SI Appendix for

"Mapping the structure of the world economy"

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Contents

Text S1 Extended Multi-region input-output tables and analysis

Thanks to Leontief's innovation and to governance by the United Nations[1], every input-output table conforms to a standardised structure (Fig. S1). Producing entities (so-called *sectors*) are listed along rows and columns in a symmetrical fashion, and every element in the table holds a number that describes the monetary value of a transaction between the row sector supplying a product to the column sector that uses it. Sectors are usually aggregates over many industrial establishments, for example wheat growing, iron ore mining, steel manufacturing, electricity generation, road transport, or banking services. An input-output table holds in its columns the inputs, or the *production recipe*, and in its rows the *sales structure* of all sectors. In its entirety, it contains complete information on the internal interdependence, or structure, of an economy.

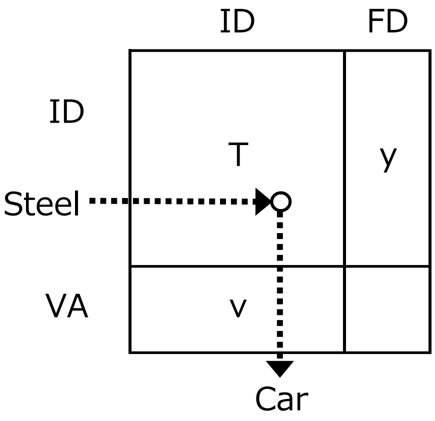
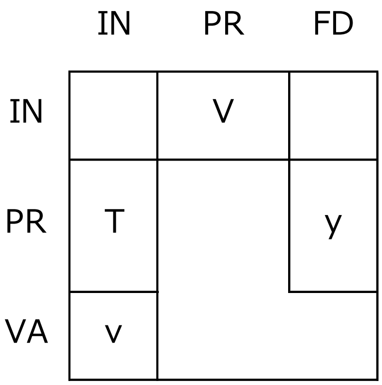


Figure S1a: Schematic of an input-output table. ID = Intermediate demand, matrix **T**; FD = Final demand, matrix **y**; PI = Primary inputs, matrix **v**.

In accordance with the standards set in the United Nations' System of National Accounts [1], input-output tables make a distinction between primary and intermediate inputs, and intermediate and final outputs. *Intermediate inputs and outputs* (matrix **T** in Fig. S1a) are supplied and used by producers of goods and services, that is companies and the public sector. However, in order to operate, each producer also needs inputs from non-producing entities, for example labour or capital, and such inputs are included in the *primary inputs* block (matrix **v**). Finally, each producer not only supplies other producers, but also final consumers such as households, and such outputs are contained in the *final demand* block (matrix **y**).

In addition, the United Nations guidelines [2] provide for an integration of the monetary input-output tables with so-called *satellite accounts* that hold additional information for example on the use of natural resources such as water or energy, on pollution such as emissions, or on other physical inputs into production such as human labour. Satellite accounts are constructed in the same sector classification as the monetary account, and then simply appended to input-output tables.

The System of National Accounts also provides for an input-output table variant called a supply-use table, where the concept of producing sectors is refined into two concepts: an *industry*, and the *products* that it produces. The difference between the sector perspective and the industry-product perspective is that the latter allows one industry to produce more than one product, and one product to be produced by more than one industry. This enhanced detail in a supply-use table is captured in two separate matrices called the *use* matrix (**T**) and the supply matrix (**V**, see Fig. S1b).



	IN	PR	FD
IN		V	
PR	T		y
VA	v		

Figure S1b: Schematic of a supply-use table. ID = Intermediate demand, matrices **T** and **V**; FD = Final demand, matrix **y**; PI = Primary inputs, matrix **v**; IN = Industries, PR = Products.

The System of National Accounts also defines three different valuations at which input-output transactions can be expressed: basic prices, producers' prices, and purchasers' prices. Basic prices refer to the factory- or farm-gate value of a product, whereas producers' and purchasers' prices include various mark-ups such as transport and trade margins, taxes, and subsidies. A full set of input-output tables may include many tables that assume the shapes shown in Figs. S1a and S1b, but contain different types of mark-ups. In unison, the three basic blocks expressed at basic prices as well as various valuations, provide an exhaustive picture of all money flows in an economy.

Input-output tables are used for input-output analysis, a versatile macroeconomic technique that is used in an enormously diverse range of applications, ranging from economic policy modelling, logistics and scheduling, key sector identification, environmental footprinting, structural decomposition, and life-cycle assessment [3, 4]. The unique feature of input-output analysis is that it uses the information on the interdependence of economic sectors in order to quantify complex, indirect repercussions, originating as a result of an initial economic activity, and then travelling along a vast supply-chain network. This capability is embodied in the famous inverse matrix conceived by Leontief [5]. Well-known examples are carbon footprints that include the emissions consequences of all indirect supply-chain transactions resulting out of a single purchasing decision.

In a single-region input-output table, primary inputs include imports, and final demand includes exports. This is because in the context of a single region, foreign agents are not in intermediate, but at the extreme positions of supply chains. One input-output table variant that was already devised by Leontief [6], but has only experienced intensive research and major breakthroughs throughout the past decade, are multi-region input-output (MRIO) tables. In essence, an MRIO table links many single-region input-output tables into one consistent account of intra-regional and inter-regional trade (Fig. S1c). Today, MRIO tables exist at the sub-national as well as the international level.

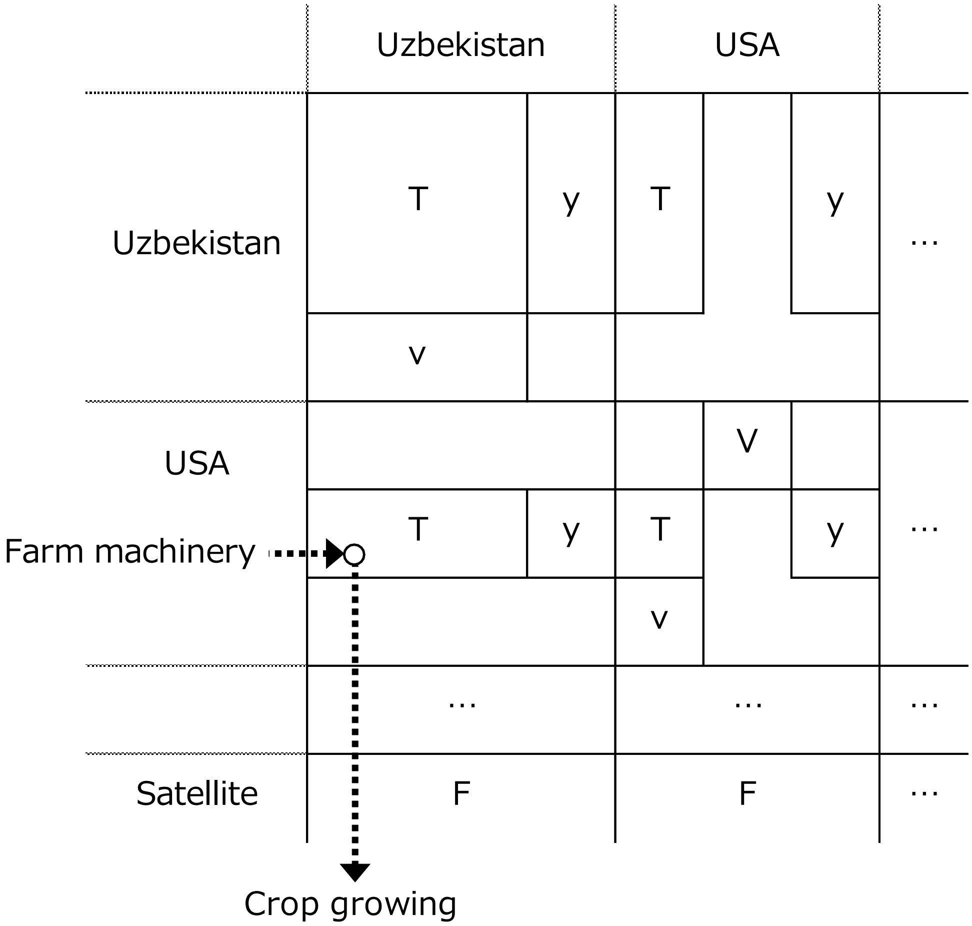


Figure S1c: Schematic of a 2-country section within an environmentally-extended multi-region input-output table, for the example of *r* = USA (supply-use table), and *s* = Uzbekistan (input-output table). ID = Intermediate demand, matrices **T** and **V**; FD = Final demand, matrix **y**; PI = Primary inputs, matrix **v**; IN = Industries, PR = Products.

When applied to MRIO tables, input-output analysis is more powerful than in single-region applications, simply because the MRIO database underlying the analytical techniques offers information on national production recipes as well as international trade relationships. This constitutes the main motivation behind developing ever-more detailed, ever-larger MRIO tables, and in particular the reason for developing the Eora MRIO database.

Text S2 Balancing and time series iteration

In the following we will denote MRIO table components for the year y in valuation v by $MRIO_{ij,y}^{rs(v)}$, where *MRIO* = **T** (domestic input-output, use, or trade), **y** (final demand excluding exports), **v** (value added), **V** (supply tables), aggregate exports **e**, aggregate imports **m**, or imports matrices **M** (for intermediate use) and **N** (for final demand), indexed by exporting country *r*, importing country *s*, supplying sector *i*, and demanding sector *j*. We derive gross output **x** = **T1** + **y** + **e**, where **1** is a summation vector. The symbols **e** and **m** are used instead of $\mathbf{T}^{rs,r\neq s}$ when we refer explicitly to exports or imports statistics. Sectors can be industries as well as commodities, depending on whether countries are represented by IIOT, CIOT or SUT. Sectors can also be value-added and final demand categories. A dot · is used to denote summation over the replaced index instead of using the summation sign Σ. A circle ° next to another index is used to denote summation over the replaced index, but excluding the adjacent index. We will denote valuation alternatively by script (pu – purchasers' price, pr – producers' price, ba – basic price, m*n* – margin *n*, tx – tax, sb – subsidy) or numeric indices. We will leave out the year index y wherever it is not needed.

The time series is constructed iteratively, by starting with the 2000 initial estimate (chosen because this year provides the best overall availability of national input-output tables, per *SI Appendix*, Table S3), reconciling this with all 2000 constraints, and taking the solution as the initial estimate for 2001, and so on. Back-casting to 1990 proceeds similarly. A balanced table for one year will be an inappropriate initial estimate for the next year under strong economic growth. Therefore, we have constructed initial estimates by scaling all prior solutions with inter-year ratios $ß_{\mathbf{T},\mathbf{y},\mathbf{v},\mathbf{V}}^{rs}$ specific to transactions (use, trade) **T**, final demand **y**, value added **v**, and supply tables **V**. These ratios were derived from country time series data on GDP, exports, imports, and value added[7].

Balanced MRIO tables were obtained by specifying an initial estimate (vectorised as $\mathbf{a}_0$), and applying the quadratic programming approach by Van der Ploeg[8]. Here, external constraint information **c** (often called "superior data") are linear functions $\mathbf{c} = \mathbf{C}\,\mathbf{a} + \boldsymbol{\varepsilon}$ of the vectorised MRIO entries **a**, as well as disturbances $\boldsymbol{\varepsilon}$ that describe the constraint violation. We chose this approach because the disturbances allow effective handling of disparate, unaligned, conflicting and unreliable information[9, 10], and because signs and zeros are not necessarily preserved. The sign- and zero-preservation inherent in the variants of the RAS balancing method is undesirable because it does not allow account items such as net taxes and changes in inventories to switch signs, and it forces all variables connected to zero-valued constraints to zero without compromise.

Van der Ploeg extends **a** with the disturbances $\boldsymbol{\varepsilon}$, to a compound unknown **p**, distributed as

$$\mathbf{p} = \begin{pmatrix} \mathbf{a} \\ \boldsymbol{\varepsilon} \end{pmatrix} \sim \mathrm{D}\left[\begin{pmatrix} \mathbf{a}_0 \\ 0 \end{pmatrix}, \begin{pmatrix} \boldsymbol{\Sigma}_{\mathbf{a}} & \\ & \boldsymbol{\Sigma}_{\mathbf{c}} \end{pmatrix}\right] = \mathrm{D}[\mathbf{p}_0, \boldsymbol{\Sigma}] \tag{S1}$$

with mean $\mathbf{p}_0 = [\mathbf{a}_0 \mid 0]$, and variance $\boldsymbol{\Sigma} = [\Sigma_a \mid \Sigma_c]$. Exactly known constraints are a special case with the corresponding element in $\boldsymbol{\Sigma}_c$ being zero. Extending $\mathbf{G} = [\mathbf{C} \mid -\mathbf{I}]$, where $\mathbf{I}$ is the unity matrix, and assuming that all covariance terms in $\boldsymbol{\Sigma}$ vanish, the generalised optimisation problem becomes

$$\text{Minimise } f(\mathbf{p}, \mathbf{p}_0, \Sigma) \text{ subject to } \mathbf{G}\,\mathbf{p} = \mathbf{c}\,. \tag{S2}$$

S2.1 Quadratic Programming approaches

One approach that has been used to reconcile large input-output tables and Social Accounting Matrices is Quadrat Programming [8]. Here the objective function is $f(\mathbf{p}, \mathbf{p}_0) = (\mathbf{p} - \mathbf{p}_0)'\, \hat{\boldsymbol{\Sigma}}^{-1} (\mathbf{p} - \mathbf{p}_0)$. Setting up the Langrangean as $\mathscr{L} = (\mathbf{p} - \mathbf{p}_0)'\, \hat{\boldsymbol{\Sigma}}^{-1} (\mathbf{p} - \mathbf{p}_0) + \lambda(\mathbf{Gp} - \mathbf{c})$, solving the first-order condition leads to analytical solutions $\lambda = (\mathbf{G}\,\hat{\boldsymbol{\Sigma}}\,\mathbf{G}')^{-1}(\mathbf{Gp;}_0 - \mathbf{c})$ and $\mathbf{p} = \mathbf{p}_0 - \hat{\boldsymbol{\Sigma}}\,\mathbf{G}\lambda$, however these do not guarantee any non-negativity that might need to be imposed on some elements. We therefore add inequality constraints $l_i \leq p_i \leq u_i$ forcing the solution to lie within lower and upper bounds l_i, $u_i \in [-\infty,+\infty]$. These lower and upper bounds result from definitions of accounting variables. For example, the bounds for changes in inventories are $[-\infty,+\infty]$, those for subsidies are $[-\infty,0]$, and those for remaining MRIO elements are are $[0,+\infty]$.

The mixing of equality and inequality conditions precludes analytical solution, and requires sophisticated numerical solvers. Several commercial solvers were tested during Eora's development phase. Most commercially available solvers such as CPLEX are designed to operate on a single processor leading to unacceptably long runtimes for the reconciliation of the Eora tables. We then focused on parallel optimisation and found that most parallel solvers such as PGAPack or PARAGenesis (which both apply the genetic algorithm) are not applicable to the reconciliation problem of the Eora tables. The GAMS modelling system (available at http://www.gams.com/), which is also popular for MRIO reconciliation, offers an optimiser that is not parallelisable. XPRESS (available at http://www.fico.com/) offers a parallel optimisation suite for a number of optimisation approaches such as linear programming, mixed-integer programming or quadratic programming. However, the large number of variables within the Eora tables exceeds the design boundaries of XPRESS by a factor of 1000. A parallel version of CPLEX is available for linear and quadratic programming. However, for linear programs, the problem is solved using different solvers in parallel (see http://www-01.ibm.com/support/docview.wss?uid=swg21400049). Each individual solver is executed serially on a single processor. The parallelization therefore doesn't gain any speed-ups for the individual solvers offered by CPLEX. Detailed explanation on the parallelization of the CPLEX solver for quadratic programming is currently not provided on the CPLEX website (see http://www.aimms.com/features/solvers/cplex). However, at the time of writing CPLEX only supported linear constraints for quadratic programming, but not boundary constraints. Hence, CPLEX's quadratic programming solver could not be applied to Eora's particular optimization problem. During the earlier development of Aisha, a distributed-memory-type parallelisation of CPLEX using MPI was investigated. This approach proved to be unsuccessful because the communication overhead caused by the exchange of data between the different computing nodes eliminated any computational speedups obtained through multi-core parallelisation. A good overview of available optimisation packages is available at http://www.mat.univie.ac.at/~neum/glopt/software_g.html.

As a result of the unavailability of commercial solvers, we resorted to writing tailored QP solvers. At the time of writing, the AISHA tool offers two optimisation algorithms to solve van der Ploeg's generalised optimisation problem for a quadratic objective function. The first one is a QP method described by Huang *et al* [11], the second one is based on Cimmino's Algorithm (see [12]).

S2.2 RAS variants

AISHA also offers a RAS-type optimisation algorithm called KRAS (see [10]), which is an extension of RAS that can be applied to RAS-type problems such as the one given in Equation S2, where the objective function is

$$f(\mathbf{p}, \mathbf{p}_0) = \sum_{j}^{N} p_j \ln\left(\frac{p_j}{e p_{0,j}}\right)$$

Let *j* be the counter over the elements of **p** and the columns of **G**, let *i* be the counter over the rows of **G**, and let *n* be the current iteration step. Let *N* be the total number of elements in **p** and let *M* be the total number of constraints (which is equal to the number of rows in **G**). Let λ_i denote the Lagrange-multipliers. Setting up a Langrangean as

$$\mathcal{L} = \sum_{j;p_j \geq 0} p_j \ln\left(\frac{p_j}{e p_{0,j}}\right) + \sum_{j;p_j < 0} p_j \ln\left(\frac{p_j}{e p_{0,j}}\right) + \sum_i \lambda_i \left[\sum_j g_{ij}\, p_j - c_i\right]$$

and solving the first-order condition leads either to either an iterative Gauss-Seidel-type adjustment scheme (GRAS variant) given by

$$r^{(n)} = \frac{c_i + \sqrt{c_i^2 + 4 \sum_{j, p_j^{(n-1)} g_{ij} > 0} g_{ij} p_j^{(n-1)} \sum_{j, p_j^{(n-1)} g_{ij} > 0} g_{ij} p_j^{(n-1)}}}{2 \sum_{j, p_j^{(n-1)} g_{ij} > 0} g_{ij} p_j^{(n-1)}}$$

and

$$p_j^{(n)} = p_j^{(n)} \left[r^{(n)}\right]^{\mathrm{sgn}\left(p_j^{(n-1)} g_{ij}\right)}$$

with *i*=*n* mod *M,* or (via Bregman's method; KRAS variant) to an updating condition

$$\lambda_i^{(n)} = \begin{array}{c} \text{use the solution of Eqn (S3) for } i = n \bmod M \\ \lambda_i^{(n-1)}, \text{for } i \neq n \bmod M \end{array}$$

that requires solving a generalised polynomial

$$P_i\left(\lambda_i^{(n)}\right) = \sum_{j;p_j\geq 0} g_{ij} p_j^{(n-1)} r_i^{(n)^{-g_{ij}}} + \sum_{j;p_j<0} g_{ij} p_j^{(n-1)} r_i^{(n)^{g_{ij}}} \tag{S3}$$

The main difference between KRAS and other RAS variants is that KRAS can handle conflicting constraints, by considering the provided reliability information during the optimisation process. Additionally KRAS is parallelisable, and can also handle sign flips and inequality constraints $l_i \leq p_i \leq u_i$. In comparison to QP algorithms, the coding of RAS variants is less complex, and their execution requires less RAM.

S2.3 Comparison of optimisation objectives

As shown in the two preceding sections, the reconciliation of an MRIO can be approached using different methods. The most common approaches are RAS-type methods, linear programming techniques and quadratic approaches such as van der Ploeg's least-square method. Each approach can be motivated, and all of them have precedents within IO research and applications (see [11]). However, obviously, each approach yields a different result. The magnitude of the differences between various methods depends highly on the nature of the constraints and the feasibility of the optimization problem. The more the initial estimate has the be adjusted by the optimisation routine in order to adhere to the externally given constraints, the more the results of various methods will differ from one another. Consider the 2-dimensional problem

$$\text{Minimise } f\left(\begin{pmatrix}p_1\\p_2\end{pmatrix},\begin{pmatrix}1\\3\end{pmatrix}\right) \text{ subject to } \begin{pmatrix}1 & -2\end{pmatrix}\begin{pmatrix}p_1\\p_2\end{pmatrix} = 0$$

Hence, in this case we have

$$\mathbf{G} = \begin{pmatrix}1 & -2\end{pmatrix}, \mathbf{p}_0 = \begin{pmatrix}1\\3\end{pmatrix}, \text{and } \mathbf{p} = \begin{pmatrix}p_1\\p_2\end{pmatrix}$$

The feasible set defined by $\mathbf{Gp} = 0$ are the points that lie on the blue line within the graph. The different objective functions for this example are:

$$f_{\text{RAS-type}} = \sum_{j=1}^{2} p_j \ln\left(\frac{p_j}{e p_{0,j}}\right)$$

$$f_{\text{linear}} = \sum_{j=1}^{2} \left|p_j - p_{0,j}\right|$$

$$f_{\text{quadratic}} = \sqrt{\sum_{j=1}^{2}\left(p_j - p_{0,j}\right)^2}$$

The constraints equation $(1 \ -2)\begin{pmatrix}p_1\\p_2\end{pmatrix} = 0$ can be used to express p_2 as a function of p_1 for the feasible set. We have

$$\begin{aligned}&(1 \ -2)\begin{pmatrix}p_1\\p_2\end{pmatrix} = 0\\ &\Leftrightarrow p_1 - 2p_2 = 0\\ &\Leftrightarrow \ p_2 = \frac{1}{2}p_1\end{aligned}$$

With this formulation we can express the objective functions as functions of the single variable p_1 on the feasible set $\mathbf{Gp} = 0$ (Fig S2a).

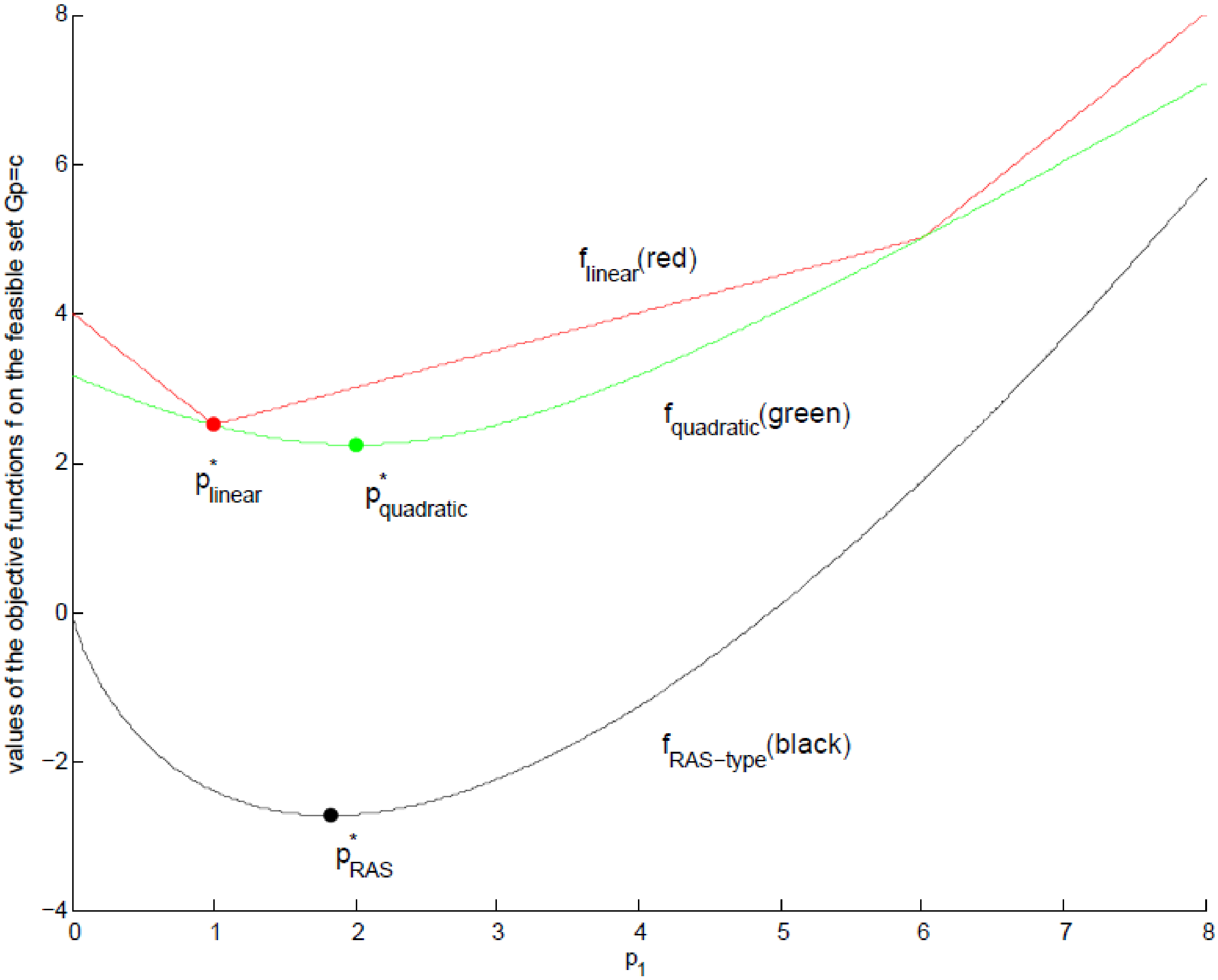


Fig S2a: Visualization of the values of the three different objective functions on the feasible set defined by $\mathbf{Gp} = 0$ as functions of p_1. All three objective functions have their unique minima, however these are different from one another. The values of the objective functions do not give any indication whether a particular objective function is more suitable for the 2-dimensional problem than others.

We observe that the p_1 values for optimal solutions of the different objective functions are different. The optimal p_1 values can be used to calculate corresponding p_2 values to find the solutions on the feasible set given by $\mathbf{Gp} = 0$. Fig S2a shows the three different solutions together with the feasible set and the initial estimate in the p_1/p_2 plane.

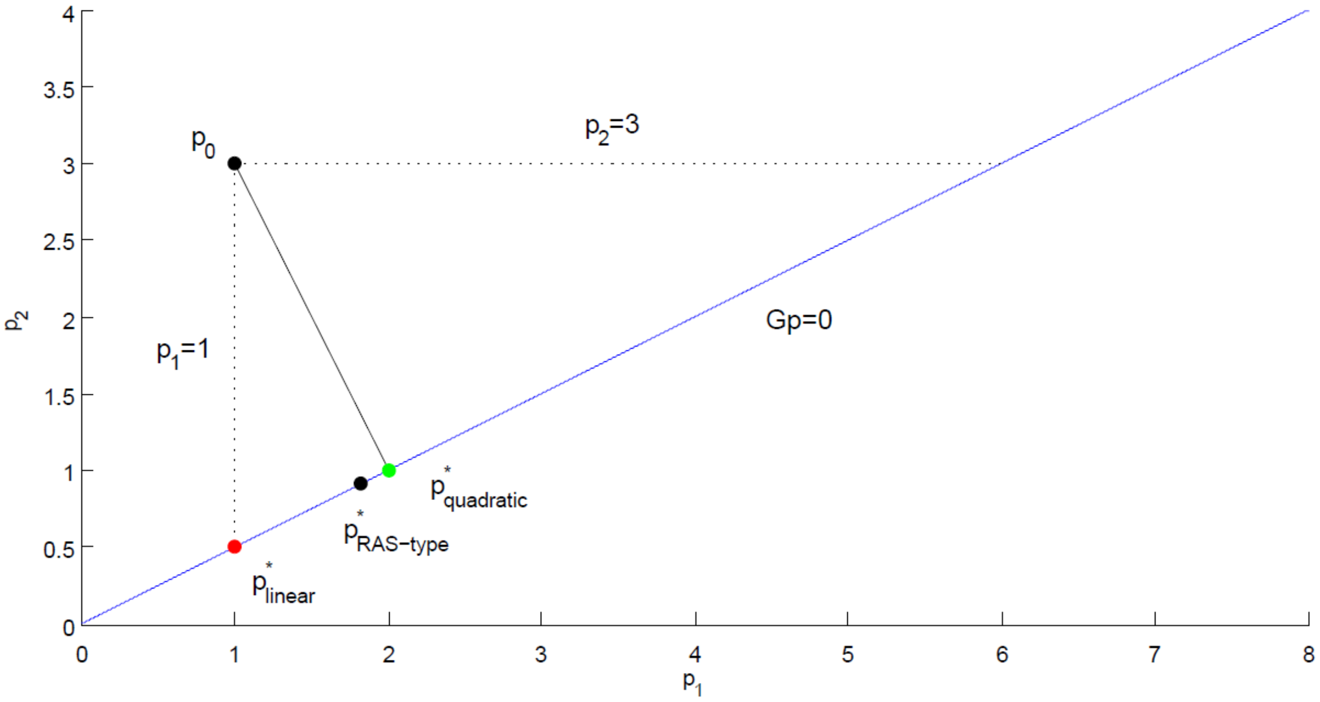


Fig S2b: Visualization of the different solutions of the 2-dimensional problem posed above, for different optimization methods. The blue line represents the set of feasible points defined by the equation $\mathbf{Gp} = 0$, $\mathbf{p}_0$ is the initial estimate. The colors for the solutions of the different approaches are the same as in plot Fig S2a: The red dot represents the solution for the linear approach, the black dot on the blue line for the RAS-type approach, and the green dot for the quadratic programming method. The line connecting the initial estimate and the result of the quadratic approach is perpendicular to the set of feasible points, and hence intuitively the "shortest" distance.

The solution to the quadratic approach is usually the one that we will interpret as the "best" solution, because it is the point "closest" to the blue line in a Euclidean sense. Also, only the quadratic approach yields the solution that represents the minimal absolute distance between the initial estimate and $\mathbf{p}_0$ the blue line.

The solution for the linear programming approach has a similar yet slightly less intuitive explanation. A linear programming approach uses a so-called $\ell 1$-type norm to measure the distance between two points. For this 2-dimensional example, the $\ell 1$-norm only allows the movement along the grid lines of the 2-dimensional plane when measuring the distance between two points. The distance between the initial estimate and any point on the blue line is measured by adding the distance in p_1–direction and the distance in p_2–direction. In this problem, the minimal distance in a $\ell 1$-norm sense is achieved if the point on the blue line and the initial estimate have the same p_1–coordinate. That way, no additional distance into the p_2–direction has to be added to the $\ell 1$-norm of the distance between the points. Another popular example to motivate the $\ell 1$-norm is that of a taxi driver in Manhattan (see http://en.wikipedia.org/wiki/Taxicab_geometry): If we consider that Manhattan's streets are made up by a perfect grid of streets in North-South direction and by streets in East-West direction, then a taxi driver who wants to driver between two arbitrary intersections within the grid has to measure the distance between those intersection by adding up the distances that he has to travel in North-South direction and in East-West direction. This is exactly the $\ell 1$-norm between the two intersections. The taxi driver cannot travel the direct way between the two intersections (which would measure the distance between the two intersections in the $\ell 2$-norm), as this might require travelling diagonally through the grid, which is obviously impossible.

RAS-type functions do not measure an intuitive distance between different points within a space, but an information loss that occurs when moving from one point to the other. Bacharach [13] goes into great detail motivating this information loss interpretation of the RAS objective function.

Text S3 Initial estimate

Considering that the estimation of our MRIO (and in fact most IO tables) from external constraints is an underdetermined problem, it is worth constructing an initial estimate that is as realistic as possible. For the 187 countries in our MRIO, data availability is vastly different, so that if not carefully planned, setting up an initial estimate can be hampered by case-dependent manual operations. In order to avoid time-consuming labour, we aim at setting up an initial estimate in a way that uses a) the same data source for all countries, b) as much specific data and as little proxy data as possible. We use: First, the National Accounts Main Aggregates Database (MA[7]), containing final demand ($y_{\cdot l}^{\cdot s(\mathrm{pu})}$; 4 categories *l*) in purchasers' prices, and value added ($v_{\cdot j}^{ss(\mathrm{ba})}$; 7 sectors *j*) in basic prices, imports ($m_{\cdot\cdot}^{\circ s(\mathrm{fb})}$) and exports ($e_{\cdot\cdot}^{r\circ(\mathrm{fb})}$) valued f.o.b.; second, the UN National Accounts Official Data (OC[14]) containing data on gross output $x_{\cdot\cdot}^{ss(\mathrm{ba})}$ and intermediate demand $T_{\cdot\cdot}^{ss(\mathrm{ba})}$, and additional detail for final demand ($y_{\cdot l}^{\cdot s(\mathrm{pu})}$; 6 categories *l*) in purchasers' prices, and value added ($v_{\cdot j}^{ss(\mathrm{ba})}$; 18 sectors *j*) in basic prices; and third the UN ComTrade international trade data (CT[15]) containing exports $e_{i\cdot}^{rs(\mathrm{fb})}$ valued f.o.b. and imports $m_{i\cdot}^{rs(\mathrm{cf})}$ valued $\mathrm{c.i.f.}$ (Table S1).

Table S1: Summary of data for each data sources

Data sources	Abbreviation of data sources	Data	Formula of data	Number of categories	Price
National Accounts Main Aggregates Database	MA	final demand	$y_{\cdot l}^{\cdot s(\mathrm{pu})}$	4	purchasers' prices
		value added	$v_{\cdot j}^{ss(\mathrm{ba})}$	7	basic prices
		imports	$m_{\cdot\cdot}^{\circ s(\mathrm{fb})}$	1	f.o.b.
		Exports	$e_{\cdot\cdot}^{r\circ(\mathrm{fb})}$	1	f.o.b.
UN National Accounts Official Data	OC	gross output	$x_{\cdot\cdot}^{ss(\mathrm{ba})}$	1	basic prices
		intermediate demand	$T_{\cdot\cdot}^{ss(\mathrm{ba})}$	1	purchasers' prices
		final demand	$y_{\cdot l}^{\cdot s(\mathrm{pu})}$	6	purchasers' prices
		value added	$v_{\cdot j}^{ss(\mathrm{ba})}$	18	basic prices
UN ComTrade	CT	exports	$e_{i\cdot}^{rs(\mathrm{fb})}$	About 5000 (HS 6-digits)	f.o.b.
		Imports	$m_{i\cdot}^{rs(\mathrm{cf})}$	About 5000 (HS 6-digits)	c. i. f.

Text S3.1 SUTs and IOTs

We construct the diagonal intra-national transaction blocks of the initial estimate according to

$$T_{ij}^{ss(v)} = \frac{\tilde{T}_{ij}^{ss(v)}}{\tilde{T}_{\cdot\cdot}^{ss(\mathrm{pu})}} \frac{T_{\cdot\cdot}^{ss(\mathrm{pu}),\mathrm{OC}}}{v_{\cdot\cdot}^{ss(\mathrm{ba}),\mathrm{OC}}} v_{\cdot\cdot}^{ss(\mathrm{ba}),\mathrm{MA}} = \underbrace{\frac{\tilde{T}_{ij}^{ss(v)}}{\tilde{T}_{\cdot\cdot}^{ss(\mathrm{pu})}}}_{\substack{\text{sector structure}\\ \text{and valuation scaling}}} \quad \underbrace{\left(\frac{x_{\cdot\cdot}^{ss(\mathrm{ba}),\mathrm{OC}}}{v_{\cdot\cdot}^{ss(\mathrm{ba}),\mathrm{OC}}} - 1\right) v_{\cdot\cdot}^{ss(\mathrm{ba}),\mathrm{MA}}}_{\text{magnitude}} \qquad \text{(S3a)}$$

$$y_{ik}^{ss(v)} = \underbrace{\frac{\tilde{y}_{ik}^{ss(v)}}{\left|\tilde{y}_{\cdot k}^{ss(\mathrm{pu})}\right|}}_{\substack{\text{supply structure}\\ \text{and valuation scaling}}} \underbrace{\frac{y_{\cdot k}^{ss(\mathrm{pu}),\mathrm{OC}}}{y_{\cdot\cdot}^{ss(\mathrm{pu}),\mathrm{OC}}}}_{\substack{\text{use}\\ \text{structure}}} \underbrace{y_{\cdot\cdot}^{ss(\mathrm{pu}),\mathrm{MA}}}_{\text{magnitude}} \tag{S3b}$$

$$v_{lj}^{ss(\mathrm{ba})} = \underbrace{\frac{\tilde{v}_{lj}^{ss(\mathrm{ba})}}{\left|\tilde{v}_{l\cdot}^{ss(\mathrm{ba})}\right|}}_{\substack{\text{use}\\ \text{structure}}} \underbrace{\frac{v_{l\cdot}^{ss(\mathrm{ba}),\mathrm{OC}}}{v_{\cdot\cdot}^{ss(\mathrm{ba}),\mathrm{OC}}}}_{\substack{\text{supply}\\ \text{structure}}} \underbrace{v_{\cdot\cdot}^{ss(\mathrm{ba}),\mathrm{MA}}}_{\text{magnitude}} \tag{S3c}$$

$$V_{ij}^{ss(\mathrm{ba})} = \underbrace{\frac{\tilde{V}_{ij}^{ss(\mathrm{ba})}}{\tilde{V}_{\cdot\cdot}^{ss(\mathrm{ba})}}}_{\substack{\text{matrix}\\ \text{structure}}} \underbrace{\frac{x_{\cdot\cdot}^{ss(\mathrm{ba}),\mathrm{OC}}}{v_{\cdot\cdot}^{ss(\mathrm{ba}),\mathrm{OC}}} v_{\cdot\cdot}^{ss(\mathrm{ba}),\mathrm{MA}}}_{\text{magnitude}}\ , \tag{S3d}$$

where MA and OC denote the source of the data.[1] Equation S3 shows that the magnitudes of each country's initial estimate $\mathbf{T}$, $\mathbf{V}$ and $\mathbf{v}$ ($\mathbf{y}$) are determined by each country's value of $\mathbf{v}$ ($\mathbf{y}$) in the MA database and the ratios in the OC database. The sectoral structure of the initial estimate is determined by proxies $\tilde{T}_{ij}^{ss(v)}$, $\tilde{V}_{ij}^{ss(v)}$, $\tilde{y}_{ij}^{ss(v)}$, and $\tilde{v}_{ij}^{ss(v)}$ in all valuations.

We use the most detailed and diverse tables – from the USA, Japan and Australia – to construct generic 25-sector "international" SUT proxies, which we use for all "common-classed" countries. We used Japan, Australia and USA for two reasons. The first reason is sector detail; all three countries have input-output tables with more than 344 sectors. We have not used China's input-output table, because this table only has 122 sectors, and the intersection of four national IO tables would have included very few sectors. The second reason is the coverage of commodities. Peters and Hertwich [17] chose other countries' input-output structure based on similar per capita energy use, CO2 emissions, and GDP. However, even if country A's per capita GDP is similar to country B's per capita GDP the economic structure of country A and B could be completely different. If country A did not produce the main products of country B, embodied emission could change considerably. Therefore, an important criterion is for the basic table structure to cover a wide variety of industries and commodities. The three countries we chose are suitable in this sense because these cover a wide range of industries and commodities such as agriculture, mining, manufacturing and service. This is supported in a study by Andrew et al [18] who found that in constructing an MRIO, modelling a Rest-of-World (RoW) region on the basis of many countries' input-output tables is preferable to choosing a "representative" country. Our approach in choosing a generic proxy for (RoW) countries without input-output tables follows the same principle. In the future we aim at adding more countries to the SUT proxies. Finally, other studies used approaches similar to ours. For example, Weber and Matthews [19] and Ahmad and Wyckoff [20] assumed that the rest of the world has the same structure and emission intensity as the US economy.

Each valuation (v in the equations) is determined by the ratios of these "common-based" countries. The initial estimates for the "separately-classed" countries, where national input-output tables exist in a classification

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[1] Neither the MA nor OC database contain information on Taiwan. **T**, **y**, **v** and **V** for Taiwan were constructed based on national data from [16].

that is more detailed than our common 25-sector classification, are constructed from the most suitable IIOT, CIOT, or SUT proxies, that is from any available table for that country that is closest in terms of year and valuation. In cases where national information on separately-classed is incomplete (for example for certain valuations) we also use the 3-country proxies.

Text S3.2 International trade in goods

The accepted approach to estimating international trade matrices in an MRIO table is via trade coefficients $\tau_{ij}^{rs} = f(i,j,r,s)$ that are a function of the exporting country *r*, the importing country *s*, the exporting sector *i*, and the importing sector *j*. The absolute value of trade flows can then be written as $\tau_{ij}^{rs}\ Tr$, where Tr is some absolute measure of trade from *r* or into *s*. The data available to enumerate this equation are imports matrices $M_{ij}^{\circ s}$ included in the input-output tables of some importing countries *s*, and trade statistics (exports or imports; $(e \vee m)_i^{rs}$) such as from Eurostat[21], IDE/JETRO[22], OECD[23], and UN ComTrade [15].

There are however a few hurdles to overcome. First, neither database gives a complete picture of trade, because in the national imports matrices there is no information on the exporting country, and in the trade databases there is no information on the using sector. Second, imported commodities $\{i\}$ in the trade database are usually classified differently to the imported commodities $\{i^{(s)}\}$ in the national input-output tables of the importing country s. A “trade-to-importing country” concordance matrix $C_{i,i^{(s)}}$ is necessary to bridge the two classification systems. Further, the international trade blocks have to adhere to the row classification $\{i^{(r)}\}$ of exporting country *r*’s input-output tables, which again usually does not coincide with the commodity classification $\{i\}$ of the trade database, requiring a second “exporting-country-to-trade” concordance matrix $C_{i^{(r)},i}$. Third, import and export data from various sources are inconsistent (Figs. S3a-b). Discrepancies can be due to valuation (usually exports are valued f.o.b., and imports c.i.f.), incompleteness with regard to trade in services, transactions coverage (for example Japan excludes transactions smaller than ¥200,000), exchange rates fluctuations, temporal delay between export and import leading to different recorded years, differences in accounting periods (for example India’s accounts April to March), and differences in recorded regions (for example if Japan exports to Hong Kong, the import may be recorded as ‘China’ not ‘Hong Kong’; or, an export to the British Virgin Islands may be recorded as ‘Great Britain’ or ‘Virgin Islands’) [24-26]. As a consequence, national imports matrices are generally preferred for representing absolute trade flow, and trade statistics are only used for allocating across trade partners [27].

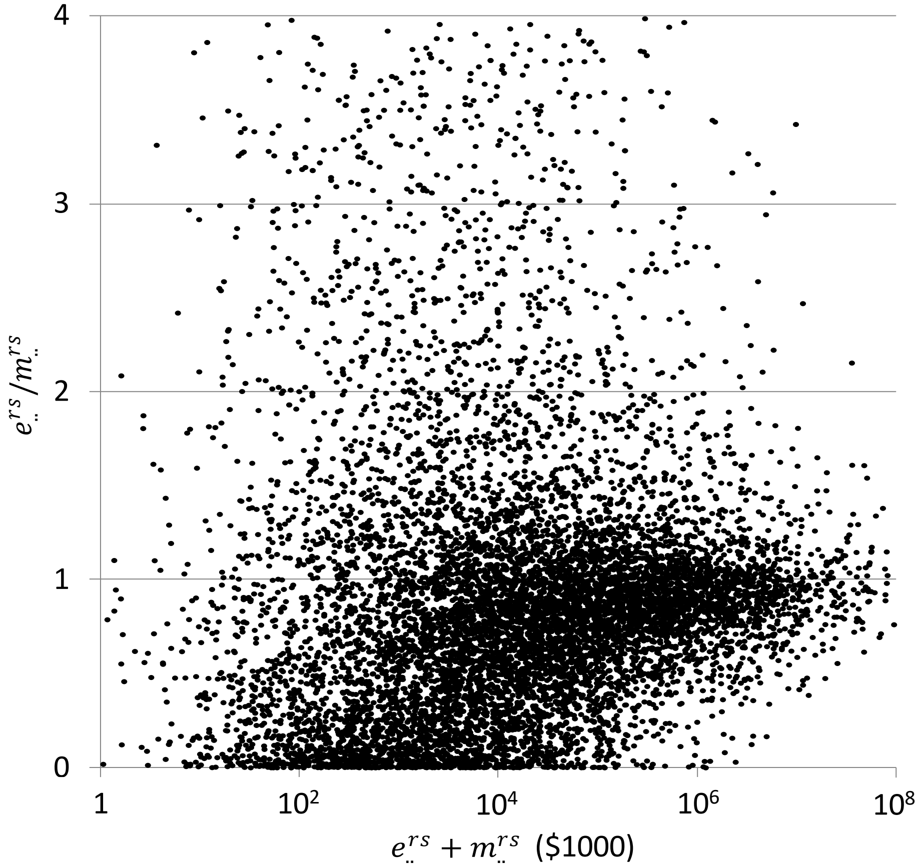

Figure S3a: Distribution of export/import ratios $e_{..}^{rs}/m_{..}^{rs}$ across magnitudes of trade flows $(e_{..}^{rs} + m_{..}^{rs})$. As expected, the distribution peaks around $\varrho = 0.9$ (Following Ahmad and Wyckoff's [20] assumption that 10% of f.o.b. import value reflects insurance and freight costs, or f.o.b. × 0.9 = c.i.f) however inconsistent ratios $\varrho > 1$ and an accumulation of what appears to be severe reporting errors exist for many small transactions.

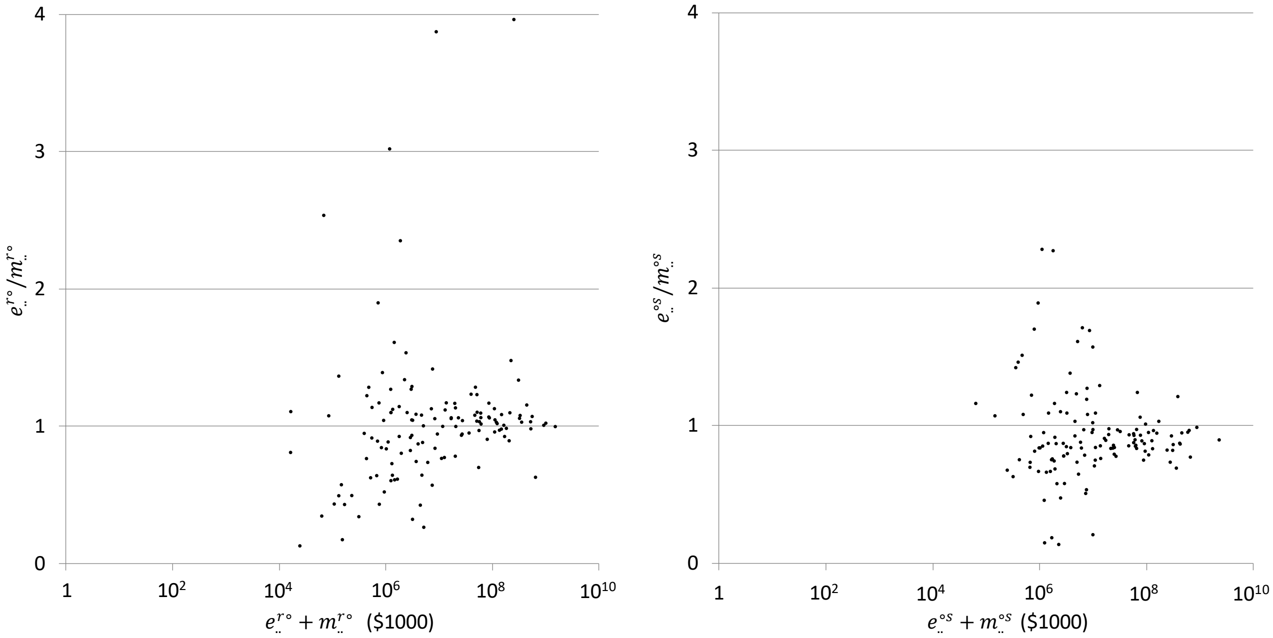

Figure S3b: Distribution of export/import ratios $e_{\cdot\cdot}^{r\circ}/m_{\cdot\cdot}^{r\circ}$ and $e_{\cdot\cdot}^{\circ s}/m_{\cdot\cdot}^{\circ s}$ across magnitudes of trade flows $(e_{\cdot\cdot}^{r\circ}+m_{\cdot\cdot}^{r\circ})$ and $(e_{\cdot\cdot}^{\circ s}+m_{\cdot\cdot}^{\circ s})$. As expected, the distributions peak around $\varrho=0.9$, however inconsistent ratios $\varrho>1$ and an accumulation of what appears to be severe reporting errors exist for small transactions even after summing over importing or exporting countries. Plotting $e_{i.}^{\cdot\cdot}/m_{i.}^{\cdot\cdot}$ by traded commodity against $e_{i.}^{\cdot\cdot}+m_{i.}^{\cdot\cdot}$ gives even worse results.

These three circumstances necessitate a general formulation $\sum_{i,i^{(s)}} C_{i^{(r)},i}\frac{(e\vee m)_{i\cdot}^{rs}}{(e\vee m)_{i\cdot}^{\circ s}} C_{i,i^{(s)}} M_{i^{(s)}j^{(s)}}^{\circ s}$ for estimating international transaction from incomplete data, with the term $M_{i^{(s)}j^{(s)}}^{\circ s}$ used for modeling the sectoral use structure, and the term $\frac{(e\vee m)_{i\cdot}^{rs}}{(e\vee m)_{i\cdot}^{\circ s}}$ used for modelling the country origin structure of traded commodities. The concordance matrices have to adhere to certain normality conditions; most importantly, the rowsum or column sum should be 1, so that the total value of the aggregated matrix still equals the total value of the original matrix. We construct the off-diagonal international transaction blocks of the initial estimate according to[2]

$$T_{i^{(r)}j^{(s)}}^{rs(\mathrm{ba})} = \underbrace{\frac{\tilde{e}_{i^{(r)}\cdot}^{r\circ\,(\mathrm{ba})}}{\tilde{e}_{i^{(r)}\cdot}^{r\circ\,(\mathrm{fb})}}}_{\text{ba scaling}} \underbrace{\frac{e_{\cdot\cdot}^{\circ\cdot(\mathrm{fb}),\mathrm{CT}}}{m_{\cdot\cdot}^{\circ\cdot(\mathrm{cf}),\mathrm{CT}}}}_{\text{fb scaling}} \sum\nolimits_{i,i^{(s)}} \underbrace{os_{r,s,i^{(r)},i,i^{(s)}}}_{\text{origin structure}} \quad \underbrace{M_{i^{(s)}j^{(s)}}^{\circ s\,(\mathrm{cf})}}_{\substack{\text{sector structure}\\ \text{and magnitude}}} \tag{S4a}$$

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[2] The CT database does not contain information on Taiwan. **T**, **y** and **v** for Taiwan were constructed using trade data from [23].

$$y^{rs(\mathrm{ba})}_{i^{(r)}k^{(s)}} = \underbrace{\frac{\tilde{e}^{r\circ\,(\mathrm{ba})}_{i^{(r)}.}}{\tilde{e}^{r\circ\,(\mathrm{fb})}_{i^{(r)}.}}}_{\text{ba scaling}} \underbrace{\frac{e^{\circ\cdot(\mathrm{fb}),\mathrm{CT}}_{..}}{m^{\circ\cdot(\mathrm{cf}),\mathrm{CT}}_{..}}}_{\text{fb scaling}} \textstyle\sum_{i,i^{(s)}} \underbrace{os_{r,s,i^{(r)},i,i^{(s)}}}_{\text{origin structure}} \underbrace{N^{\circ s\,(cf)}_{i^{(s)}k^{(s)}}}_{\substack{\text{sector structure}\\ \text{and magnitude}}} \tag{S4b}$$

$$T^{rs(\mathrm{m}n=1:2)}_{i^{(r)}j^{(s)}} = \underbrace{\frac{1}{2}\left[\frac{v^{rr(\mathrm{ba}),\mathrm{MA}}_{\cdot n}}{v^{rr(\mathrm{ba}),\mathrm{MA}}_{\cdot n=\mathrm{trd,tra}}} + \frac{v^{ss(\mathrm{ba}),\mathrm{MA}}_{\cdot n}}{v^{ss(\mathrm{ba}),\mathrm{MA}}_{\cdot n=\mathrm{trd,tra}}}\right]}_{\substack{\text{margin type}\\ \text{structure}}} \underbrace{\left(1 - \frac{\tilde{e}^{r\circ\,(\mathrm{ba})}_{i^{(r)}.}}{\tilde{e}^{r\circ\,(\mathrm{fb})}_{i^{(r)}.}}\right)}_{\text{margin scaling}} \underbrace{\frac{e^{\circ\cdot(\mathrm{fb}),\mathrm{CT}}_{..}}{m^{\circ\cdot(\mathrm{cf}),\mathrm{CT}}_{..}}}_{\text{fb scaling}} \textstyle\sum_{i,i^{(s)}} \underbrace{os_{r,s,i^{(r)},i,i^{(s)}}}_{\text{origin structure}} \underbrace{M^{\circ s\,(\mathrm{cf})}_{i^{(s)}j^{(s)}}}_{\substack{\text{sector structure}\\ \text{and magnitude}}} \tag{S4c}$$

$$y^{rs(\mathrm{m}n=1:2)}_{i^{(r)}k^{(s)}} = \underbrace{\frac{1}{2}\left[\frac{v^{rr(\mathrm{ba}),\mathrm{MA}}_{\cdot n}}{v^{rr(\mathrm{ba}),\mathrm{MA}}_{\cdot n=\mathrm{trd,tra}}} + \frac{v^{ss(\mathrm{ba}),\mathrm{MA}}_{\cdot n}}{v^{ss(\mathrm{ba}),\mathrm{MA}}_{\cdot n=\mathrm{trd,tra}}}\right]}_{\substack{\text{margin type}\\ \text{structure}}} \underbrace{\left(1 - \frac{\tilde{e}^{r\circ\,(\mathrm{ba})}_{i^{(r)}.}}{\tilde{e}^{r\circ\,(\mathrm{fb})}_{i^{(r)}.}}\right)}_{\text{margin scaling}} \underbrace{\frac{e^{\circ\cdot(\mathrm{fb}),\mathrm{CT}}_{..}}{m^{\circ\cdot(\mathrm{cf}),\mathrm{CT}}_{..}}}_{\text{fb scaling}} \textstyle\sum_{i,i^{(s)}} \underbrace{os_{r,s,i^{(r)},i,i^{(s)}}}_{\text{origin structure}} \underbrace{N^{\circ s\,(cf)}_{i^{(s)}k^{(s)}}}_{\substack{\text{sector structure}\\ \text{and magnitude}}} \tag{S4d}$$

$$T^{rs(\mathrm{tx})}_{i^{(r)}j^{(s)}} = \overbrace{\textstyle\sum_{i,i^{(s)}} \underbrace{os_{r,s,i^{(r)},i,i^{(s)}}}_{\text{origin structure}} \underbrace{\frac{\widetilde{M}^{\circ s\,(\mathrm{tx})}_{i^{(s)}j^{(s)}}}{\widetilde{M}^{\circ s\,(\mathrm{cf})}_{i^{(s)}j^{(s)}}}}_{\text{tx scaling}} \underbrace{M^{\circ s\,(\mathrm{cf})}_{i^{(s)}j^{(s)}}}_{\substack{\text{sector structure}\\ \text{and magnitude}}}}^{\text{taxes on imports}} + \overbrace{\underbrace{\frac{\tilde{e}^{r\circ\,(tx)}_{i^{(r)}.}}{\tilde{e}^{r\circ\,(fb)}_{i^{(r)}.}}}_{\text{tx scaling}} \underbrace{mos_{r,s,i^{(r)},i,i^{(s)}}}_{\substack{\text{magnitude, country}\\ \text{and supply structure}}} \underbrace{\frac{M^{\circ s\,(cf)}_{i^{(s)}j^{(s)}}}{M^{\circ s\,(cf)}_{i^{(s)}.}}}_{\text{use structure}}}^{\text{taxes on exports}} \tag{S4e}$$

$$y^{rs(\mathrm{tx})}_{i^{(r)}k^{(s)}} = \overbrace{\textstyle\sum_{i,i^{(s)}} \underbrace{os_{r,s,i^{(r)},i,i^{(s)}}}_{\text{origin structure}} \underbrace{\frac{\widetilde{N}^{\circ s\,(\mathrm{tx})}_{i^{(s)}j^{(s)}}}{\widetilde{N}^{\circ s\,(\mathrm{cf})}_{i^{(s)}j^{(s)}}}}_{\text{tx scaling}} \underbrace{N^{\circ s\,(\mathrm{cf})}_{i^{(s)}k^{(s)}}}_{\substack{\text{sector structure}\\ \text{and magnitude}}}}^{\text{taxes on imports}} + \overbrace{\underbrace{\frac{\tilde{e}^{r\circ\,(tx)}_{i^{(r)}.}}{\tilde{e}^{r\circ\,(fb)}_{i^{(r)}.}}}_{\text{tx scaling}} \underbrace{mos_{r,s,i^{(r)},i,i^{(s)}}}_{\substack{\text{magnitude, country}\\ \text{and supply structure}}} \underbrace{\frac{N^{\circ s\,(cf)}_{i^{(s)}k^{(s)}}}{N^{\circ s\,(cf)}_{i^{(s)}.}}}_{\text{use structure}}}^{\text{taxes on exports}} \tag{S4f}$$

$$T^{rs(\mathrm{sb})}_{i^{(r)}j^{(s)}} = \overbrace{\underbrace{\frac{\tilde{e}^{r\circ\,(sb)}_{i^{(r)}.}}{\tilde{e}^{r\circ\,(fb)}_{i^{(r)}.}}}_{\text{sb scaling}} \underbrace{mos_{r,s,i^{(r)},i,i^{(s)}}}_{\substack{\text{magnitude, country}\\ \text{and supply structure}}} \underbrace{\frac{M^{\circ s\,(cf)}_{i^{(s)}j^{(s)}}}{M^{\circ s\,(cf)}_{i^{(s)}.}}}_{\text{use structure}}}^{\text{subsidies on exports}} \tag{S4g}$$

$$y^{rs(\mathrm{sb})}_{i^{(r)}k^{(s)}} = \overbrace{\underbrace{\frac{\tilde{e}^{r\circ\,(sb)}_{i^{(r)}.}}{\tilde{e}^{r\circ\,(fb)}_{i^{(r)}.}}}_{\text{sb scaling}} \underbrace{mos_{r,s,i^{(r)},i,i^{(s)}}}_{\substack{\text{magnitude, country}\\ \text{and supply structure}}} \underbrace{\frac{N^{\circ s\,(cf)}_{i^{(s)}k^{(s)}}}{N^{\circ s\,(cf)}_{i^{(s)}.}}}_{\text{use structure}}}^{\text{subsidies on exports}} \tag{S4h}$$

where

$$os_{r,s,i^{(r)},i,i^{(s)}} = C_{i^{(r)},i} \frac{m^{rs(\mathrm{cf}),\mathrm{CT}}_{i\cdot} + \left\{m^{rs(\mathrm{cf}),\mathrm{CT}}_{..} = 0\right\} e^{rs(\mathrm{fb}),\mathrm{CT}}_{i\cdot} \frac{m^{\circ\cdot(\mathrm{cf}),\mathrm{CT}}_{..}}{e^{\circ\cdot(\mathrm{fb}),\mathrm{CT}}_{..}}}{m^{\circ s(\mathrm{cf}),\mathrm{CT}}_{i\cdot} + \sum_{\left\{r \middle| m^{rs(\mathrm{cf}),\mathrm{CT}}_{..} = 0\right\}} e^{r\,s(\mathrm{fb}),\mathrm{CT}}_{i\cdot} \frac{m^{\circ\cdot(\mathrm{cf}),\mathrm{CT}}_{..}}{e^{\circ\cdot(\mathrm{fb}),\mathrm{CT}}_{..}}} C_{i,i^{(s)}}$$

$$mos_{r,s,i^{(r)},i,i^{(s)}} = C_{i^{(r)},i} \left(e^{rs\,(fb),CT}_{i\cdot} + \left\{e^{rs\,(fb),CT}_{..} = 0\right\} m^{rs\,(cf),CT}_{i\cdot} \frac{e^{\circ\cdot(\mathrm{fb}),\mathrm{CT}}_{..}}{m^{\circ\cdot(\mathrm{cf}),\mathrm{CT}}_{..}}\right) C_{i,i^{(s)}}$$

are the two structure terms used in the set of Equations S4. In the equation for margins *n*=1:2, we use the trade (trd) and transport (tra) sectors in the UN SNA Main Aggregates database to distribute across margin types. We use $\frac{1}{2}\left[\frac{v_{\cdot n}^{rr(\mathrm{ba}),\mathrm{MA}}}{v_{\cdot n=\mathrm{trd,tra}}^{rr(\mathrm{ba}),\mathrm{MA}}}+\frac{v_{\cdot n}^{ss(\mathrm{ba}),\mathrm{MA}}}{v_{\cdot n=\mathrm{trd,tra}}^{ss(\mathrm{ba}),\mathrm{MA}}}\right]$, because we assume that international margins are equally likely to be supplied by the supplying or receiving country. We use a total aggregate of the cif-to-fob scaler $\frac{e_{\cdot\cdot}^{\circ\cdot(\mathrm{fb}),\mathrm{CT}}}{m_{\cdot\cdot}^{\circ\cdot(\mathrm{cf}),\mathrm{CT}}}$ throughout because disaggregated ratios proved to fluctuate excessively (see Figs. S4a-b). Where national imports matrices $M_{i^{(s)}j^{(s)}}^{\circ s\,(\mathrm{cf})}$ and $N_{i^{(s)}k^{(s)}}^{\circ s\,(\mathrm{cf})}$ are not available, we approximate

$$M_{i^{(s)}j^{(s)}}^{\circ s\,(\mathrm{cf})}=\underbrace{\frac{\widetilde{M}_{i^{(s)}j^{(s)}}^{\circ s\,(\mathrm{cf})}}{\widetilde{M}_{\cdot\cdot}^{\circ s\,(\mathrm{cf})}+\widetilde{N}_{\cdot\cdot}^{\circ s\,(\mathrm{cf})}}}_{\text{matrix structure}}\;\underbrace{m_{\cdot\cdot}^{\circ s(\mathrm{cf}),\mathrm{MA}}}_{\text{magnitude}}\quad\text{and}\quad N_{i^{(s)}k^{(s)}}^{\circ s\,(\mathrm{cf})}=\underbrace{\frac{\widetilde{N}_{i^{(s)}k^{(s)}}^{\circ s\,(\mathrm{cf})}}{\widetilde{M}_{\cdot\cdot}^{\circ s\,(\mathrm{cf})}+\widetilde{N}_{\cdot\cdot}^{\circ s\,(\mathrm{cf})}}}_{\text{matrix structure}}\;\underbrace{m_{\cdot\cdot}^{\circ s(\mathrm{cf}),\mathrm{MA}}}_{\text{magnitude}}. \tag{S5}$$

The equations in this section show that national imports matrices are key data items for estimating country-pair-specific trade matrices by pro-rating across countries of origin and using sectors.

Eq. S4a basically means that we estimate the international trade block in basic (factory or farm gate) prices by disaggregating the import matrix (M) using bilateral trade data for describing the imports origin structure (os) for each importing country. Two obstacles in this estimation are that a) the raw import matrix is expressed in c.i.f. (cost-insurance-freight) prices, and that b) the exporting country's classification is not same as the importing country's classification. Therefore, we first convert c.i.f. prices to f.o.b. (free-on-board) prices using COMTRADE data for deriving c.i.f.-to-f.o.b. scalers, and then convert f.o.b. prices to basic prices using national IO table for deriving f.o.b.-to-basic-price scalers. We change the import matrix's origin structure to match the exporting country's classification using concordance matrix and COMTRADE's bilateral trade data. Some countries do not report their exports and imports to COMTRADE. In this case, we have used other country's reports to approximate the origin structure. For example, if Iran doesn't provide data for imports from Japan then we used exports from Japan to Iran that Japan reports to COMTRADE.

Text S3.3 International trade in services

The ComTrade database[15] does not include trade in services. We added service sectors at the end of all concordance, and use

$$os_{r,s,i^{(r)},i,i^{(s)}}=\frac{m_{\cdot\cdot}^{rs(\mathrm{cf}),\mathrm{CT}}+\left\{m_{\cdot\cdot}^{rs(\mathrm{cf}),\mathrm{CT}}=0\right\}e_{\cdot\cdot}^{rs(\mathrm{fb}),\mathrm{CT}}}{m_{\cdot\cdot}^{\circ s(\mathrm{cf}),\mathrm{CT}}+\sum_{\left\{r\middle|m_{\cdot\cdot}^{rs(\mathrm{cf}),\mathrm{CT}}=0\right\}}e_{\cdot\cdot}^{rs(\mathrm{fb}),\mathrm{CT}}} \tag{S6}$$

$$mos_{r,s,i^{(r)},i,i^{(s)}} = \left(e_{..}^{ro\,(fb),MA} - e_{..}^{r\circ\,(fb),CT}\right)\frac{e_{..}^{rs\,(fb),CT} + \left\{e_{..}^{rs\,(fb),CT} = 0\right\} m_{..}^{rs\,(cf),CT}\frac{e_{..}^{\circ\cdot(fb),CT}}{m_{..}^{\circ\cdot(cf),CT}}}{e_{..}^{r\circ\,(fb),CT} + \sum_{\left\{s\middle|e_{..}^{rs\,(fb),CT} = 0\right\}} m_{..}^{rs\,(cf),CT}\frac{e_{..}^{\circ\cdot(fb),CT}}{m_{..}^{\circ\cdot(cf),CT}}} \tag{S7}$$

as the origin structure term. As an initial estimate of the service trade we used commodity import and export ratios. The ensuing relationships are analogous to Equations S4a–f.

Text S3.4 Re-exports

According to the United Nations[28], "*exports of a country can be distinguished as exports of domestic goods and exports of foreign goods. The second class is generally referred to as re-exports*". Similarly, "*imports can be distinguished as imports of foreign goods and imports of domestic goods. Import of domestic goods is referred as re-imports*". Re-exports and re-imports can cause some of the inconsistencies of trade data, so that their explicit inclusion into the MRIO leads to less data conflict. Therefore we added only one column (row) of re-exports (re-imports) into our MRIO. We construct re-export initial estimates (rows) according to

$$T_{I^{(r)}+1j^{(s)}}^{rs(v)} = RX^{(r)} \underbrace{\frac{T_{\cdot j^{(s)}}^{rs(v)}}{T_{..}^{r\circ(v)} + y_{..}^{r\circ(v)}}}_{\text{use and destination structure}} \ , \ y_{I^{(r)}+1k^{(s)}}^{rs(v)} = RX^{(r)} \underbrace{\frac{y_{\cdot k^{(s)}}^{rs(v)}}{T_{..}^{r\circ(v)} + y_{..}^{r\circ(v)}}}_{\text{use and destination structure}} \tag{S8}$$

where $I^{(r)}$ is the total number of sectors in country *r*'s classification, and $RX^{(r)}$ are total re-exports of country *r.* Re-import initial estimates (columns, into intermediate demand only) can be expressed as

$$T_{i^{(r)}J^{(s)}+1}^{rs(v)} = RX^{(r)} \underbrace{\frac{T_{i^{(r)}\cdot}^{rs(v)}}{T_{..}^{\circ s(v)}}}_{\text{origin and supply structure}} \ , \tag{S9}$$

where $J^{(s)}$ is the total number of sectors in country *s*'s classification. Finally, the row and column sum balance reads

$$T_{I^{(r)}+1\cdot}^{r\circ(v)} + y_{I^{(r)}+1\cdot}^{r\circ(v)} = RX^{(r)} = T_{\cdot J^{(s)}+1}^{\circ s(v)} \ . \tag{S10}$$

Text S3.5 FISIM

Some financial intermediaries defray cost and generate profits through imposing borrowing and lending rate differentials on the capital they service, thus avoiding direct transactions with customers. In such cases financial intermediation services are indirectly measured (FISIM). Whilst the SNA 1968 stipulates to record such estimated output as the intermediate consumption of a nominal industry, the SNA 1993 allows allocating FISIM across using sectors[1]. Reporting practices differ amongst countries: the UK's accounts always include a nominal FISIM sector, Japan's accounts have FISIM always allocated across users, and Spain switched from nominal FISIM sector to user allocation between 1999 and 2000. On one hand there is no information to transform one practice into the other. On the other hand FISIM are not negligible, hence they must be included to avoid severe account imbalances. We have hence decided to always include a nominal FISIM sector into our MRIO classification, and to leave this sector empty where FISIM is allocated across users. Note that in cases such as Spain, this can lead to sharp discontinuities over time when practices are changed. In order to eliminate such discontinuities we follow a procedure suggested by EUROSTAT, which is to spread total FISIM to using industries proportionally to their share of gross output, and reduce the operational surplus of each industry by the pro-rated amount.

Text S4 Concordances and maps

In order to carry out calculations on trade blocks most effectively, we link national product classifications (NPC; N_C classes for country C) to the 6-digit subheadings of the OECD Harmonised System (HS6; N_{HS6} classes), and store those as N_C x N_{HS6} sparse binary matrices. The link is established directly for countries where a NPC-HS6 concordance is provided. Alternatively, we have produced NPC-HS6[23] concordances in a two-step process via either NPC↔ISIC (International Standard Industrial Classification of All Economic Activities) and ISIC↔HS6 or NPC↔CPC (Central Product Classification) and CPC↔HS6. In case of trade in services, we use the CPC service classification instead of the Harmonised System.

Binary concordance matrices **C** cannot be used to convert vectors **v** from one to another classification (via matrix multiplication $\mathbf{v}' = \mathbf{C}\mathbf{v}$), because multiple correspondences of an aggregate product in the disaggregated classification mean that **C** is not normalised, so that **v**' would have a row sum different to that of **v**. In order to enumerate the trade blocks of our MRIO (Equations S4a-f), we require both row- and column-normalised mapping matrices, or maps. We calculate these maps from concordances by pro-rating with a suitable proxy trade variable (see Text S4.2). In most cases, HS6 is always more detailed than national input-output classification, so that the correspondence is unique, and the binary concordance matrix is already normalised to distribute HS6-classed data across national classes, and only needs to be normalised to distribute national-classed data across HS6. This is achieved by using HS6 import data as a proxy. In a few cases (notably Japan and the USA), parts of the national input-output classifications are more detailed than HS6, thus requiring a second normalisation to distribute HS6-classed data across national classes.

Problems with concordances appear especially when sector classifications aggregate sectors that are substantially different in nature. For example, some databases do not separate electricity generation from electricity distribution, presumably because these services are offered by the same utility company. In these cases, one cannot even clearly delineate pure goods from pure services, let alone uniquely concord such a classification to ISIC or HS, since electricity is generally included in the category "goods" whilst its distribution is classed a "service". The only remaining solution is to aggregate electricity distribution into electricity generation. For example, the UN National Accounts Official Country database provides the totals for both goods and services exported and imported, and the Eora tables use these data as four constraints per country. If one country features an aggregate electricity generation/distribution sector, we would strictly speaking need to aggregate these four constraints into two total export and import constraints. To avoid such a loss of detail, we regard electricity distribution as a good, like electricity, enabling us to keep goods and services export and import data as separate constraints.

Text S4.1 Normalisation of concordance matrices used for trade flow estimation

The form in Equations S4 and S5 must adhere to the normalisation

$$\sum_{r,i^{(r)},j^{(s)}} MRIO^{rs}_{i^{(r)}j^{(s)}} = \sum_{i^{(s)},j} M^{s}_{i^{(s)}j^{(s)}} = M^{s}\ , \tag{S11}$$

or

$$\begin{aligned} &\sum_{r,i^{(r)},j^{(s)}} \sum_{i,i^{(s)}} C_{i^{(r)},i}\; t_i^{rs}\; C_{i,i^{(s)}}\; M^{s}_{i^{(s)}j^{(s)}} = M^{s} \\ \Leftrightarrow &\sum_{r,i^{(r)},i} C_{i^{(r)},i}\; t_i^{rs} \sum_{i^{(s)},j^{(s)}} C_{i,i^{(s)}}\; M^{s}_{i^{(s)}j^{(s)}} = M^{s}. \end{aligned} \tag{S12}$$

The equality in Equation S11 can be fulfilled if

$$\Leftarrow \sum_{i^{(s)},j^{(s)}} C_{i,i^{(s)}} M^{s}_{i^{(s)}j^{(s)}} = M_i^{s} \;\wedge\; \sum_i M_i^{s} = M^{s} \wedge \sum_{r,i^{(r)}} C_{i^{(r)},i}\; t_i^{rs} = 1\ \forall\, i\ . \tag{S13}$$

This is because

$$\begin{aligned} &\sum_{r,i^{(r)},i} C_{i^{(r)},i} t_i^{rs} \sum_{i^{(s)},j^{(s)}} C_{i,i^{(s)}} M^{s}_{i^{(s)}j^{(s)}} \\ &= \sum_{r,i^{(r)},i} C_{i^{(r)},i}\; t_i^{rs} M_i^{s} \\ &= \sum_i M_i^{s} \sum_{r,i^{(r)}} C_{i^{(r)},i}\; t_i^{rs} \\ &= \sum_i M_i^{s} 1_i = \sum_i M_i^{s} = M^{s}. \end{aligned} \tag{S14}$$

Here, the M_i^s are the row sums of $M^{s}_{i^{(s)}j^{(s)}}$ re-classified from row classification $\{i^{(s)}\}$ into trade database classification $\{i\}$. The three conditions in Equation S14 have the form of weighted sums over $i^{(s)}$ and $i^{(r)}$. Summing the first conditions over *i* yields

$$\sum_{i^{(s)}} \sum_i C_{i,i^{(s)}} M^{s}_{i^{(s)}} = \sum_{i^{(s)}} M^{s}_{i^{(s)}} \sum_i C_{i,i^{(s)}} = M^{s}\ , \tag{S15}$$

from which we can deduce the normalisation condition on $C_{i,i^{(s)}}$ as

$$\sum_i C_{i,i^{(s)}} = 1 \ \forall \ i^{(s)}. \tag{S16}$$

Expressed in words, this condition says that each commodity $i^{(s)}$ in the national input-output tables of importing country *s* must be fully and uniquely allocated to one or more trade classes i. Summing the second condition over i yields

$$\sum_{r,i^{(r)}} C_{i^{(r)},i} t_i^{rs} = \sum_r \frac{T_i^{rs}}{\sum_r T_i^{rs}} \sum_{i^{(r)}} C_{i^{(r)},i} = 1 \ \forall \ i, \tag{S17}$$

from which we can deduce the normalisation condition on $C_{i^{(r)},i}$ as

$$\sum_{i^{(r)}} C_{i^{(r)},i} = 1 \ \forall \ i\,. \tag{S18}$$

Expressed in words, this condition says that each trade class i in the trade database must be fully and uniquely allocated to one or more commodities $i^{(r)}$ in the national input-output tables of exporting country *r*.

Both concordance matrices hence have to be normalised so that their column sums equal 1. This is a direct consequence of the choice of the national imports matrix $M^s_{i^{(s)}j^{(s)}}$ as a scaler, since this imports matrix is located at the right hand side of the product in Equation S12, and its summed value has to be preserved.

Text S4.2 Creation of maps from concordances

Let **C** be a *n* × *m* binary concordance matrix. Let *m* > *n*, so that the columns of **C** contain the disaggregated classification. Then, there will be rows *i* of **C** with $\sum_j C_{ij} > 1$. During the normalisation of **C** to a map, these rows have to be scaled so that $\sum_j C_{ij} = 1$. Let $\mathbf{x}_m$ be a row vector containing the *m*-classed proxy variable to be used for pro-rating, and $\hat{\mathbf{x}}_m$ be the diagonal matrix corresponding to $\mathbf{x}_m$. Using an *m*-classed summation vector $\mathbf{1}_m$, the *n*-classed representation of $\mathbf{x}_m$ can be written as $\mathbf{x}_n = \mathbf{C}\hat{\mathbf{x}}_m\mathbf{1}_m$. The row-normalised map (row map) corresponding to **C** is then $\mathbf{M} = \left(\widehat{\mathbf{C}\hat{\mathbf{x}}_m\mathbf{1}_m}\right)^{-\mathbf{1}}\mathbf{C}\hat{\mathbf{x}}_m = \hat{\mathbf{x}}_n^{-1}\mathbf{C}\hat{\mathbf{x}}_m$. Column-normalisation proceeds similarly.

Text S5 A small example

Here we provide a simplified small example showing how we treat conflicting data, time series data, different sector detail, and so on. Further detail is provided in this paper and also in reference [29].

Assume we have data for a 3-sector IO table in 2000 (Table S5.1), a 2-sector intermediate demand matrix in 2001 (Table S5.2), and a 1-sector final demand and value added scalar in 2000 and 2001 (Table S5.3).

Table S5.1 2000 input-output table

	Primary industry	Secondary industry	Services	Final demand
Primary industry	10	1	3	10
Secondary industry	3	20	4	15
Services	1	5	10	20
Value added	10	16	19	

Table S5.2 2001 input-output table

	Goods	Services
Goods	40	9
Services	7	11

Table S5.3 Final demand and value added in 2000 and 2001

Total final demand in 2000	50
Total value added in 2000	50
Total final demand in 2001	60
Total value added in 2001	60

We use the 3-sector IO table in 2000 for the year 2000 initial estimate. Then we write the data in Tables S5.2 and S5.3 as additional constraints. The optimizer handles the MRIO table as a vector (*SI Appendix*, Text S2, above) so we vectorize the initial estimate **a** as

$$\mathbf{a} = \begin{pmatrix} 10 \\ 3 \\ 1 \\ \vdots \\ 10 \\ 15 \\ 20 \end{pmatrix} \qquad (1)$$

In 2000, we have constraints for total final demand and value added,

$$\mathbf{c} = \begin{pmatrix} 50 \\ 50 \end{pmatrix} \qquad (2)$$

Total final demand corresponds to “1” values (in grey) in Table S5.4,

Table S5.4 Final demand correspondence

	Primary industry	Secondary industry	Services	Final demand
Primary industry	0	0	0	1
Secondary industry	0	0	0	1
Services	0	0	0	1
Value added	0	0	0	

and the total value added corresponds to the “1” values (grey) in Table S5.5,

Table S5.5 Value added correspondence

	Primary industry	Secondary industry	Services	Final demand
Primary industry	0	0	0	0
Secondary industry	0	0	0	0
Services	0	0	0	0
Value added	1	1	1	

So we can vectorize and transpose these two binary correspondence matrices to create the constraint equation rows in **G** for the two constraints established at step (2):

$$\mathbf{G} = \begin{pmatrix} 0 & 0 & 0 & 0 & \dots & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & \dots & 1 & 0 & 0 & 0 \end{pmatrix} \tag{3}$$

Following the optimization problem formulated in Text S2 and Eqs 1-3 we establish the following problem to find a solution $\mathbf{p}$ (where $\mathbf{p}$ is the MRIO table $\mathbf{a}$ extended with slack variables $\boldsymbol{\varepsilon}$ to allow deviation from prescribed constraint values **c**, as described in Text S2) that fulfils all constraints,

$$\min_{\mathbf{p}} f(\mathbf{p}, \mathbf{p}_0) \quad \text{subject to} \quad \mathbf{Gp} = \mathbf{c} \tag{4}$$

Of course, our study considers other problems such as upper and lower bounds and data uncertainty, but for simplicity we will not cover these situations in this example. In 2001, we use the 2000 MRIO solution as an initial estimate for the 2001 MRIO.

The aggregated 2-sector intermediate demand matrix for 2001 is handled in the same way. The constraints for the 2001 MRIO would include

$$\mathbf{c} = \begin{pmatrix} 40 \\ 7 \\ 9 \\ 11 \\ 60 \\ 60 \end{pmatrix} \tag{5}$$

$$\mathbf{G} = \begin{pmatrix} 1 & 1 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \dots & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & \dots & 1 & 0 & 0 & 0 \end{pmatrix} \tag{6}$$

For example, the first element of the intermediate demand matrix in 2001 (40 in Table S5.2) corresponds to four data points in the initial estimate MRIO as seen in Table S5.6:

Table S5.6 Intermediate demand correspondence example

	Primary industry	Secondary industry	Services	Final demand
Primary industry	1	1	0	0
Secondary industry	1	1	0	0
Services	0	0	0	0
Value added	0	0	0	

Using the 2000 solution as an initial estimate and the 2001 constraints we can solve the optimization problem and arrive at a 2001 MRIO solution. Using this approach we can treat any data as constraints in an input-output table with any level of sector detail.

This example shows only one sheet (basic prices) for simplicity, but our study has 5 price sheets (basic price, taxes on products, subsidies on products, trade margin, and transport margin) as illustrated in Figure S5a.

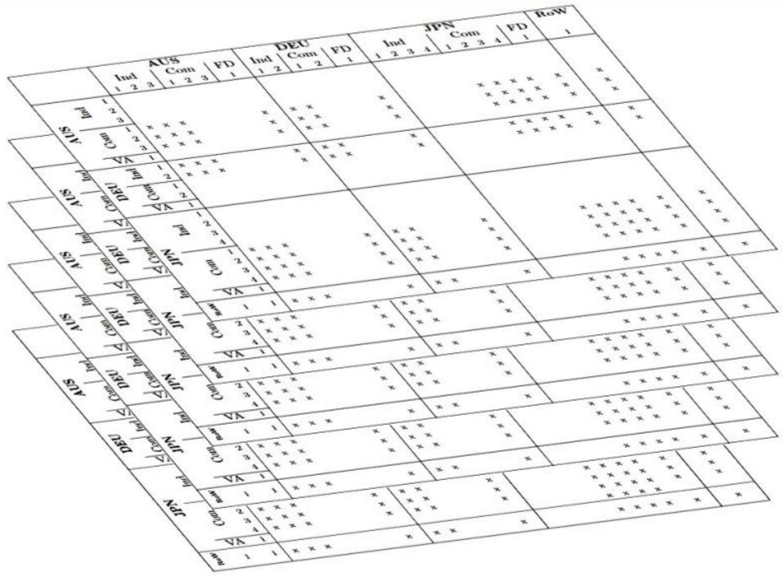

Figure S5a: Stack of input-output tables representing basic prices, margins and taxes.

Text S6 National IO Table Data Sources

We have used following national input-output tables. We showed only primary data sources for each country to avoid duplication. In addition to these tables, we have used Eurostat [21], IDE/JETRO[22], OECD[23] database.

Aruba

Central Bureau of Statistics Aruba. (2002). Supply and use table 1995-2000. *National Accounts of Aruba, 1995-2000*. Retrieved November 16, 2010, from http://www.cbs.aw/cbs/manageDocument.do?dispatch=view&id=488

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Central Bureau of Statistics Aruba. (2007). Supply and use table 2000. *National Accounts of Aruba, 2000 - 2006*. Retrieved November 16, 2010, from http://www.cbs.aw/cbs/manageDocument.do?dispatch=view&id=1220

Netherlands Antilles

Central Bureau Of Statistics Netherlands Antilles. (2009). The Supply and Use Table 2004 Netherlands Antilles. Retrieved November 16, 2010, from http://www.cbs.an/files/SUS NA 2004.pdf

Argentina

Instituto Nacional de Estadística y Censos. (2001). Matriz de Insumo - Producto Argentina 1997 (MIPAr97).

Armenia

Armenian Statistical Service of Republic of Armenia. (n.d.). Supply & Use tables Armenia 2006.

Australia

Australian supply and use tables 1990-2007; Wood, R., Construction, stability and predictability of an input-output time-series for Australia. *Economic Systems Research* **2011,** *23*, (2), 175-211.

Austria

Eurostat. (2009). ESA 95 Supply, Use and Input-Output tables. Retrieved April 30, 2009, from http://epp.eurostat.ec.europa.eu/portal/page/portal/esa95_supply_use_input_tables/data/workbooks

Belgium

Eurostat. (2009). ESA 95 Supply, Use and Input-Output tables. Retrieved April 30, 2009, from http://epp.eurostat.ec.europa.eu/portal/page/portal/esa95_supply_use_input_tables/data/workbooks

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Switzerland

Swiss Statistics. (2009). Tableau Input-Output 2001. Retrieved June 3, 2009, from http://www.bfs.admin.ch/bfs/portal/fr/index/themen/04/02/01/dos/02.html

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Chile

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National Bureau of Statistics of China. (2006). *Input-output table of China 2002*. Beijing: China Statistical Publishing House.

National Bureau of Statistics of China. (n.d.). Input-output table of China 1990, 1992, 1995, 1997, 2000, 2002, 2005, 2007.

Columbia

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Eurostat. (2009). ESA 95 Supply, Use and Input-Output tables. Retrieved April 30, 2009, from http://epp.eurostat.ec.europa.eu/portal/page/portal/esa95_supply_use_input_tables/data/workbooks

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Statistics Denmark. (2009). Danish annual Input-Output tables 1990 - 2006. Retrieved May 21, 2009, from http://www.dst.dk/HomeUK/Statistics/ofs/NatAcc/IOTABLES.aspx

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National Statistics Institute. (2010). Spanish National Accounts: Input-output Framework 1995-2006. Retrieved February 15, 2010, from http://www.ine.es/jaxi/menu.do?type=pcaxis&path=/t35/p008&file=inebase&L=1

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Eurostat. (2009). ESA 95 Supply, Use and Input-Output tables. Retrieved April 30, 2009, from http://epp.eurostat.ec.europa.eu/portal/page/portal/esa95_supply_use_input_tables/data/workbooks

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Taiwan

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Table S2: List of countries in the Eora MRIO database

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
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
428	Latvia	61/61
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
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	United Kingdom	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

Table S3: Availability of input-output tables

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Aruba						x	x	x	x	x	x	x	x								
Netherlands Antilles															x						
Argentina								x													
Armenia																	x				
Australia	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
Austria						x		x		x	x	x	x	x	x	x					
Belgium						x		x		x	x	x	x	x	x						
Bolivia										x	x	x	x								
Brazil	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Canada						x					x										
Switzerland												x				x					
Chile							x							x							
China	x		x			x		x			x		x			x		x			
Colombia											x	x	x	x	x	x	x	x			
Czech Republic						x	x	x	x	x	x	x	x	x	x	x					
Germany		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Denmark	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Ecuador											x	x	x	x	x	x	x	x			
Spain	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Estonia								x			x	x	x	x	x	x					
Finland						x	x	x	x	x	x	x	x	x	x	x					
France						x	x	x	x	x	x	x	x	x	x	x					
United Kingdom			x	x	x	x	x	x	x	x	x	x	x	x	x	x					
Georgia																	x	x	x		
Greece											x	x	x	x	x	x	x	x			
Greenland			x												x						
Hong Kong			x																		
Hungary									x	x	x	x	x	x	x	x					
Indonesia											x										
India				x					x					x			x				
Ireland									x		x	x	x			x					
Iran		x										x									
Israel						x	x	x	x	x	x	x	x	x	x	x	x	x			
Italy						x	x	x	x	x	x	x	x	x	x						
Japan	x					x					x					x					
Kazakhstan	x																				

Kenya														x						
Kyrgyzstan												x								
South Korea	x			x		x			x		x					x	x	x		
Kuwait											x									
Lithuania											x	x	x	x	x					
Luxembourg						x	x	x	x	x	x	x	x	x	x	x	x	x		
Latvia							x		x											
Maldives								x												
Mexico														x						
Macedonia																x				
Malta											x	x								
Mongolia																x				
Mauritius								x					x							
Malaysia		x									x									
Netherlands						x	x	x	x	x	x	x	x	x	x	x				
Norway												x	x	x	x	x	x			
New Zealand						x							x					x		
Peru					x															
Philippines											x									
Poland											x	x	x	x	x					
Portugal						x	x	x	x	x	x	x	x	x	x	x	x			
Paraguay					x															
Romania											x			x	x	x				
Russian Federation	x					x					x									
Singapore	x					x					x									
Slovakia						x	x	x	x	x	x	x	x	x	x					
Slovenia											x	x	x	x	x	x				
Sweden						x	x	x	x	x	x	x	x	x	x	x	x			
Thailand	x					x			x		x					x				
Turkey													x							
Taiwan		x			x		x			x		x			x					
Ukraine	x													x	x	x	x	x	x	
Uruguay								x												
USA			x				x	x	x	x	x	x	x	x	x	x	x	x	x	x
Uzbekistan	x																			
Venezuela								x												
Viet Nam							x				x							x		
South Africa				x					x	x	x		x							