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Constructing a Time Series of Chinese Multi-region Input-Output Tables

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Abstract

A high-resolution time series of Chinese multi-region input-output (MRIO) tables for 30 provinces linked with 185 countries was developed. This innovative series was constructed using an Automated Integration System for Harmonised Accounts (AISHA) and has numerous benefits. First, it is the first annual time series of subnational MRIO tables in the world constructed by AISHA; previous studies mainly exist for a few discontinuous years or exist only at the global level using national data. Second, this series represents greater sectoral detail than any other existing Chinese MRIO tables. It distinguishes 135 sectors in combination with detailed sectors (from 25 to 510) of 185 countries in the EORA MRIO database. Third, it provides updated information from 1997 to 2011, thus significantly improving timeliness. Fourth, an uncertainty analysis with standard deviations of elements was also carried out for the Chinese MRIO to understand the reliability of data. These advances will dramatically improve the capability of applications relying on Chinese MRIO tables. The timeliness of information makes analyses more relevant to current policy questions. The high region and sector detail will lead to drastic improvements in life cycle assessments. The continuity of the time series enables the robust identification of key trends and drivers of environmental and social-economic flow changes. Finally, the availability of information on uncertainty allows policy-makers and analysts to quantitatively judge the level of confidence that can be placed in the results of analyses.

Keywords: Subnational multi-region input-output table; High-resolution time series; Trade linkage; Uncertainty

1.Introduction

Multi-region input-output (MRIO) tables and their applications have aroused substantial interest in the forefront of environmental policy debates such as the consumption-based accounting of emissions (Wiedmann et al., 2011; Wiedmann, 2009; Wiedmann et al., 2007), footprint research (Lenzen et al., 2012c; Wiedmann et al., 2013; Lenzen et al., 2013b; Liang et al., 2014; Ewing et al., 2012), and economic analysis (Timmer et al., 2013; Foster-McGregor and Stehrer, 2013; Inklaar and Timmer, 2013; Koopman et al., 2014). Recently, global MRIO databases have already been developed (Tukker and Dietzenbacher, 2013), such as EORA (Lenzen et al., 2012b; Lenzen et al., 2013a), WIOD (The World Input Output Database, 2010; Dietzenbacher et al., 2013), GTAP (Narayanan et al., 2012; Andrew and Peters, 2013), EXIOPOL (EXIOPOL, 2008; Tukker et al., 2013), AIIOT (Institute of Developing Economies, 2006; Meng et al., 2013), GLIO (Nansai et al., 2009), and GRAM (Giljum et al., 2008). These databases are all country-specific MRIO tables constructed based on national input-output tables, trade statistics, and macroeconomic data, and their key features have been summarized in the work of Peters et al. (Peters et al., 2011).

With the growth of global MRIO tables, the development of a MRIO time series is a potential key trend in this field. The UK-MRIO carbon footprint time series is the first annual time series MRIO in the world (Wiedmann et al., 2010). It integrates economic and environmental accounts for the three world regions in the UK-MRIO model, using a matrix-balancing procedure to handle conflicting external data and inconsistent constraints. Detailed sectoral and country-specific trade data for the UK were compiled for the period from 1992 to 2004 and reconciled with the UK input-output data. Based on UK methodologies and applications (Wiedmann and Barrett, 2013), EORA, the first continuous time series of a global MRIO, was launched in 2012, providing a time series of high-resolution input-output tables with matching environmental and social satellite accounts for 185 countries (Lenzen et al., 2012b). These datasets are both important cornerstones for the construction of MRIO time series.

Many global environmental problems are not only concerned with countries but also have subnational implications, especially in large countries with large regional disparity. However, the existing subnational MRIO tables of nations such as China (Zhang and Qi, 2012; State Information Center, 2005), Spain (Cazcarro et al., 2013), and Germany (Többen, 2013) have been sporadically compiled. There is still a lack of continuous subnational MRIO tables for widespread adoption in environmental problems. To the author’s knowledge, only a group of Australian MRIO researchers is working on constructing a time series of highly disaggregated Australian MRIOs called *The Mother of all Australian MRIOs* (MoAusMRIO) (Wiedmann et al., 2012). The series is being constructed using an Automated Integration System for Harmonised Accounts (AISHA) developed by the EORA team (Lenzen et al., 2012a). MoAusMRIO features all regional Australian MRIO tables that are currently being developed or have been developed. To date, the series is still not finished.

China, having experienced over three decades of spectacular growth, is the world's second-largest economy behind the United States (Barboza, 2010). The Chinese economy has also been globalized since joining the World Trade Organization in 2001. Now, it is the largest exporter and second-largest importer of goods in the world (International Monetary Fund, 2013). China's powerful development depends strongly on its regional economic growth and trade linkages. However, there exists significantly unbalanced development in Chinese regions because of policy preferences, industrial foundations and natural resource distribution. Therefore, it is increasingly important to construct a continuous time series of subnational MRIO data for China at high resolution and to maintain consistency with global MRIO data. This can not only map the regional structure of the Chinese economy but also reflect the interregional and international linkages between Chinese regions and other countries.

Several versions of Chinese subnational MRIO tables have been developed (Zhang and Qi, 2012; State Information Center, 2005; Ichimura and Wang, 2003; Shi and Zhang, 2012; Li, 2010; Liu et al., 2012). However, the widespread adoption of MRIO models to map the structure of the Chinese economy has been so far hampered by a number of reasons. First, constructing a Chinese MRIO is labor-intensive and time-consuming. Second, the currently available Chinese MRIO tables have low resolution, grouping all 30 provinces into several grand regions and/or aggregating detailed industries into broad sectors. Third, Chinese MRIO tables are often not available as a long, continuous time series, and at the time of their release, the newest tables are at least five years out of date. Finally, Chinese MRIO tables currently provide only results, without any accompanying estimates of reliability and uncertainty. Therefore, the limited resolution, outdated tables and lack of reliability of Chinese MRIOs have resulted in limited applications in determining environmental footprints, life-cycle assessments, and analyses of driving forces.

The shortcomings discussed above have been overcome by a new time series of Chinese MRIO tables. The time series was constructed using AISHA and is kept consistent with the EORA multi-region input-output database (www.worldmrio.com). The series is focused at the subnational level, including 30 provinces but excluding Tibet, Hong Kong, Macau and Taiwan due to a lack of data availability (Appendix A). Each province contains 135 detailed commodity sectors. Currently, linkages between the Chinese MRIO and a large number of foreign countries are measured in terms of the most detailed information on regional and country coverage, sector coverage, continuity, timeliness and reliability.

In the following discussion, the methods of construction of the Chinese MRIO time series are provided in section 2. The construction process is described step-by-step in section 3, and section 4 shows the results of the Chinese MRIO tables and their accompanying standard deviations. Conclusions are drawn in section 5.

2.Methodology

2.1Structure of Chinese MRIO Tables

Figure 1 lays out the basic structure of the Chinese MRIO table. C1, C2 … C30 represent 30 provinces in China, and O1, O2 … O185 denote the rest of the 185 countries in EORA excluding China (Appendix C). **T** is the intermediate input and/or demand matrix, **y** is the final demand, and **v** is the primary input (value added matrix) for each province. Q represents various satellite indicators for different research purposes.

For domestic blocks, all provinces have input-output data in a commodity-by-commodity format in accordance with official Chinese input-output tables. **T** and **y** matrices in the diagonal directions are the domestic intermediate and final demands for provinces, respectively. Off-diagonal matrices show inter-provincial transactions with separate intermediate and final demand. The intermediate matrices **T** include 135 sectors based on the classification of the 2007 National IO table of China (Appendix B) (National Bureau of Statistics of China, 2010). The final demand matrices **y** are consistent with the six categories in EORA: household final consumption, non-profit institutions serving households, government final consumption, gross fixed capital formation, changes in inventories, and acquisitions less disposals of valuables. The primary input matrices **v** for provinces include four components: compensation of employees, net taxes on production, depreciation of fixed assets, and operating surplus.

For international trade blocks, transactions between Chinese provinces and other countries in the world are represented by export and import matrices. Provincial exports to each country are distinguished by intermediate demand and final demand. Similarly, provincial imports from 185 countries are separated into intermediate input and final demand. Country classifications are the same as the sectoral classifications in EORA, ranging from 25 to 510 (Appendix C).

2.2Data Sources

We constructed the Chinese MRIO in current US dollars in order to balance the entire MRIO table and to allow comparison with other countries in EORA. All raw data are stored expressed in their original Chinese currency RMB, and the International Monetary Fund official exchange rate was used to convert RMB to US dollars to reconcile the currency and units within constraints. The transformation procedures used during the development of constraints allow research investigating constraint realizations (and violation) to adhere as closely as possible to the original data.

- The benchmark data available for the Chinese MRIO table are obtained from the Chinese interregional input-output table for 30 provinces in a commodity-by-commodity format based on the producers' prices, with a classification of 30 sectors (Liu et al., 2012).
- The National Input-output Table of China for 2007 was used as the basis for classification in this work to disaggregate the various levels of classifications to a consistent and detailed classification of 135 sectors (National Bureau of Statistics of China, 2010).
- The export and import data between all provinces and 185 individual countries used for initial estimates and time series constraints were obtained from the annual statistical yearbooks of 30 provinces from 1998 to 2012 (National Bureau of Statistics of China, 1998-2012).
- International trade data between China and other individual countries were from EORA's latest MRIO dataset version 199.74, including continuous coverage for the period 1990-2011. The classifications of 185 countries were represented by detailed

separate classifications in EORA and a total of 15761 sectors (www.worldmrio.com).

- Three official Chinese MRIO tables, i.e., the Interregional Input-Output Table for China for 1997 and the Chinese Multi-Regional Input-Output Table for 2002 and 2007, were taken into account. These tables were constrained to our time series of Chinese MRIO tables for the years 1997, 2002, and 2007, respectively (State Information Center, 2005; Zhang and Qi, 2012).

2.3Valuations

National and provincial input-output tables of China published by National Bureau of Statistics of China and other relevant input-output tables usually use producers' prices. Thus, our Chinese MRIO tables are consistent with producers' prices. However, there is no such price concept in EORA tables. EORA provides 5 valuations for its MRIO tables: basic price, trade, transport, tax, and subsidies. Producers' prices are basic prices plus taxes on products minus subsidies on products. The **T**, **y** and **v** blocks used in Chinese MRIO tables are presented at producers' prices due to benchmark data construction based on province-specific input-output tables published by the National Bureau of Statistics of China (Liu et al., 2012; National Bureau of Statistics of China, 2011). International trade data from EORA were used to embed Chinese MRIO data into EORA. Thus, we only needed to transform international trade blocks into suitable prices using EORA data.

The EORA database uses Free On Board (FOB) and Cost, Insurance and Freight (CIF) price alternatives to producers' and purchasers' prices. Import prices are divided into five sheets. Import_sheet1 is the FOB price, import_sheet2 is the international trade margin, import_sheet3 is the international transport margin, import_sheet4 is the import tax (e.g., duties), and import_sheet5 is the import subsidies. The sum of import_sheet1, import_sheet2, and import_sheet3 equals the CIF price. The sum of all import sheets yields the purchasers' price. Exports are the same as imports. The Chinese MRIO is the producers' price, but the output is always the basic price. The EORA table only has the output basic price. Therefore, exports in the Chinese MRIO use the basic price/FOB price (import_sheet1), while imports in the Chinese MRIO use the purchasers' price.

2.4Concordances and Maps

Various data sources used in this work have different classifications. These classifications have to be reconciled into a consistent classification in order to construct the Chinese MRIO. This reconciliation was performed by constructing a prorating matrix from a binary concordance matrix based on the ratios of proxy vectors (Geschke, 2012; Lenzen et al., 2012b; Lenzen, 2011). The coefficient values in a concordance matrix are either 0 or 1 and determine how the value is split between the original sector classifications and the more disaggregated or aggregated sector classifications. Different approaches were used to obtain the ratio between the corresponding sectors. The sums of the row/column elements of a concordance matrix for disaggregation must always equal one. Then, both row- and column-normalized maps were created from the concordances by prorating with a suitable proxy output variable.

Let C be an $m \times n$ binary concordance matrix. Let x be the vector containing the n-sectoral output data, and $\hat{x}$ be the diagonal matrix corresponding to x. The normalised map M corresponding to C is then expressed as equation 1.

$$\mathrm{M} = (\widehat{Cx})^{-1} C\hat{x} \tag{1}$$

Let T be an $n \times n$ intermediate input/demand matrix of a new (MR)IO, y be the final demand matrix, and v be the primary input matrix. The original (MR)IO is then transformed into the one as follows:

$$T_{new} = M'TM \tag{2}$$

$$y_{new} = M'y \tag{3}$$

$$v_{new} = vM \tag{4}$$

2.5Transforming International/Provincial Trade Data into Sectors

The only data regarding the imports and exports of all provinces from and to individual countries are the total imports and exports, with no information on individual products (National Bureau of Statistics of China, 2008). To construct international trade blocks in the Chinese MRIO for the base year 2007, it was necessary to separate the total imports and exports between the 30 Chinese provinces and the 185 individual countries into sectoral data.

We used trade share coefficients to generate the initial estimates of trade flows to intermediate demand and final demand between the provinces and other countries. The trade share coefficients were calculated based on the import and export data between China and other countries from the EORA database. For the share of imports $\mu_{s=1,\cdots,30}^{r=1,\cdots,185}$ and the share of exports $\delta_{s=1,\cdots,185}^{r=1,\cdots,30}$ the row sum and the column sum must each equal one. Then, the import and export matrices for initial estimates can be constructed according to the following:

$$M_{ij}^{rs} = M_{ij}^{r\,China} \mu^{rs} N' \quad \text{with} \quad \textstyle\sum_{r\cdot} \mu^{rs} = 1 \tag{5}$$

$$X_{ij}^{rs} = N X_{ij}^{China\,s} \delta^{rs} \quad \text{with} \quad \textstyle\sum_{\cdot s} \delta^{rs} = 1 \tag{6}$$

Where M represents the import matrices and X represents the export matrices in the Chinese MRIO; r is the origin (provinces or other countries) and s is the destination (provinces or other countries); i, j are the number of sectors in provinces or countries; and N is a suitable prorating matrix used to reconcile the classifications between China in EORA and the provinces in this work.

The initial estimates of imports and exports for other years are therefore based on the assumption that the ratios of imports from countries to total imports and of exports to countries to total exports at the product level are constant over time.

2.6Establishing Uncertainty Estimates

There is no uncertainty information available for the Chinese data sources used to construct the Chinese MRIO. Thus, one innovative aspect of Chinese MRIO tables is the estimation of information on data reliability. Standard deviations (SDs) are essential for determining the uncertainty of any quantitative measure derived from MRIO tables (Lenzen et al., 2012b). Estimates of standard deviations for data supporting the construction of input-output tables for Australia and the United Kingdom have been calculated (Wiedmann et al., 2010; Lenzen, 2000). SDs usually can be estimated as proxy information for data uncertainty. The inference of the raw data SDs from the proxy data SDs can be facilitated using regression techniques (Lenzen et al., 2010). We calculate SD-estimators of the raw data by specifying the basic regression model:

$$f(c) = xlnc + y \quad (7)$$

Where c is a value taken from the raw data and x and y are the regression parameters, x being the relative standard error (RSE) of the maximum of the data, and y the RSE of the minimum of the data (Lenzen et al., 2012a).

2.7AISHA Tool for Conflict Data and Constraints

The construction of a Chinese MRIO requires harmonizing and balancing tables due to the combination of a vast amount of data from different sources and from potentially conflicting data. AISHA was developed for constructing a series of large contingency tables (Lenzen et al., 2012a). A key function of AISHA is to balance input-output matrices with satellite accounts. AISHA operates the matrix-balancing algorithm KRAS (‘Konfliktfreies RAS’) and uses externally defined constraints to solve a constrained optimization problem (Lenzen et al., 2007; Lenzen et al., 2009). Therefore, we employed the KRAS optimization technique to balance data according to constraints defined by the available data from the Chinese MRIO.

3.Construction Process

Constructing a time series of tables involves preparing initial estimates, defining and scripting constraints to generate final estimates, and then obtaining final estimates as the initial estimates for the next year. The satellites are constructed just like the MRIO, with an initial estimate for one year and constraints for other years.

3.1Constructing the Chinese MRIO Table for the Base Year

The estimation of the base year 2007 was the crux of the time series construction of the Chinese MRIO. The initial estimate was generated from a selected set of raw data for the base year 2007 because the available data in this year were the best. We determined 2007 Chinese MRIO tables by reconciling all of the raw data available for 2007. The entire construction procedure can be summarized in four steps.

Step 1 Make Domestic Matrices for Initial Estimates

The available data were in various states of classification and aggregation. Consistent and detailed disaggregation for all of the data were transformed into disaggregated sectors as initial estimates using equations 2 to 4. We also transformed the original classification of the final demand of all provinces to coincide with that of EORA.

Step 2 Make International Trade Matrices for Initial Estimates

For the initial estimates of export and import blocks in the Chinese MRIO, we transform China's import and export matrices taken from EORA into the provincial import and export matrices using the methods in section 2.5.

Step 3 Embedding the Chinese MRIO into EORA

To link with the EORA database and remain consistent with it, we used the Chinese MRIO cross in the EORA MRIO table, and don't bother the rest of EORA. For imports to intermediate input, only T^{rC_j} was used. $\sum_j T^{rC_j}$, the sum of the imports of each country to all provinces (C=Chinese provinces, j=1,2,…,30 and r=1,2,…,185) was set as a hard constraint (i.e., the SD-estimators was set to 0), and the same was done for each country's exports to the intermediate demand of all provinces $\sum_i T^{C_i s}$ (i=1,2,…,30 and s=1, 2,…,185). For final demand, the same process was used. In such situation, the Chinese MRIO cross coupled well with EORA and did not disturb the EORA sector balance.

Step 4 Make Final Estimates by Using AISHA Constraints

When the initial estimates for the year 2007 are made by AISHA, we add constraints on the initial estimates and then use the KRAS optimizer to obtain the final estimates for 2007. Three categories of constraints are used: balancing constraints, the right-hand side of constraints, and the boundary constraints.

In addition, external data sources are considered as constraining data due to the availability of official Chinese MRIO tables for the year 2007 (Zhang and Qi, 2012). The "a-operator" is used to reconcile the more aggregated classification in the official table with the corresponding Chinese MRIO table in this work.

3.2Generating Time Series of Chinese MRIO Using Constraints

The entire time series of Chinese MRIO tables from 1997-2011 was constructed iteratively. The 2007 initial estimate (Step 1 to Step 2) was reconciled with all 2007 constraints (Step 3 and Step 4) to generate a final estimate for 2007. Taking the solution as the initial estimate for 2008, the constraint data for all imports and exports from the National Bureau Statistics of China and EORA where original data were available for 2008, as well as for the three categories of constraints in Step 5, were subsequently re-balanced using the KRAS procedure by AISHA to generate a final estimate for 2008. Back-casting to 1997 proceeded similarly. The entire time series was completed in the same stepwise manner.

External data sources were also considered as constraint data for the year 1997 (State Information Center, 2005) and 2002 (Zhang and Qi, 2012). The "t-operator" for 1997 and "a-operator" for 2002 were used to reconcile the classifications in the official tables that were more aggregated than the corresponding Chinese MRIO tables of 1997 and 2002.

3.3Constructing Satellite Accounts

The construction process for satellite accounts was similar to that of the Chinese MRIO. At this stage, the AISHA tree structure was only suitable for satellite indicators. Initial estimates were constructed by raw data and disaggregated into 135 sectors using map matrices. If the raw data for all of the years were from the same sources, constrained optimization for conflicting data was not necessary. Otherwise, a year-2007 satellite account was formed by reconciling all of the raw data available for 2007, which was taken as the initial estimate for the following year, 2008. A new satellite account was then calculated on the basis of all raw data available for the year 2008, and so on. The construction of the remaining satellite accounts was the same as that of the Chinese MRIO.

4.Results

4.1Heat Maps of the Chinese MRIO

For each year of a time series, a heat map gives a general overview of the order of magnitude of the value in the corresponding table (Lenzen et al., 2012b; Lenzen et al., 2013a). Figure 2 shows the result of the 2007 Chinese MRIO table. The horizontal axis and vertical axis show the provincial and country classifications, respectively, as they appear in the Chinese MRIO. The color indicates the order of magnitude of the corresponding value (in units of 1000 US$). The deeper the color is, the larger the values are. The square area in the upper left corner presents Chinese domestic activities. Diagonal blocks in the upper left corner are the domestic input-output tables of all provinces, and off-diagonal blocks contain inter-provincial trade transactions. The upper-right blocks are provincial exports to 185 countries, and the lower left blocks are provincial imports from the same countries. Figure 2 also illustrates that inter-provincial trade is greater than international trade.

The heat map of the Chinese MRIO is equipped with a zoom-in/zoom-out facility that allows the user to focus on certain regions. Figure 3 provides a detailed picture of Chinese domestic activities. Liaoning, Shanghai, Jiangsu, Zhejiang, Shandong, Guangdong, and Sichuan show large industrial transactions in their domestic regions. The first three provinces in Figure 3, called the *Beijing-Tianjin-Hebei metropolitan circle*, also display remarkable transactions within and between provinces, which are closely associated with each other. In the middle of Figure 3, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, and Guangdong feature inter-provincial transactions. We also can see that Guangdong is a prominent export-led province in China, and Hainan's economy rarely depends on imports and exports from other provinces (Figure 3).

Figure 4 takes Beijing as a close-up example. Its intermediate demand, final demand and value-added blocks are clearly visible. The deep blue sectors show a large intermediate demand and gross capital formation generated by construction in 2007 due to the *2008 Beijing Olympic Games*. The taxes on production minus subsidies on production are negatives on Beijing's production and distribution of gas and its production and distribution of water (red). Light blue represents the transport via railway and road of Beijing's exports to Tianjin. Beijing's catering services imports are from grain milling, forage processing, vegetable oil refining, slaughtering and processing of meat, and processing of other foods.

Figure 5 reveals the nature of trade relationships between provinces and other countries in the world. As shown in the left of Figure 5, Zhejiang and Fujian manufactured products exported to the UK and the USA. Imports from India, Indonesia, and Japan are visible on the right side of Figure 5 (this can also be seen from Figure 2.).

4.2Uncertainty Analysis of the Chinese MRIO

We calculated the SD-estimators as the reliability for each data point and associated the SD matrices with annual Chinese MRIO tables and their satellite indicators. Figure 6 shows the relative standard deviation of Chinese MRIO data for the years 2007, 1997, and 2011. The sloping diagrams indicate that the relative standard deviations of the Chinese MRIO tables are small for large table elements, and vice versa. These results are similar with those of EORA MRIO tables (Lenzen et al., 2012b). This is because small table elements are usually inadequately supported by raw data points and because under the KRAS balancing procedure, small elements with only a few constraints are subject to large adjustments, and hence their reliability is low. Conversely, large table elements are adequately supported by raw data points, and the adjustment of these elements is usually minimal and thus has low uncertainty. This can be seen by comparing the relative standard deviations of three years with the different raw data available. The reliability of the base year is lowest in 1997, 2007, and 2011 because of the quantity of raw data available. The reliability of 1997 is next, constrained by official MRIO data, and the uncertainty of 2011 is the highest due to its fewer raw data constraints.

Although there exists a large number of small and unreliable elements in Chinese MRIO tables, we can use an innovative time series of tables for further applications such as calculating multipliers, footprints, and other impact measures. Jensen has demonstrated that a large number of small elements can be perturbed without significantly changing estimates for multipliers or footprints (Jensen, 1980). Furthermore, the concept of holistic accuracy has been established by Jensen’s work (Jensen, 1980; Jensen and West, 1980). From the holistic accuracy perspective, the accuracy of single elements may be unimportant, as long as the results of Chinese MRIO modeling can yield a realistic picture for the purpose of decision-makers or analysts. Therefore, the presence of a large number of small and unreliable elements in Chinese MRIO tables is irrelevant.

5.Conclusions

The paper demonstrates the process of constructing a Chinese MRIO table time series using AISHA. This is the first annual time series of a subnational MRIO (1997-2011) that includes a large number of provinces and countries and sectors accompanying the uncertainty information. The state-of-the-art balancing optimizer KRAS was used with conflicting information, and the regression technique was used to estimate the standard deviations of the raw data.

The construction of annual MRIO tables from 1997 to 2011 fills a current gap in China’s sporadic and low-resolution multi-region data. The most recent official data and researchers’ data for the year 2007 were both released in 2012. This was the fastest issue since the first 1987 Chinese MRIO published in 2003. Our work is the first high-resolution mapping of the Chinese economy and identifies the important trading partners of all provinces, which cannot be determined form the existing data.

Chinese MRIO tables can be applied in various extended input-output applications. The timeliness of Chinese MRIO tables makes a more relevant analysis of current policy possible. The continuity of the time series enables the robust identification of key drivers of social, financial, and environmental change. The high number of domestic regions, foreign countries and sector detail could significantly improve the resolution of Life Cycle Assessments. Uncertainty estimations of the Chinese MRIO can benefit decision-makers by allowing them to judge quantitative information not only with respect to its magnitude but also with regard to its reliability. These innovations dramatically improve the applications of Chinese MRIO tables for policy-makers and analysts.

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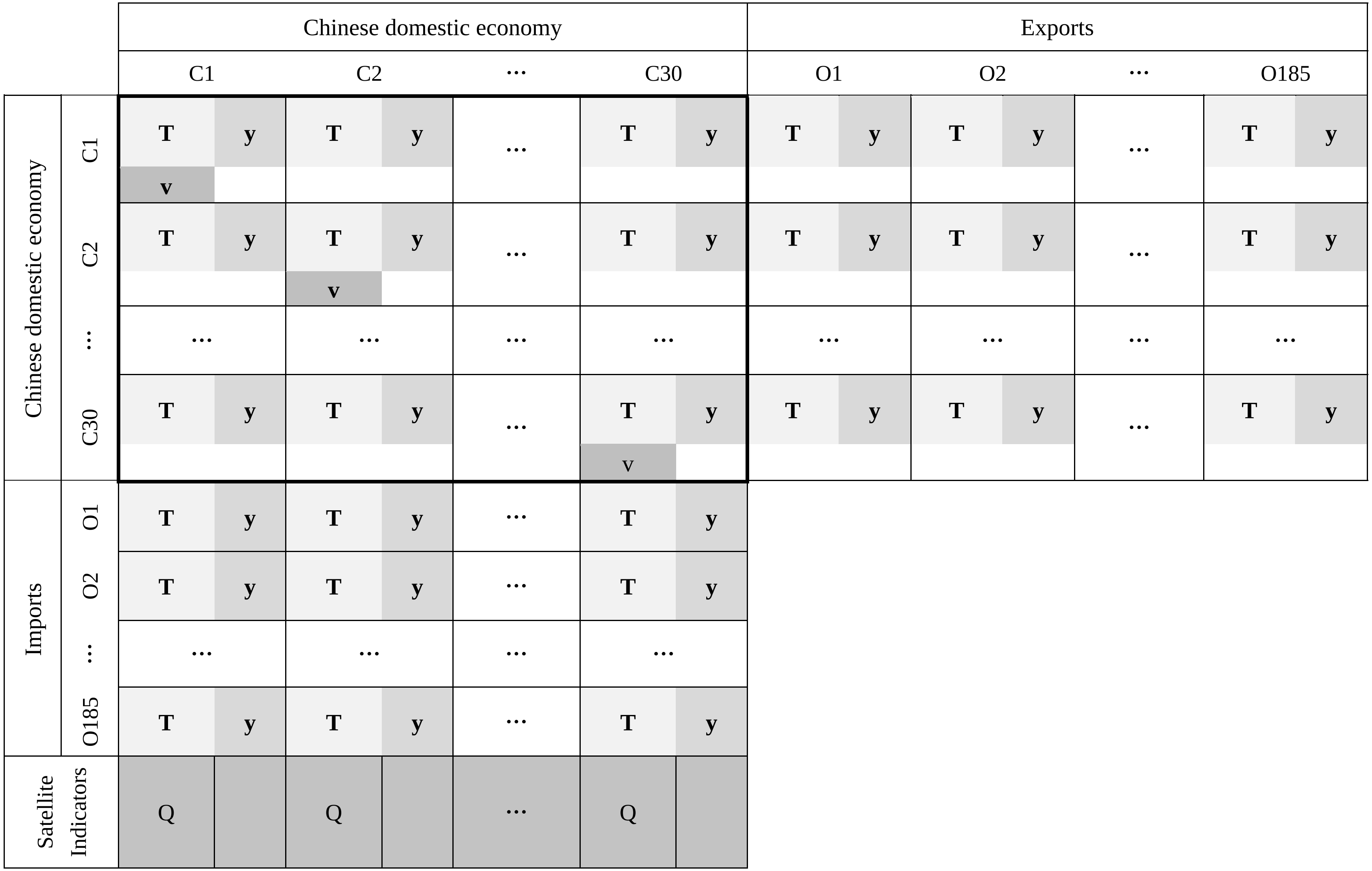


Figure 1. Structure of Chinese MRIO (T=intermediate matrices, y=final demand matrices, v= value added matrices, and Q=satellite indicators).

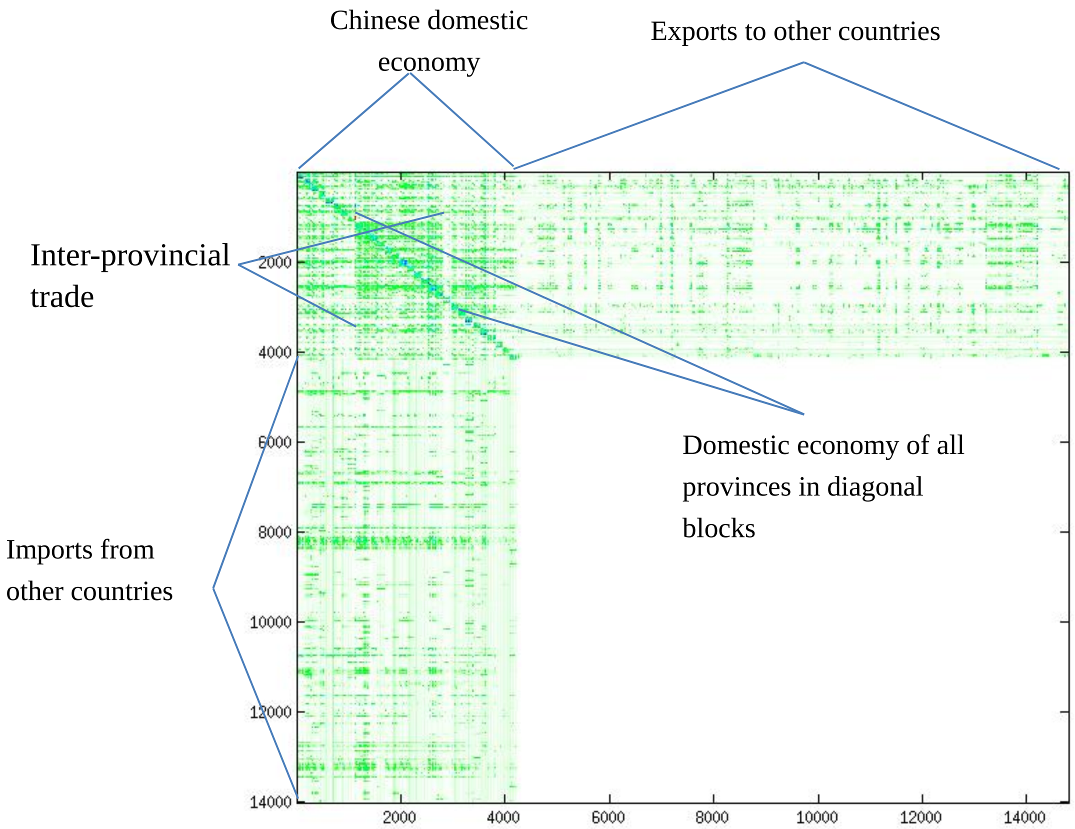


Figure 2. The Heat map of Chinese MRIO table for the year 2007. Each pixel represents one data on the transaction matrix, with deeper cells representing larger transaction values.

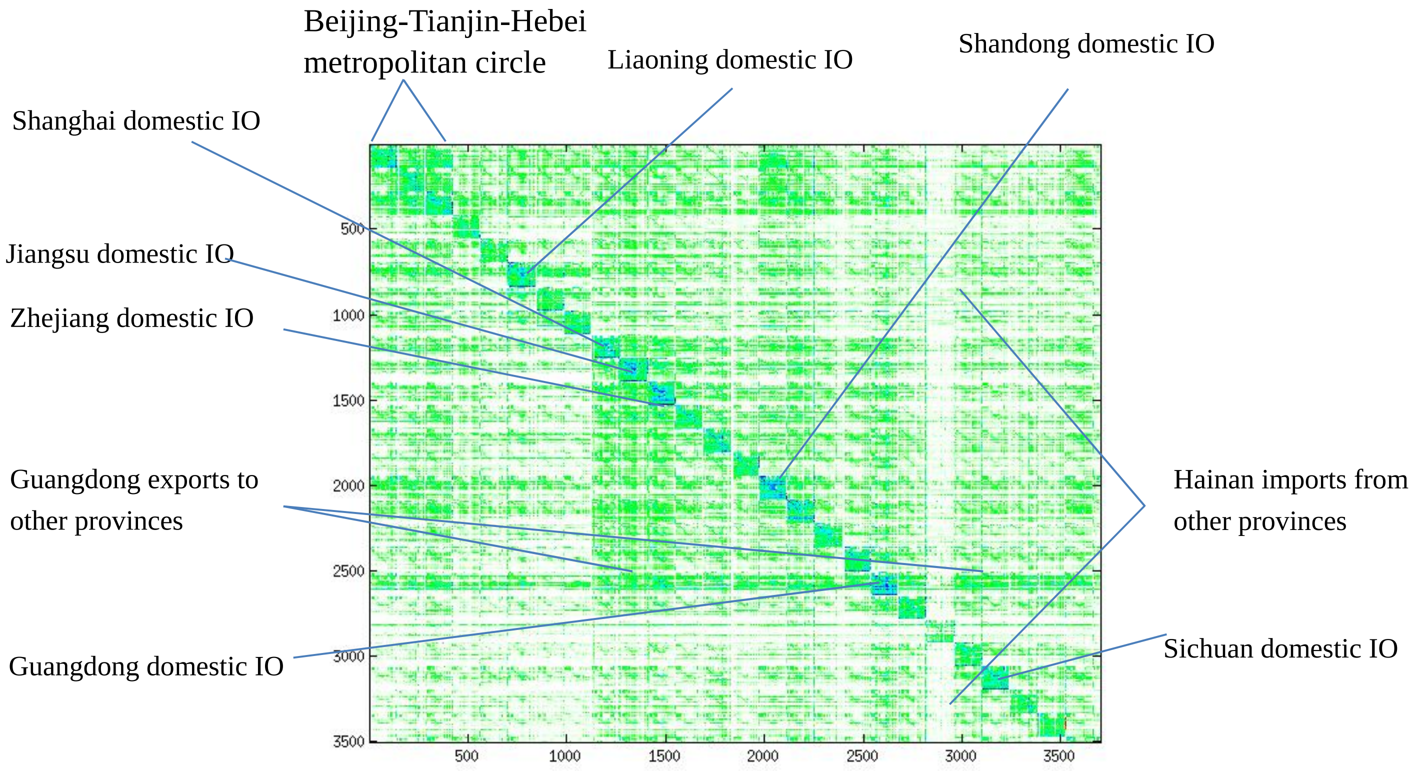


Figure 3. Close-up of Figure 2. Chinese domestic economy.

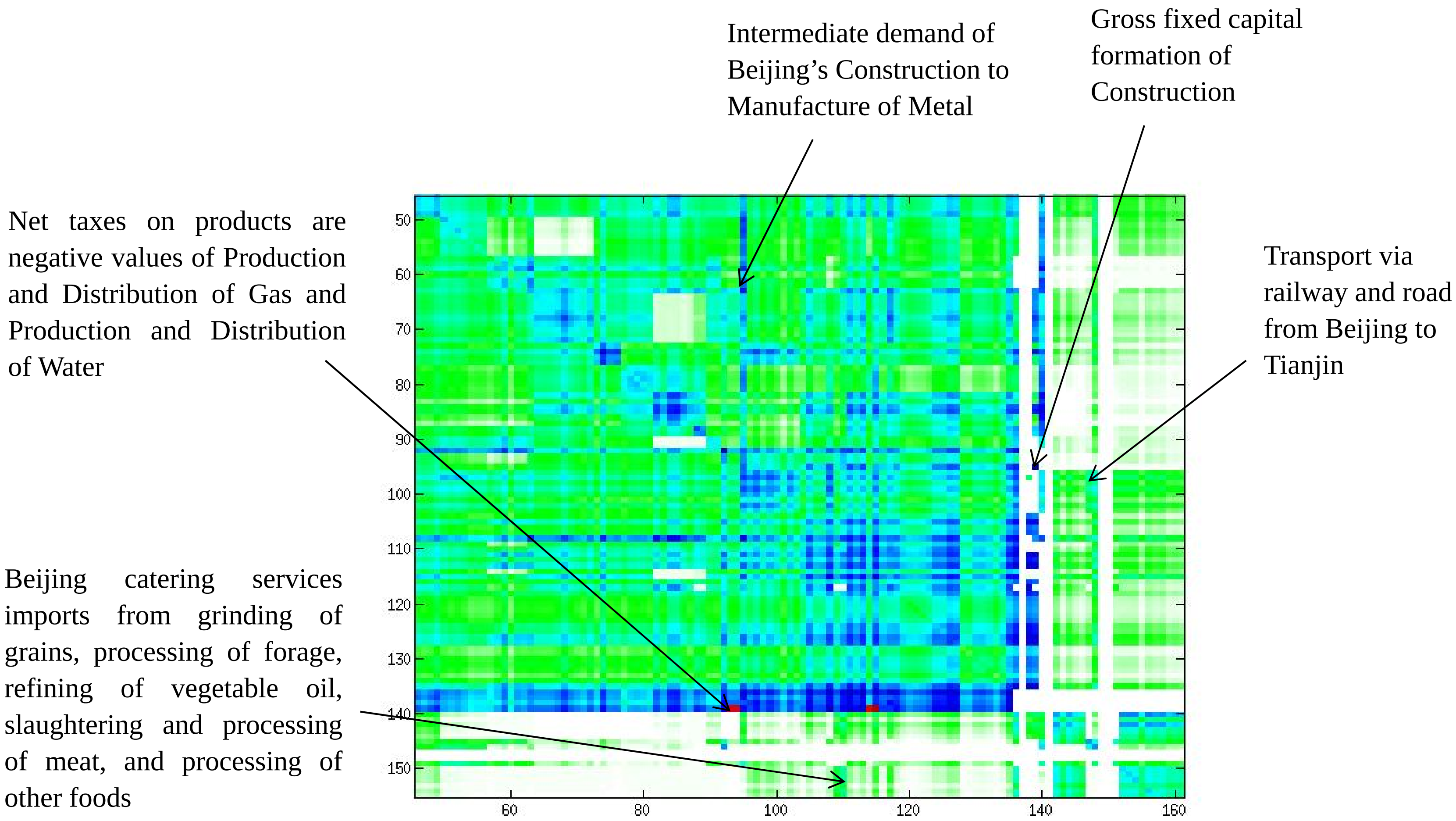
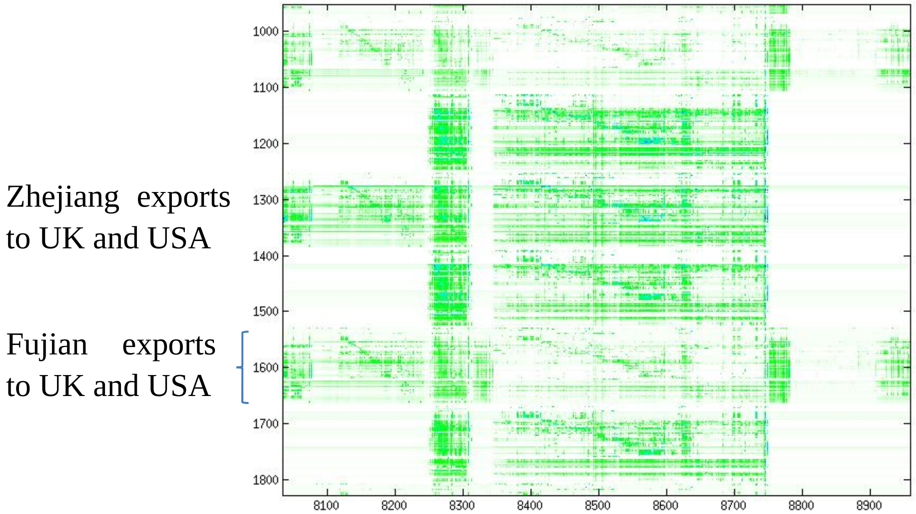


Figure 4. Close-up of Figure 2. Beijing domestic IO table.



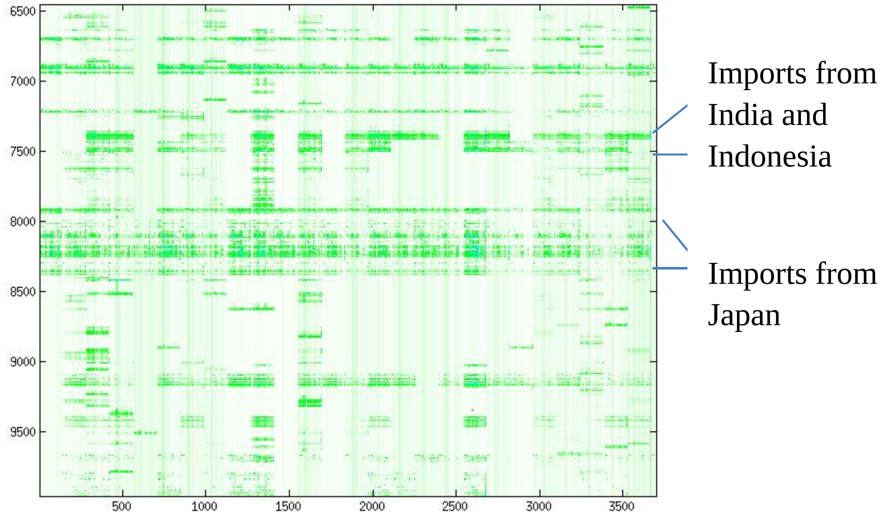
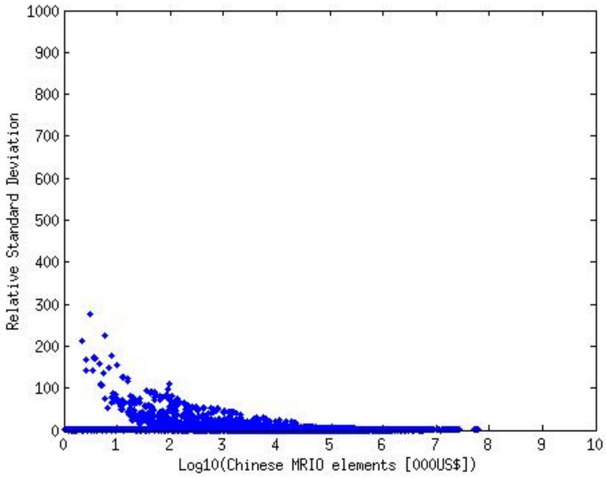
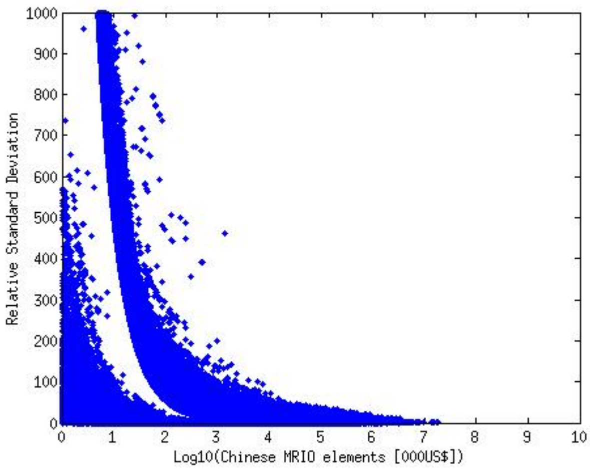


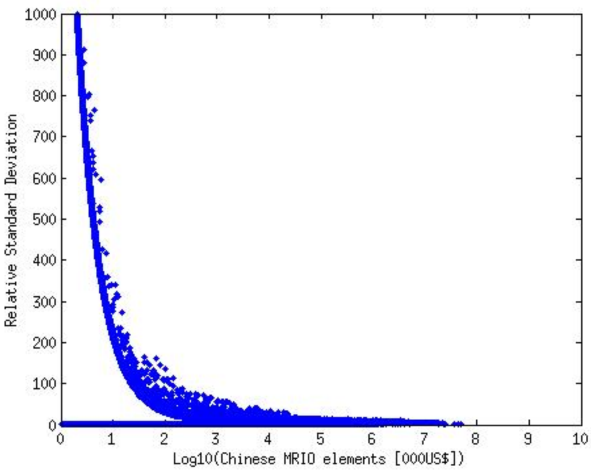
Figure 5. Close-up of Figure 2. Zhejiang and Fujian exports to UK and USA; Imports from India, Indonesia, and Japan.



(a) The base year 2007 with best raw data



(b) The year 1997 with an official MRIO table as constraints



(c) The year 2011 without an official MRIO table as constraints

Figure 6. Relative standard deviation of Chinese MRIO.

Appendix A. List of provinces used in Chinese MRIO excluded Tibet, Hong Kong, Macau and Taiwan.

No.	Province Name	No.	Province Name
1	Beijing	16	Henan
2	Tianjin	17	Hubei
3	Hebei	18	Hunan
4	Shanxi	19	Guangdong
5	InnerMonglia	20	Guangxi
6	Liaoning	21	Hainan
7	Jilin	22	Chongqing
8	Heilongjiang	23	Sichuan
9	Shanghai	24	Guizhou
10	Jiangsu	25	Yunnan
11	Zhejiang	26	Shaanxi
12	Anhui	27	Gansu
13	Fujian	28	Qinghai
14	Jiangxi	29	Ningxia
15	Shandong	30	Xinjiang

Appendix B. 135 commodity classification of Chinese provinces in Chinese MRIO table.

No.	Sector Name
1	Farming
2	Forestry
3	Animal Husbandry
4	Fishery
5	Services in Support of Agriculture
6	Mining and Washing of Coal
7	Extraction of Petroleum and Natural Gas
8	Mining of Ferrous Metal Ores
9	Mining of Non-Ferrous Metal Ores
10	Mining and Processing of Nonmetal Ores and Other Ores
11	Grinding of Grains
12	Processing of Forage
13	Refining of Vegetable Oil
14	Manufacture of Sugar
15	Slaughtering and Processing of Meat
16	Processing of Aquatic Product
17	Processing of Other Foods
18	Manufacture of Convenience Food
19	Manufacture of Liquid Milk and Dairy Products
20	Manufacture of Flavoring and Ferment Products
21	Manufacture of Other Foods
22	Manufacture of Alcohol and Wine
23	Processing of Soft Drinks and Purified Tea
24	Manufacture of Tobacco
25	Spinning and Weaving, Printing and Dyeing of Cotton and Chemical Fiber
26	Spinning and Weaving, Dyeing and Finishing of Wool
27	Spinning and Weaving of Hemp and Tiffany
28	Manufacture of Textile Products
29	Manufacture of Knitted Fabric and Its Products
30	Manufacture of Textile Wearing Apparel, Footwear and Caps
31	Manufacture of Leather, Fur, Feather(Down) and Its Products
32	Processing of Timbers, Manufacture of Wood, Bamboo, Rattan, Palm and Straw Products
33	Manufacture of Furniture
34	Manufacture of Paper and Paper Products
35	Printing, Reproduction of Recording Media
36	Manufacture of Articles for Culture, Education and Sports Activities
37	Processing of Petroleum and Nuclear Fuel
38	Coking
39	Manufacture of Basic Chemical Raw Materials
40	Manufacture of Fertilizers
41	Manufacture of Pesticides

42	Manufacture of Paints, Printing Inks, Pigments and Similar Products
43	Manufacture of Synthetic Materials
44	Manufacture of Special Chemical Products
45	Manufacture of Chemical Products for Daily Use
46	Manufacture of Medicines
47	Manufacture of Chemical Fiber
48	Manufacture of Rubber
49	Manufacture of Plastic
50	Manufacture of Cement, Lime and Plaster
51	Manufacture of Products of Cement and Plaster
52	Manufacture of Brick, Stone and Other Building Materials
53	Manufacture of Glass and Its Products
54	Manufacture of Pottery and Porcelain
55	Manufacture of Fire-resistant Materials
56	Manufacture of Graphite and Other Nonmetallic Mineral Products
57	Iron-smelting
58	Steelmaking
59	Rolling of Steel
60	Smelting of Ferroalloy
61	Smelting of Non-Ferrous Metals and Manufacture of Alloys
62	Rolling of Non-Ferrous Metals
63	Manufacture of Metal Products
64	Manufacture of Boiler and Prime Mover
65	Manufacture of Metalworking Machinery
66	Manufacture of Lifters
67	Manufacture of Pump, Valve and Similar Machinery
68	Manufacture of Other General Purpose Machinery
69	Manufacture of Special Purpose Machinery for Mining, Metallurgy and Construction
70	Manufacture of Special Purpose Machinery for Chemical Industry, Processing of Timber and Nonmetals
71	Manufacture of Special Purpose Machinery for Agriculture, Forestry, Animal Husbandry and Fishery
72	Manufacture of Other Special Purpose Machinery
73	Manufacture of Railroad Transport Equipment
74	Manufacture of Automobiles
75	Manufacture of Boats and Ships and Floating Devices
76	Manufacture of Other Transport Equipment
77	Manufacture of Generators
78	Manufacture of Equipments for Power Transmission and Distribution and Control
79	Manufacture of Wire, Cable, Optical Cable and Electrical Appliances
80	Manufacture of Household Electric and Non-electric Appliances
81	Manufacture of Other Electrical Machinery and Equipment
82	Manufacture of Communication Equipment

83 Manufacture of Radar and Broadcasting Equipment
84 Manufacture of Computer
85 Manufacture of Electronic Component
86 Manufacture of Household Audiovisual Apparatus
87 Manufacture of Other Electronic Equipment
88 Manufacture of Measuring Instruments
89 Manufacture of Machinery for Cultural Activity & Office Work
90 Manufacture of Artwork, Other Manufacture
91 Scrap and Waste
92 Production and Supply of Electric Power and Heat Power
93 Production and Distribution of Gas
94 Production and Distribution of Water
95 Construction
96 Transport Via Railway
97 Transport Via Road
98 Urban Public Traffic
99 Water Transport
100 Air Transport
101 Transport Via Pipeline
102 Loading, Unloading, Portage and Other Transport Services
103 Storage
104 Post
105 Telecom & Other Information Transmission Services
106 Computer Services
107 Software Industry
108 Wholesale and Retail Trades
109 Hotels
110 Catering Services
111 Banking, Security, Other Financial Activities
112 Insurance
113 Real Estate
114 Leasing
115 Business Services
116 Tourism
117 Research and Experimental Development
118 Professional Technical Services
119 Services of Science and Technology Exchanges and Promotion
120 Geological Prospecting
121 Management of Water Conservancy
122 Environment Management
123 Management of Public Facilities
124 Services to Households
125 Other Services
126 Education

127	Health
128	Social Security
129	Social Welfare
130	Journalism and Publishing Activities
131	Broadcasting, Movies, Televisions and Audiovisual Activities
132	Cultural and Art Activities
133	Sports Activities
134	Entertainment
135	Public Management and Social Organization

Appendix C. List of other countries used in Chinese MRIO, including United Nations abbreviation, numbers of sectors (row and column).

No.	Country Name	Abbreviation	row	column
1	Afghanistan	AFG	25	25
2	Albania	ALB	25	25
3	Algeria	DZA	25	25
4	Andorra	AND	25	25
5	Angola	AGO	25	25
6	Antigua and Barbuda	ATG	25	25
7	Argentina	ARG	195	124
8	Armenia	ARM	25	25
9	Aruba	ABW	25	25
10	Australia	AUS	344	344
11	Austria	AUT	60	60
12	Azerbaijan	AZE	25	25
13	Bahamas	BHS	25	25
14	Bahrain	BHR	25	25
15	Bangladesh	BGD	25	25
16	Barbados	BRB	25	25
17	Belarus	BLR	25	25
18	Belgium	BEL	60	60
19	Belize	BLZ	25	25
20	Benin	BEN	25	25
21	Bermuda	BMU	25	25
22	Bhutan	BTN	25	25
23	Bolivia	BOL	36	36
24	Bosnia and Herzegovina	BIH	25	25
25	Botswana	BWA	25	25
26	Brazil	BRA	110	55
27	British Virgin Islands	VGB	25	25
28	Brunei Darussalam	BRN	25	25
29	Bulgaria	BGR	25	25
30	Burkina Faso	BFA	25	25
31	Burundi	BDI	25	25
32	Cambodia	KHM	25	25
33	Cameroon	CMR	25	25
34	Canada	CAN	48	48
35	Cape Verde	CPV	25	25
36	Cayman Islands	CYM	25	25
37	Central African Republic	CAF	25	25
38	Chad	TCD	25	25
39	Chile	CHL	74	74
40	Colombia	COL	59	59
41	Congo	COG	25	25

42	Costa Rica	CRI	25	25
43	Croatia	HRV	25	25
44	Cuba	CUB	25	25
45	Cyprus	CYP	25	25
46	Czech Republic	CZE	60	60
47	Côte d'Ivoire	CIV	25	25
48	Democratic People's Republic of Korea	PRK	25	25
49	Democratic Republic of the Congo, previously Zaïre	COD	25	25
50	Denmark	DNK	130	130
51	Djibouti	DJI	25	25
52	Dominican Republic	DOM	25	25
53	Ecuador	ECU	60	48
54	Egypt	EGY	25	25
55	El Salvador	SLV	25	25
56	Eritrea	ERI	25	25
57	Estonia	EST	60	60
58	Ethiopia	ETH	25	25
59	Fiji	FJI	25	25
60	Finland	FIN	60	60
61	France	FRA	60	60
62	French Polynesia	PYF	25	25
63	Gabon	GAB	25	25
64	Gambia	GMB	25	25
65	Georgia	GEO	67	46
66	Germany	DEU	71	71
67	Ghana	GHA	25	25
68	Greece	GRC	60	60
69	Greenland	GRL	30	30
70	Guatemala	GTM	25	25
71	Guinea	GIN	25	25
72	Guyana	GUY	25	25
73	Haiti	HTI	25	25
74	Honduras	HND	25	25
75	Hong Kong	HKG	37	37
76	Hungary	HUN	60	60
77	Iceland	ISL	25	25
78	India	IND	115	115
79	Indonesia	IDN	76	76
80	Iran	IRN	147	99
81	Iraq	IRQ	25	25
82	Ireland	IRL	60	60
83	Israel	ISR	162	162
84	Italy	ITA	60	60

85	Jamaica	JAM	25	25
86	Japan	JPN	401	401
87	Jordan	JOR	25	25
88	Kazakhstan	KAZ	120	120
89	Kenya	KEN	50	50
90	Kuwait	KWT	54	54
91	Kyrgyzstan	KGZ	86	88
92	Lao People's Democratic Republic	LAO	25	25
93	Latvia	LVA	60	60
94	Lebanon	LBN	25	25
95	Lesotho	LSO	25	25
96	Liberia	LBR	25	25
97	Libyan Arab Jamahiriya	LBY	25	25
98	Liechtenstein	LIE	25	25
99	Lithuania	LTU	60	60
100	Luxembourg	LUX	25	25
101	Macao Special Administrative Region of China	MAC	25	25
102	Madagascar	MDG	25	25
103	Malawi	MWI	25	25
104	Malaysia	MYS	97	97
105	Maldives	MDV	25	25
106	Mali	MLI	25	25
107	Malta	MLT	60	60
108	Mauritania	MRT	25	25
109	Mauritius	MUS	66	56
110	Mexico	MEX	79	79
111	Monaco	MCO	25	25
112	Mongolia	MNG	25	25
113	Montenegro	MNE	25	25
114	Morocco	MAR	25	25
115	Mozambique	MOZ	25	25
116	Myanmar	MMR	25	25
117	Namibia	NAM	25	25
118	Nepal	NPL	25	25
119	Netherlands	NLD	60	60
120	Netherlands Antilles	ANT	40	15
121	New Caledonia	NCL	25	25
122	New Zealand	NZL	209	126
123	Nicaragua	NIC	25	25
124	Niger	NER	25	25
125	Nigeria	NGA	25	25
126	Norway	NOR	60	60
127	Occupied Palestinian Territory	PSE	25	25

128	Oman	OMN	25	25
129	Pakistan	PAK	25	25
130	Panama	PAN	25	25
131	Papua New Guinea	PNG	25	25
132	Paraguay	PRY	46	33
133	Peru	PER	45	45
134	Philippines	PHL	76	76
135	Poland	POL	60	60
136	Portugal	PRT	60	60
137	Qatar	QAT	25	25
138	Republic of Korea	KOR	77	77
139	Republic of Moldova	MDA	25	25
140	Romania	ROU	60	60
141	Russian Federation	RUS	48	48
142	Rwanda	RWA	25	25
143	Samoa	WSM	25	25
144	San Marino	SMR	25	25
145	Sao Tome and Principe	STP	25	25
146	Saudi Arabia	SAU	25	25
147	Senegal	SEN	25	25
148	Serbia	SRB	25	25
149	Seychelles	SYC	25	25
150	Sierra Leone	SLE	25	25
151	Singapore	SGP	153	153
152	Slovakia	SVK	60	60
153	Slovenia	SVN	60	60
154	Somalia	SOM	25	25
155	South Africa	ZAF	95	94
156	Spain	ESP	118	75
157	Sri Lanka	LKA	25	25
158	Suriname	SUR	25	25
159	Swaziland	SWZ	25	25
160	Sweden	SWE	60	60
161	Switzerland	CHE	42	42
162	Syrian Arab Republic	SYR	25	25
163	Taiwan	TWN	162	162
164	Tajikistan	TJK	25	25
165	Thailand	THA	179	179
166	Macedonia	MKD	60	60
167	Togo	TGO	25	25
168	Trinidad and Tobago	TTO	25	25
169	Tunisia	TUN	25	25
170	Turkey	TUR	60	60
171	Turkmenistan	TKM	25	25

172	Uganda	UGA	25	25
173	Ukraine	UKR	120	120
174	United Arab Emirates	ARE	25	25
175	United Kingdom	GBR	510	510
176	United Republic of Tanzania	TZA	25	25
177	USA	USA	428	428
178	Uruguay	URY	102	83
179	Uzbekistan	UZB	122	122
180	Vanuatu	VUT	25	25
181	Venezuela	VEN	121	121
182	Viet Nam	VNM	112	112
183	Yemen	YEM	25	25
184	Zambia	ZMB	25	25
185	Zimbabwe	ZWE	25	25