absolute values (in units of US$) of MRIO entries according to a logarithmic scale.[15]

Heat maps allow for rapid quality inspection immediately after table balancing (Figure 7). Any gross errors in the table structure or magnitude would show up as conspicuous dark shadings. Eora's world MRIO heat map is equipped with a zoom-in/zoom-out facility that allows the user to focus on certain regions. Brazil's strongly asymmetrical supply-use structure (55 industries and 110 commodities) is clearly visible (Figure 8), with the main joint production occurring in the agricultural and food manufacturing sectors represented as a horizontal line in the supply matrix. The dark vertical line in the top left corner of the use matrix represents the supply of agricultural goods to Brazil's food manufacturing sectors.

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[14] 10,160 sectors excluding supply-use industries, 15,909 sectors including both supply-use industries and products.

[15] The Eora website features colour-coded maps in order to distinguish positive and negative entries by magnitude.

FIGURE 8. Close-up of Figure 7. Brazilian SUT embedded in transactions matrices for Bhutan, Bolivia, Bosnia, Botswana (to the left), and Brunei, Bulgaria, Burkina Faso, and Burundi (to the right).

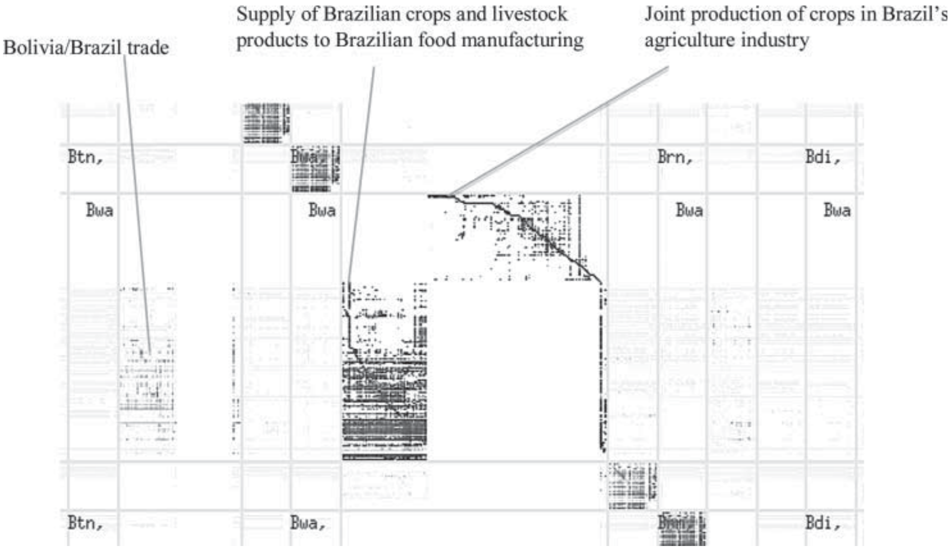
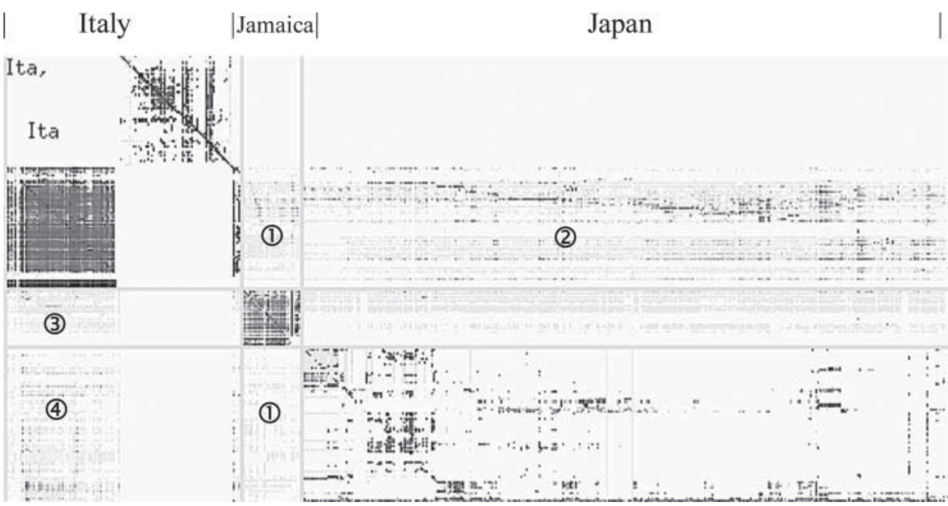


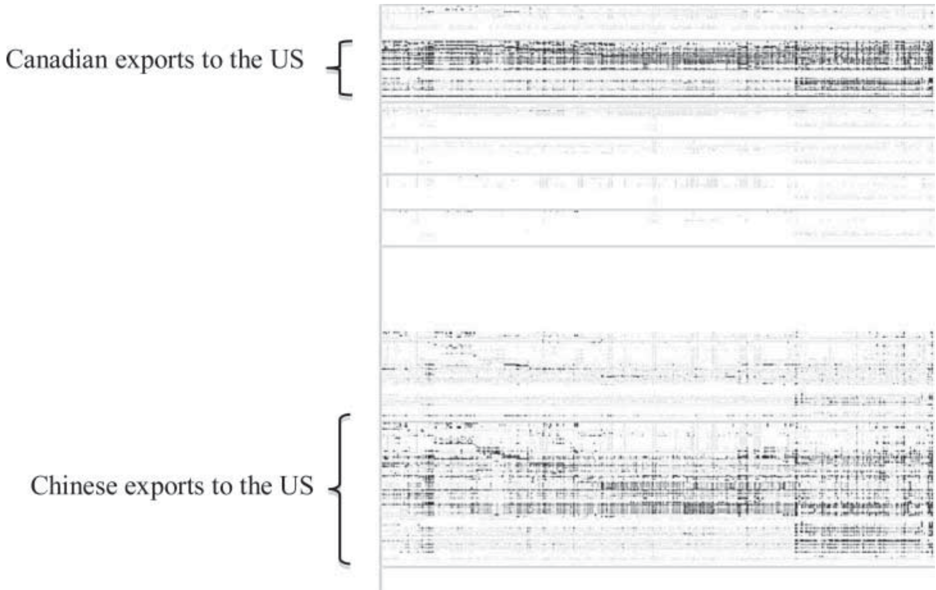
FIGURE 9. Close-up of Figure 7. Interconnected SUT of Italy, industry-by-industry I–O tables of Jamaica, and commodity-by-commodity I–O tables of Japan.



Note: The numerical labels denote four types of international trade matrices described in the main text. Japan's 401-sector table is only partly shown in the bottom right corner of the figure.

The integration of SUT (Italy) with industry-by-industry I–O tables (Jamaica) and commodity-by-commodity I–O tables (Japan) gives rise to four types of international trade matrices (Figure 9): two commodity-by-industry trade matrices, one for Italian exports to Jamaica and one for Japanese exports to Jamaica ①, a commodity-by-commodity trade matrix for Italian exports to Japan ②, an industry-by-industry trade matrix for Jamaican

FIGURE 10. Close-up of Figure 7. The Canadian export block has its top part dominated, signifying important trade flows of primary commodities such as minerals.



Note: The Chinese export block has its central part dominated, signifying important trade flows of manufactured commodities. The remaining trade blocks include exports of Chad and Chile to the USA.

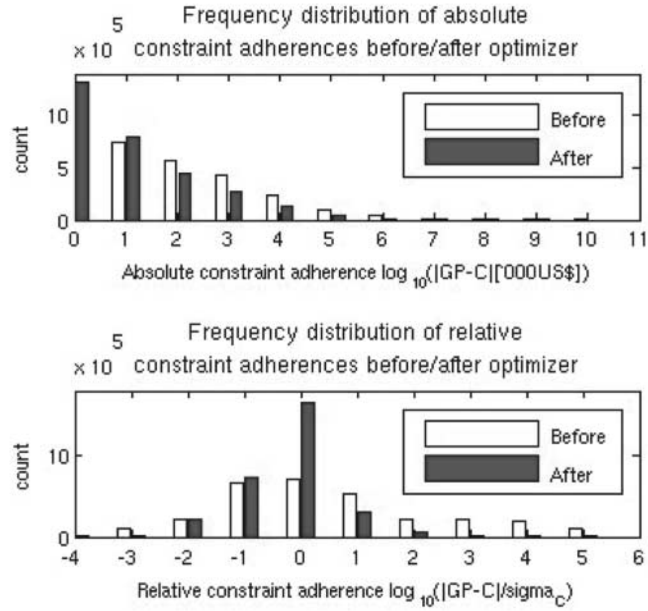
exports to Italy ③, and an industry-by-commodity trade matrix for Jamaican exports to Japan ④. Figure 10 demonstrates how zooming in on particular blocks reveals the nature of trade relationships, such as Canadian primary products and Chinese manufactured products imported into the USA.

5.4.2. Quality Statistics

In addition to the rocket and hillside graphs illustrating MRIO table reliability (Figures 4 and 6), the Eora website offers diagnostic statistics that can be used to judge the performance of the optimisation runs, and as a result the overall quality of results. These include optimiser performance histograms (Figure 11) and size distributions of constraints and MRIO elements (Figure 12). All types of diagnostic visualisations are available for the entire MRIO table, as well as for individual countries.

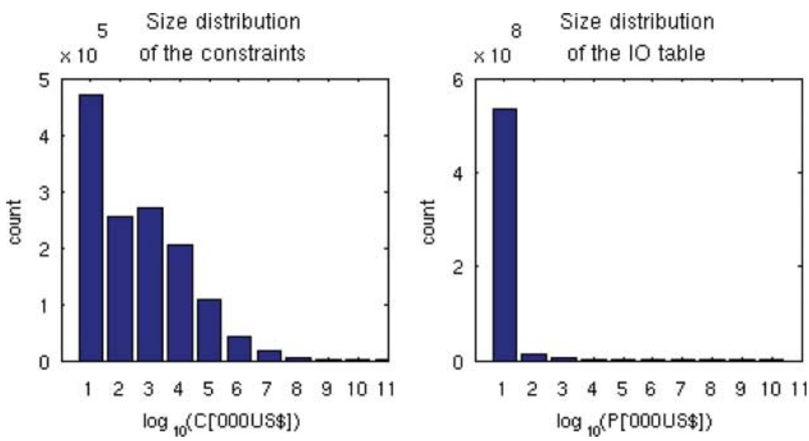
The optimiser performance histograms (Figure 11) allow the user to judge how much the optimiser has improved the constraint realisation $\mathbf{GP}$ of the MRIO solution $\mathbf{P}$ to constraints posed by raw data $\mathbf{c}$, compared to the constraint realisation $\mathbf{GP}_0$ of the MRIO initial estimate. Usually, counts of large constraint violations are low both in absolute terms, and in relative terms as multiples of σ_c. The frequency distribution for the MRIO solution $\mathbf{P}$ is always skewed towards better adherences, compared to the frequency distribution for the MRIO initial estimate $\mathbf{P}_0$. Constraint realisations are also available from the website as ranked lists, one showing top-adhering constraints, well matched by the MRIO, and top violators. Especially, the ranked list of violators proved helpful in detecting any quality issues with

FIGURE 11. Performance histograms for optimisation runs, taken from the Eora website.



Notes: The bars show the frequency distribution of constraint adherences $|\mathbf{GP} - \mathbf{c}|$, before and after optimisation, in absolute ('000 US$) terms (top histogram), and in relative terms as multiples of $\sigma_{\mathbf{c}}$ (bottom histogram). Large constraint violations are situated to the right of the histogram. After optimisation, more counts are registered in the left part of the histograms, representing better constraint adherences. In this example, virtually all initial constraint violations in excess of 100 standard deviations have been eliminated by the optimiser.

FIGURE 12. Size distribution of constraints **c** (left), and of MRIO table elements **P** (right).



Note: The horizontal axes are expressed in logarithms of '000 US$, and is cut off at values smaller than 1000 US$.

the raw data, and in increasing the transparency of the procedural outcome by linking the MRIO entries back to the raw data.

Size distributions of constraints **c** and MRIO elements **P** (Figure 12) are helpful in understanding the optimisation problem. First, the different vertical-axis scales for the constraints size counts and table element size counts show once again how underdetermined the optimisation problem is (compare with Section 4.5). Second, a comparison of the two distributions shows that whilst constraints are to a large extent based on aggregates ranging between 100,000 US$ and 100 million US$, the actual MRIO table is dominated by elements sized 10,000 US$ and less, lending support to Jensen's (1980) view on holistic accuracy.

6. CONCLUSIONS AND OUTLOOK

By focussing on standardisation, automation, and advanced computation, we have achieved a method for rapid, timely, and at the same time low labour- and time-intensive construction and updating of high-resolution MRIO tables. Through these achievements, we have addressed a number of issues identified with respect to MRIO compilation (Wiedmann et al., 2011). The labour and cost savings achieved by compiling MRIO frameworks with a high degree of automation of course come at a trade-off. The relatively unsupervised procedures applied in the Eora approach minimise the departure of MRIO entries from external information by assuming raw data can be taken at face value. Thus, it cannot match the degree of manual reality-checking of information that characterises other MRIO frameworks. Quality assurance is only partly provided in from of on-line violation and adherence reports.

A key principle of our approach is the incorporation and publication of information on data reliability. The latter can be subjective, and the actual realisation of an MRIO table can depend on the choice of reliability settings. Rather than perceiving this ambiguity as a drawback, we argue that there is no unique MRIO table, and every table realisation must be understood and used in conjunction with an accompanying worldview on reliability. One consequence of uncertainty generally increasing towards smaller table elements (Figure 6) is that – generally speaking – the more detailed the results are that we ask from analyses, the more uncertain these results will be. This consequence is simply due to a lack of primary information, and can be made be evident for any analysis based on Eora data simply by supplementing analytical results with an uncertainty calculation. Given that all global MRIO frameworks draw on largely similar types and sources of primary information, we would argue that the lack of such information more or less equally pervades all global MRIO tables. The philosophy behind the Eora database is to be transparent and disclose uncertainty resulting from lack of information, rather than publish just one data table that could lead users to take the numbers at face value.

Using the Eora database, any analyst can check the accuracy of results through analytical or sampling approaches (Heijungs and Lenzen, 2013). In general, the accuracy of results based on Eora will depend on the research question: Results will generally be uncertain at the sectoral level and for small sectors, but not necessarily uncertain for small countries, especially not for small countries with high-quality IO data (for example Mauritius). Once again, the main impetus behind the Eora work is not to aim at accuracy beyond the capability of raw data, but to use (nearly) all existing information, and to make uncertainty transparent so that analysts can better judge what MRIO frameworks can and cannot deliver.

Looking ahead, it is clear that the increasing variety of global MRIO frameworks needs to be brought into some comparative categorisation or taxonomy. This is the mission of the Réunion Project (mentioned in the Editorial), which is aimed at initiating a large-scale research collaboration that will be able to compare and wherever possible and desirable harmonise world-wide activities on environmental-economic MRIO database compilation. A beneficial outcome of a reunion of MRIO initiatives would be the creation of an international collaborative research platform, through which data could be pooled and shared, and MRIO tables released in a regular and timely manner. The Eora research group at the University of Sydney has recently obtained funding to set up a Virtual Laboratory aimed at trialling such a collaborative approach to MRIO compilation for an Australian sub-national MRIO application (http://nectar.org.au/news/nectar-announces-stage-2-projects). The idea of this Virtual Laboratory is that a 'mother of all MRIOs' could incorporate a maximum of information, and all tailored, purpose-focused MRIO tables (such as the current EXIOPOL, GTAP, WIOD, and Eora tables), could be derived from this mother. Joint methodologies would combine the best of all existing approaches. Such an international collaborative research platform would transform MRIO tables from their current status as expensive, complicated, one-off undertakings, into affordable, consistent, and internationally governed and standardised tools. Once placed into easy reach of policy analysts, such tools could improve geopolitical decision-making.

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APPENDIX 1. List of countries in the Eora MRIO database, including UN country code, and number of products (PR) and industries (IN).

UN code	Name	Sectors (PR/IN)
4	Afghanistan	26/0
8	Albania	26/0
12	Algeria	26/0
20	Andorra	26/0
24	Angola	26/0
28	Antigua and Barbuda	26/0
32	Argentina	125/196
51	Armenia	26/0
533	Aruba	26/0
36	Australia	345/345
40	Austria	61/61
31	Azerbaijan	26/0
44	Bahamas	26/0
48	Bahrain	26/0
50	Bangladesh	26/0
52	Barbados	26/0
112	Belarus	26/0
56	Belgium	61/61
84	Belize	26/0
204	Benin	26/0
60	Bermuda	26/0
64	Bhutan	26/0
68	Bolivia	37/37
70	Bosnia and Herzegovina	26/0
72	Botswana	26/0
76	Brazil	56/111
92	British Virgin Islands	26/0
96	Brunei Darussalam	26/0
100	Bulgaria	26/0
854	Burkina Faso	26/0
108	Burundi	26/0
116	Cambodia	26/0
120	Cameroon	26/0
124	Canada	49/0
132	Cape Verde	26/0
136	Cayman Islands	26/0
140	Central African Republic	26/0
148	Chad	26/0
152	Chile	75/75
156	China	0/123
170	Colombia	60/60
178	Congo	26/0
188	Costa Rica	26/0

(*Continued*)

APPENDIX 1. Continued.

UN code	Name	Sectors (PR/IN)
428	Latvia	61/61
191	Croatia	26/0
192	Cuba	26/0
196	Cyprus	26/0
203	Czech Republic	61/61
384	Côte d'Ivoire	26/0
408	Democratic People's Republic of Korea	26/0
180	Democratic Republic of the Congo, previously Zaïre	26/0
208	Denmark	131/0
262	Djibouti	26/0
214	Dominican Republic	26/0
218	Ecuador	49/61
818	Egypt	26/0
222	El Salvador	26/0
232	Eritrea	26/0
233	Estonia	61/61
231	Ethiopia	26/0
242	Fiji	26/0
246	Finland	61/61
250	France	61/61
258	French Polynesia	26/0
266	Gabon	26/0
270	Gambia	26/0
268	Georgia	47/68
276	Germany	0/72
288	Ghana	26/0
300	Greece	61/61
304	Greenland	31/0
320	Guatemala	26/0
324	Guinea	26/0
328	Guyana	26/0
332	Haiti	26/0
340	Honduras	26/0
344	Hong Kong	38/38
348	Hungary	61/61
352	Iceland	26/0
356	India	116/116
360	Indonesia	0/77
364	Iran	100/148
368	Iraq	26/0
372	Ireland	61/61
376	Israel	163/163
380	Italy	61/61
388	Jamaica	26/0
392	Japan	0/402
400	Jordan	26/0
398	Kazakhstan	0/121
404	Kenya	51/51
414	Kuwait	55/0
417	Kyrgyzstan	89/87
418	Lao People's Democratic Republic	26/0

(*Continued*)

APPENDIX 1. Continued.

UN code	Name	Sectors (PR/IN)
422	Lebanon	26/0
426	Lesotho	26/0
430	Liberia	26/0
434	Libyan Arab Jamahiriya	26/0
438	Liechtenstein	26/0
440	Lithuania	61/61
442	Luxembourg	26/0
446	Macao Special Administrative Region of China	26/0
450	Madagascar	26/0
454	Malawi	26/0
458	Malaysia	0/98
462	Maldives	26/0
466	Mali	26/0
470	Malta	61/61
478	Mauritania	26/0
480	Mauritius	57/67
484	Mexico	80/80
492	Monaco	26/0
496	Mongolia	26/0
499	Montenegro	26/0
504	Morocco	26/0
508	Mozambique	26/0
104	Myanmar	26/0
516	Namibia	26/0
524	Nepal	26/0
528	Netherlands	61/61
530	Netherlands Antilles	16/41
540	New Caledonia	26/0
554	New Zealand	127/210
558	Nicaragua	26/0
562	Niger	26/0
566	Nigeria	26/0
578	Norway	61/61
275	Occupied Palestinian Territory	26/0
512	Oman	26/0
586	Pakistan	26/0
591	Panama	26/0
598	Papua New Guinea	26/0
600	Paraguay	34/47
604	Peru	46/46
608	Philippines	0/77
616	Poland	61/61
620	Portugal	61/61
634	Qatar	26/0
410	Republic of Korea	0/78
498	Republic of Moldova	26/0
642	Romania	61/61
643	Russian Federation	49/0
646	Rwanda	26/0
882	Samoa	26/0
674	San Marino	26/0

(*Continued*)

APPENDIX 1. Continued.

UN code	Name	Sectors (PR/IN)
678	Sao Tome and Principe	26/0
682	Saudi Arabia	26/0
686	Senegal	26/0
688	Serbia	26/0
690	Seychelles	26/0
694	Sierra Leone	26/0
702	Singapore	154/154
703	Slovakia	61/61
705	Slovenia	61/61
706	Somalia	26/0
710	South Africa	95/96
724	Spain	76/119
144	Sri Lanka	26/0
736	Sudan	26/0
740	Suriname	26/0
748	Swaziland	26/0
752	Sweden	61/61
756	Switzerland	43/43
760	Syrian Arab Republic	26/0
761	Taiwan	0/163
762	Tajikistan	26/0
764	Thailand	0/180
807	Macedonia	61/61
768	Togo	26/0
780	Trinidad and Tobago	26/0
788	Tunisia	26/0
792	Turkey	61/61
795	Turkmenistan	26/0
800	Uganda	26/0
804	Ukraine	0/121
784	United Arab Emirates	26/0
826	UK	511/511
834	United Republic of Tanzania	26/0
840	USA	429/429
858	Uruguay	84/103
860	Uzbekistan	0/123
548	Vanuatu	26/0
862	Venezuela	122/122
704	Viet Nam	0/113
887	Yemen	26/0
894	Zambia	26/0
716	Zimbabwe	26/0

APPENDIX 2. Availability of national I–O tables.

Country name	Year
Aruba	1995–2002
Netherlands Antilles	2004
Argentina	1997
Armenia	2006

(*Continued*)

APPENDIX 2. Continued.

Country name	Year
Australia	1990–2009
Austria	1995, 1997, 1999–2005
Belgium	1995, 1997, 1999–2004
Bolivia	1999–2002
Brazil	1990–2008
Canada	1995, 2000
Switzerland	2001, 2005
Chile	1996, 2003
China	1990, 1992, 1995, 1997, 2000, 2002, 2005, 2007
Colombia	2000–2007
Czech Republic	1995–2005
Germany	1991–2006
Denmark	1990–2006
Ecuador	2000–2007
Spain	1990–2006
Estonia	1997, 2000–2005
Finland	1995–2005
France	1995–2005
United Kingdom	1992–2005
Georgia	2006–2008
Greece	2000–2007
Greenland	1992, 2004
Hong Kong	1992
Hungary	1998–2005
Indonesia	2000
India	1993, 1998, 2003, 2006
Ireland	1998, 2000–2002, 2005
Iran	1991, 2001
Israel	1995–2007
Italy	1995–2004
Japan	1990, 1995, 2000, 2005
Kazakhstan	1990
Kenya	2003
Kyrgyzstan	2001
South Korea	1990, 1993, 1995, 1998, 2000, 2005–2007
Kuwait	2000
Lithuania	2000–2004
Luxembourg	1995–2007
Latvia	1996, 1998
Maldives	1997
Mexico	2003
Macedonia	2005
Malta	2000–2001
Mongolia	2005
Mauritius	1997, 2002
Malaysia	1991, 2000
Netherlands	1995–2005
Norway	2001–2006
New Zealand	1995, 2002, 2007
Peru	1994
Philippines	2000

(*Continued*)

APPENDIX 2. Continued.

Country name	Year
Poland	2000–2004
Portugal	1995–2006
Paraguay	1994
Romania	2000, 2003-2005
Russian Federation	1990, 1995, 2000
Singapore	1990, 1995, 2000
Slovakia	1995–2004
Slovenia	2000–2005
Sweden	1995–2006
Thailand	1990, 1995, 1998, 2000, 2005
Turkey	2002
Taiwan	1991, 1994, 1996, 1999, 2001, 2004
Ukraine	1990, 2003–2008
Uruguay	1997
USA	1992, 1996–2009
Uzbekistan	1990
Venezuela	1997
Viet Nam	1996, 2000, 2007
South Africa	1993, 1998–2000, 2002

APPENDIX 3. Common 25 ISIC-type classification.

Sector name	ISIC Rev.3 correspondence
Agriculture	1, 2
Fishing	5
Mining and quarrying	10, 11, 12, 13, 14
Food and beverages	15, 16
Textiles and wearing apparel	17, 18, 19
Wood and paper	20, 21, 22
Petroleum, chemical, and non-metallic mineral products	23, 24, 25, 26
Metal products	27, 28
Electrical and machinery	29, 30, 31, 32, 33
Transport equipment	34, 35
Other manufacturing	36
Recycling	37
Electricity, gas, and water	40, 41
Construction	45
Maintenance and repair	50
Wholesale trade	51
Retail trade	52
Hotels and restaurants	55
Transport	60, 61, 62, 63
Post and telecommunications	64
Financial intermediation and business activities	65, 66, 67, 70, 71, 72, 73, 74
Public administration	75
Education, health, and other services	80, 85, 90, 91, 92, 93
Private households	95
Others	99