CHAPTER 4
Processing Trade in Chinese Interregional Input-Output Tables: Construction and Application

4.1 Introduction

The deepening of international production fragmentation led to a boom in the trade of intermediate goods. As a consequence, imports and exports data did no longer reflect accurately what was going on in the world and were supplemented with the so-called “global value chain” (GVC) perspective (Los et al., 2015a; Johnson, 2014, 2018). To arrive at GVC results, however, global intercountry input-output (IO) tables are necessary. Their construction was at the heart of several large research projects (see Tukker and Dietzenbacher, 2013, for an overview). Given China’s role in global trade patterns, the country has been widely examined (Chen et al., 2012; Duan et al., 2012; Koopman et al., 2012; Los et al., 2012; Kee and Tang, 2016; Aichele and Heiland, 2018). The question, however, is whether a thorough analysis can be done at the country level. China is an enormous country with a huge population, and it faces serious regional inequalities in terms of physical and geographical conditions, infrastructure, globalization involvement, and economic growth. In particular, pronounced differences exist between the coastal provinces and the inland provinces. The coastal provinces participate more actively in the globalization process and grow much faster (Meng et al., 2017). This chapter therefore examines how the globalization effects propagate inside China and impact regional economies.

Existing studies find that China’s interior regions are increasingly involved in globalization by providing intermediates to the export production in coastal regions (see Feng et al., 2013; Meng et al., 2013, 2017; Pei et al., 2017). However, a defect

1 For example, Pei et al. (2017) demonstrate that interior regions usually occupy upstream activities (such as providing natural resources and raw materials) while coastal regions carry out downstream activities and export the final products. From an environmental perspective, previous studies have emphasized that developed countries have outsourced emissions to China through international trade (Weber et al., 2008). Feng et al. (2013) further document that large parts of these emissions are transferred from China’s coastal regions to interior regions through upstream value chain activities.
of the earlier studies is that they ignore a typical feature of China’s foreign trade, i.e. the prevalence of processing trade. Processing trade in China refers to the three-step business activity of (i) importing all (or part of) the raw and auxiliary materials, components and parts, accessories and packaging materials from enterprises abroad, after which (ii) these goods are processed and assembled, before (iii) the finished products are re-exported (Yang et al., 2015). Processing trade in China developed over time by leaps and bounds and shows an extremely uneven distribution over the domestic regions. According to China’s Customs statistics, processing exports comprised about half of the gross exports since the early 1990s (and this share declined to 34.1% in 2016) and they were concentrated in coastal regions. The left panel of Table 4.1 shows the shares of regional processing exports in the national totals. In 2012, for example, processing exports in East Coast and South Coast constituted 75.2% of China’s total processing exports. In contrast, the inland provinces were only responsible for less than 15% of China’s processing exports. Moreover, processing trade played very different roles in different regions. The right panel of Table 4.1 gives the share of a region’s processing exports in its total exports. It shows that processing exports in South Coast, the major exporter of China, accounted for 48.2% of its total exports in 2012. In the inland region Northwest, this proportion was only 7.8%. Over time, the shares of processing exports have decreased for all regions except the Central Regions and Southwest from 2002 to 2012.

China’s policy that imported materials for processing trade were exempted from taxes, led to the heavy reliance of processing exports on imported inputs (Yang et al., 2015). Consequently, processing exports generated only limited domestic activities, when compared to other production. At the national level, it has been shown in the literature that failing to separate production for processing exports from other production biases the results. For example, the contribution of China’s exports to

1 Ma and Van Assche (2016) analyze the possible factors that affect the location choice of China’s export processing plants.
2 Northeast includes Heilongjiang, Jilin, and Liaoning; Northern Municipalities includes Beijing and Tianjin; North Coast includes Hebei and Shandong; East Coast includes Shanghai, Jiangsu, and Zhejiang; South Coast includes Guangdong, Fujian, and Hainan; Central Regions includes Shanxi, Henan, Hubei, Hunan, Anhui, and Jiangxi; Northwest includes Inner Mongolia, Shaanxi, Ningxia, Gansu, and Xinjiang; Southwest includes Sichuan, Chongqing, Yunnan, Guizhou, Guangxi, Qinghai, and Tibet. See also Appendix 4.2 for a map.
3 Notice that Liaoning, Tianjin and Guangxi, which are coastal provinces, are respectively included in Northeast, Northern Municipalities and Southwest. Therefore, the share of processing exports in inland provinces is smaller than the sum of the shares in Northeast, Northern Municipalities, Central Regions, and Southwest.
economic growth is inflated (Pei et al., 2012), the damage of international trade to China’s environment is overestimated (Dietzenbacher et al., 2012; Su et al., 2013), and China’s vertical specialization is underestimated (Yang et al., 2015). We expect that also regional studies that use data which fail to separate processing exports will lead to misleading conclusions. However, in order to be able to check we need accurate interregional input-output (IO) tables that differentiate the production of processing exports from other production.

Table 4.1 Distribution of processing exports across regions, 2002 - 2012

<table>
<thead>
<tr>
<th>Region</th>
<th>Distribution of processing exports (%)</th>
<th>Share of processing exports (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>4.1</td>
<td>2.9</td>
</tr>
<tr>
<td>Northern Municipalities</td>
<td>6.2</td>
<td>5.6</td>
</tr>
<tr>
<td>North Coast</td>
<td>6.0</td>
<td>6.8</td>
</tr>
<tr>
<td>East Coast</td>
<td>24.5</td>
<td>34.4</td>
</tr>
<tr>
<td>South Coast</td>
<td>56.6</td>
<td>40.8</td>
</tr>
<tr>
<td>Central Regions</td>
<td>1.1</td>
<td>4.7</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Southwest</td>
<td>1.0</td>
<td>4.7</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Because exports in the coastal regions are mainly processing exports, which have limited backward linkages (in terms of economics or the environment) toward inland regions, biased results are expected (Fu, 2004). This raises a series of questions. What are the “true” intra-regional and interregional linkages in China, given the prevalence of processing exports? To what extent does one region’s involvement in globalization influence economic growth in other regions? Moreover, because of China’s increasing labor costs and the country’s policy with respect to processing trade, the share of processing exports in total exports has declined in recent years.\(^4\) Also, processing

\(^4\) For instance, Pei et al. (2012) analyzed the contribution of changes in exports to China’s value added change between 2002 and 2007. It was found to be 32% higher when the ordinary IO tables were used than when the tables capturing processing trade were used. Amiti and Freund (2010) found a significant skill upgrade in China’s total exports between 1992 and 2005, but they found no evidence of skill upgrading when processing exports were excluded from total exports. See also Dean et al. (2011), Johnson and Noguera (2012), Koopman et al. (2012), Upward et al. (2013), Dai et al. (2016).

\(^5\) In 2006, the Ministry of Commerce announced that processing trade was prohibited or restricted for seven categories of goods. These categories currently account for about 15% of all commodities in HS 10 digit codes. HKTDC (2007) deduced that changes in China’s processing trade policy have reduced the processing trade of
exports show a shift from coastal regions to inland destinations. To what extent will these changes affect intra-regional and interregional linkages as well as regional growth? Answering these questions has a large societal relevance. Answering these questions requires the appropriate interregional IO tables, which need to be constructed first.

So far, due to its extraordinary feature, processing trade has already aroused extensive attention at the national level. Using various methods, Chen et al. (2001), Koopman et al. (2012), Su et al. (2013), Ma et al. (2015) have separated production of processing exports from other production in Chinese national IO tables. Chen et al. (2019) and OECD-ICIO tables have distinguished China’s production of processing exports in international IO tables. However, to the best of our knowledge, no one has constructed interregional tables.

This chapter constructs an interregional IO table with separated processing exports (IRIOP table). We describe explicitly how information from a wide range of data sources has been harmonized, reconciled and used to arrive at this new IO table.

The rest of the chapter is structured as follows. Firstly, Section 4.2 illustrates the framework of the IRIOP table. Section 4.3 overviews the available raw data for the table construction and describes the construction methodology. Based on the new tables, Section 4.4 reexamines the domestic parts of global value chains in which China’s exports are involved, demonstrating the necessity of differentiating processing exports at the regional level. Finally, Section 4.5 concludes.

4.2 Framework of the IRIOP table

We start with a description on the IRIOP table. It is a product by product IO table for eight regions and 17 product categories. Its general structure is shown in Figure 3.1, which depicts a 2-region case to keep the exposition simple. The unique feature of this table is that the production of each region is divided into two types: the production of...
processing exports and ordinary production. Processing exports includes two types of export regimes: ‘Processing & Assembly’ (P&A) exports and ‘Processing with Imported Materials’ (PIM) exports. Ordinary production then incorporates all production for the domestic market and the production of ‘ordinary’ exports (i.e. any exports but processing exports).

Before introducing the entities in Table 4.2, we first clarify some notational principles regarding the use of indices. The subscript indices i, j, and k represent sectors, the subscript indices r, s, l, and w represent regions, and the superscript indices O, P, and M represent the different types of production. The data in the IROP table are expressed in monetary units and valued in current basic prices.

Table 4.2 Schematic outline of the IROP table (2-region case)

<table>
<thead>
<tr>
<th></th>
<th>Intermediate use</th>
<th>Final use</th>
<th>INV</th>
<th>EXP</th>
<th>TOT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Region r</td>
<td>Region s</td>
<td>Region r</td>
<td>Region s</td>
<td>DFC</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>O</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Z_{OP}</td>
<td>Z_{OS}</td>
<td>Z_{OP}</td>
<td>Z_{OS}</td>
<td>c_{r}</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>O</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Z_{OP}</td>
<td>Z_{OS}</td>
<td>Z_{OP}</td>
<td>Z_{OS}</td>
<td>c_{r}</td>
</tr>
<tr>
<td>IMP</td>
<td>Z_{r}^{MP}</td>
<td>Z_{r}^{MO}</td>
<td>Z_{s}^{MP}</td>
<td>Z_{s}^{MO}</td>
<td>c_{r}^{M}</td>
</tr>
</tbody>
</table>

Notes: P = production of processing exports; O = other (or ordinary) production; DFC = domestic final consumption; FCF = fixed capital formation; INV = inventory changes; EXP = exports; TOT = gross sector outputs or total imports; IMP = imports; VA = value added. The cells in the IROP table are divided into five parts to ease the presentation of the construction steps. The cells in grey represent step 1; the cells in yellow step 2; the cells in blue step 3; the cells in orange step 4; and the cells in green step 5.

7 P&A trade and PIM trade differ in terms of ownership and payment for the imported materials. Under P&A trade, materials and components are supplied by a foreign company and processed by a Chinese enterprise on a consignment basis. Ownership of raw materials and components remains with the foreign company. The Chinese enterprise (i) does not pay for the imported materials, and (ii) receives a processing fee. After processing and assembly, the finished products are owned by the foreign company which distributes them further. In contrast, under PIM trade, a Chinese enterprise purchases the raw materials and components. It therefore makes foreign currency payments and becomes the owner of the imported commodities. After processing and assembly, the Chinese enterprise exports the finished products to foreign customers.

8 Bold-faced lower-case letters are used to indicate vectors, bold-faced capital letters indicate matrices, italic lower-case letters indicate scalars (including elements of a vector or matrix). Vectors are columns by definition, row vectors are obtained by transposition, denoted by a prime (e.g. X'). Diagonal matrices are denoted by a circumflex (e.g. \( X \)).
The variables in the IRIOP table are as follows: the matrix $Z_{rs}^{OP}$ (with typical element $z_{rs}^{OP}$) gives the intermediate deliveries from ordinary production in region $r$ to processing exports production in region $s$; the matrix $Z_{s}^{MO}$ (with typical element $z_{sij}^{MO}$) gives the imports used as intermediate inputs for ordinary production in region $s$; the (row) vector $(v_{s}^{p})'$ (with typical element $v_{sij}^{p}$) gives the value added in each sector for the production of processing exports in region $s$; the vector $x_{s}^{O}$ (with typical element $x_{sij}^{O}$) gives the sectoral outputs of ordinary production in region $s$; the vectors $e_{rs}^{O}$ $(e_{rs}^{M})$ and $f_{rs}^{O}$ $(f_{rs}^{M})$ are respectively the sectoral deliveries of ordinary products from region $r$ for final consumption and fixed capital formation in region $s$; the vector $a_{r}^{O}$ $(a_{r}^{M})$ gives the sectoral inventory changes of ordinary products in region $r$; the vectors $c_{s}^{M}$ $(c_{s}^{M})$ and $d_{s}^{M}$ $(d_{s}^{M})$ respectively give the sectoral imports used as final consumption and fixed capital formation in region $s$; the vectors $e_{r}^{p}$ $(e_{r}^{p})$ and $e_{r}^{O}$ $(e_{r}^{O})$ are respectively sectoral processing exports and ordinary exports by region $r$; the vector $m$ gives the sectoral total imports by all regions. Note that re-exports are zero.

4.3 Construction of the IRIOP table

In the ideal case, data for all the variables in the IRIOP table are obtained through a series of comprehensive surveys. However, conducting such surveys is extremely time-consuming and expensive. Therefore we have developed a semi-survey method, using a combination of survey data, proportionality assumptions, and applying a RAS procedure. The following subsections describe the construction process and pay attention to issues like harmonization and reconciliation of data.

4.3.1 Overview of available information

The availability of consistent and reliable data is often regarded as a major barrier to construct a new IO table (Peters et al., 2011). For the IRIOP table, we have primarily used four data sources. These are: the national IO tables capturing processing trade (NIOP tables, also known as the national bipartite IO tables); the standard interregional
IO tables (IRIO tables); international trade statistics from China’s Customs; and the Regional Economic Accounts (REA).

The NIOP table separates the production of processing exports from ordinary production in the national IO table (see Table A4.1.1 in Appendix 4.1). Aggregating the IRIOP table over the regions yields the NIOP table. The NIOP tables that we have used are compiled jointly by the Chinese Academy of Sciences (CAS) and the National Bureau of Statistics (NBS). These tables are available for 2002, 2007, and 2012 and were constructed by using a combination of survey data and mathematical methods (see Chen et al., 2001; Chen et al., 2012). They include the same 42 sectors as the official national IO tables.

The IRIO tables are derived from the national IO tables and provide all inter- and intra-regional deliveries in a country. A 2-region version is outlined in Table A4.1.2 in Appendix 4.1. Aggregating the IRIOP table over the two types of productions (i.e., processing exports production and ordinary production) gives the IRIO table. The IRIO tables used in this chapter are compiled by the State Information Center (SIC) and the NBS (Zhang and Qi, 2012). The tables are available for 2002, 2007, and 2012, cover eight regions and 17 sectors (see Appendix 4.2 for the definition of the regions and Appendix 4.3 for the sector classification). Provinces are grouped into the same region not only because of geographical proximity, but also because they share a similar macroeconomic environment and show a similar development performance. This division of regions thus captures several spatial characteristics.

The third data that we have used are the international trade statistics from China’s Customs. For each province, they provide detailed data on exports and imports based on the origins and destinations of the deliveries of goods. The imports of a province

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9 There also exists another NIOP table. It is constructed for 2007 by Koopman et al. (2012) using a quadratic optimization procedure. However, we have used the tables from the CAS and the NBS because they are semi-official, publicly accessible and cover more years.

10 It needs to be mentioned that the original CAS and NBS NIOP tables are not ‘bipartite’, but ‘triptartite’. Other production was split into two parts: production of domestic enterprises to satisfy domestic demand, and a combination of the production of non-processing exports and the production of foreign invested enterprises to satisfy domestic demand. Due to data limitations, however, this split of other production cannot be made at the regional level.

11 Also other institutes (e.g. the Development Research Centre of the State Council of China) have constructed Chinese IRIO tables, using different compilation methods and different classifications of provinces into regions. We have used the SIC-NBS tables because they are semi-official and publicly accessible, and because they adhere to division of regions that is most common in China.

12 In China’s Customs statistics, two types of provincial trade data are available. One type is based on the source or destination of a delivery, the other type is according to the location of trading companies. Usually, the two types of
thus give the value of the foreign commodities that are consumed or used in this province. The exports of a province indicate the delivery abroad of commodities for which the production, or the final assembly, or the original dispatch occurred in this province (NBS, 2017). The data are not only by commodity (at 8-digit level under the Harmonized Commodity Description and Coding System, i.e. HS for short), but also by trade regime (e.g., P&A trade, PIM trade, and ordinary trade) and by firm type (e.g., foreign-invested enterprises and domestic enterprises). The HS 8-digit data are further aggregated using the NBS concordance table. This yields the trade data classified by IO sector. These data are essential for us to determine the output, exports, imports and intermediate deliveries in the IRIOP tables. We will come back to this in Section 3.3.

The last data source we have used are the REAs published annually by the NBS. They provide the value added for several broad industries (including agriculture, manufacturing, construction, trade and transport, and other service sectors) at the province level. Moreover, the provincial totals for final consumption, fixed capital formation, and inventory changes are also taken from the REAs.

### 4.3.2 Inconsistency issues and some underlying principles

#### 4.3.2.1 Inconsistencies

The use of different data sources implies conflicts between the sources. For example, ideally, aggregating the NIOP table over the two types of production and aggregating the IRIO table over the regions should give the national IO table. However, this is not the case and all variables (except value added) show clear discrepancies. This is not surprising because the NIOP and the IRIO tables are based on different data sources. The NIOP tables are based on the official national IO tables and the IRIO tables are

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13 The correspondence between this broad 5-category classification and the 17-sector classification in the interregional IO table is given in Appendix 4.3.
14 For example, the total exports in 2007 are 24.6% larger in the NIOP table than in the IRIO table.
largely based on the provincial IO tables. In the rest of this subsection, we will summarize the main inconsistency issues in the data sources.

First, P&A imports are treated differently in the NIOP tables from that in the IRIO tables for 2007 and 2012. Recall that P&A imports are materials that are owned by foreign companies and that are supplied to Chinese enterprises to produce P&A exports. This production involves processing and assembly activities for which the Chinese enterprises receive a processing fee. The national IO tables and the IRIO tables record just these processing fees and not the P&A imports and exports themselves. The NIOP tables, however, aim at reflecting the underlying technology of the processing sector. All imports (including P&A imports) used to produce processing exports are therefore recorded as intermediate inputs. As a result, imports, exports, and outputs are all larger in the NIOP tables than in the IRIO and the national IO tables. If we subtract the P&A imports from the corresponding items in the NIOP table, it is basically consistent with the official national IO table.\textsuperscript{15}

Second, the value of trade differs considerably at the regional level between the IRIO table and China’s Customs’ statistics. Part of the explanation is that P&A imports are included in both the imports and the exports in China Customs’ statistics, but not in the imports and exports in the IRIO tables. However, after deducting the P&A imports from Customs’ statistics, considerable gaps still remain between the two sources. In the NIOP tables, on the other hand, is merchandise trade basically consistent with China’s Customs statistics and with the official national IO tables (provided we correct for the different treatment of P&A imports).

Third, discrepancies exist also between IO tables and the REAs. For example, in 2007, Chinese GDP in the NIOP table is 3.5% less than the total value added (i.e. summed over the 31 provinces) in the REAs. This is not surprising given the huge gaps reported by Holz (2004). Also at the regional level are sources not consistent. For example, value added in South Coast is 5.7% less in the IRIO table than in the REAs.\textsuperscript{16}

\textsuperscript{15} This inconsistency issue does not exist for 2002. That year, P&A imports were included both in the national IO table and the IRIO table.

\textsuperscript{16} According to Zhang and Qi (2012), the value added in the IRIO table is obtained by adjusting the value added in provincial IO tables to the official national IO tables.
4.3.2.2 Underlying principles and choices

The inconsistencies discussed above imply that choices and adjustments need to be made before the actual construction of the IRIOP table takes place. In this subsection, we will describe the choices we have made and what the underlying principles were.

First, reliable and accurate trade statistics have the highest priority in connection to the separation of processing exports production from ordinary production, which is the distinguishing feature of the IRIOP table. This implies that the NIOP table (rather than the IRIO table) has become our preferred data source. The NIOP tables are basically consistent with China’s Customs’ statistics (while the IRIO tables are not) and trade statistics from China’s Customs are believed to be the most authoritative and reliable. This is because China’s Customs is the only official institute to monitor international trade and is responsible for the trade statistics following strict regulations.

To construct the IRIOP table, we use the NIOP table as a benchmark and then distribute the two types of production over the different regions.\(^{17}\) This means that if we aggregate the IRIOP table over the regions we will get the NIOP table. The distribution is obtained from the IRIO tables, which reflect the input linkages between the regions. Another advantage of our approach to take the NIOP table as the benchmark is that all imported materials for processing exports (including P&A imports) are recorded as intermediate inputs in the IRIOP tables. The tables thus provide a full picture of the input structure of processing exports production.

Second, we give the REAs the next highest priority because they are officially published and more authoritative than other data sources. This means that, for example, data on regional value added, final consumption, and fixed capital formation are taken from the REAs, not from the IRIO tables (which also include these variables). Note that the data from the REAs should first be rescaled, however, to match with the NIOP table (which we have taken as a benchmark).

Third, in order to nest the IRIO tables into the NIOP tables, the sector classification should match. The NIOP tables have 42 sectors and the IRIO tables have

\(^{17}\) An alternative way would have been to take the IRIO table as a benchmark and then split each region’s production into processing exports production and other production.
17 sectors. One way would be to disaggregate certain IRIO sectors, because more sector detail generates more accurate results (as argued by Su et al., 2010). However, making this split of sectors will require costly efforts to obtain additional data and, meanwhile, may lead to more biased results if these additional data are insufficiently accurate. Therefore we have chosen the other option, which is to aggregate the NIOP tables in line with the IRIO sector classification. See Appendices 4.2 and 4.3 for the details on regions and sectors.

4.3.3 The construction methodology

To construct the IRIOP tables, the variables in Table 4.2 need to be estimated. The estimation in Step 1 includes exports, domestic inventory changes, and outputs, Step 2 covers the imported final consumption and fixed capital formation, Step 3 deals with the value added, Step 4 estimates the intermediate use of imports (i.e. the import matrices), and Step 5 yields the intermediate input use, the final consumption, and the fixed capital formation, all for domestically produced goods and services. The estimation in Steps 3, 4, and 5 is somewhat convoluted. However, the basic idea of the estimation is that initial estimates for each variable are obtained first, after which the RAS method is performed to make the table balanced and consistent with the official statistics.\(^{18}\) In the rest of this subsection we will sketch the main construction steps, leaving the details for Appendix 4.4.

4.3.3.1 Step 1: exports, inventory changes, and outputs

This step estimates the exports (vectors \(e_r^p\) and \(e_r^D\) in the case of country \(r\)), inventory changes (\(q_r^p\)), and outputs (\(x_r^p\) and \(x_r^D\)) in IRIOP tables.

\[\text{Exports.}\] For manufacturing sectors, region-sector data for processing exports and for ordinary exports are obtained by aggregating data from China’s Customs’ statistics.

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\(^{18}\) The RAS method is commonly used to bi-proportionally scale a matrix of unbalanced preliminary estimates of an unknown real matrix to prescribed row and column sums (Stone and Brown, 1962; Bacharach, 1970; Lenzen et al., 2009; Miller and Blair, 2009).
These region-sector data are then scaled to match the export data in the NIOP tables. Processing exports of services mainly refers to the commercial margins or to other services related to the processing exports of manufacturing goods. The processing exports of services at the regional level are estimated by distributing the processing exports of services in the NIOP table over the regions, using the regional distribution of the processing exports in manufacturing. Ordinary exports of services at the regional level are obtained by distributing the ordinary exports of services from the NIOP tables over the regions by the regional distribution of sector-specific services exports in the IRIO tables.

*Domestic inventory changes.* It should be noted that a region’s inventory changes are the inventory changes in the whole of China regarding products delivered by that particular region. A two-step procedure is adopted to estimate the elements $q_{ri}^o$ of the vector $q_r^o$. First, the regional totals of the inventory changes for region $r$ are taken from the REAs and distributed over the sectors using shares based on the sector-specific inventory changes for region $r$ from the IRIO table (i.e. $\tilde{q}_r^o$, where a tilde indicates that the variable is from an IRIO table). This yields the initial estimate of $q_{ri}^o$. Next, these initial estimates are rescaled such that the aggregation over the regions equals the inventory changes in the NIOP table (i.e. $\bar{q}^o$, where an overbar indicates that the variable is from a NIOP table).

*Outputs.* By definition, the output of processing exports production is just the exports themselves (i.e. $x_r^o = e_r^o$). To estimate the regional output of ordinary production ($x_r^o$), we first estimate the domestic sales of regional ordinary production ($d_r^o = x_r^o - q_r^o - e_r^o$). At the national level, the domestic sales are obtained from subtracting the ordinary exports and inventory changes from the output of ordinary production in the NIOP tables, i.e. $\tilde{d}^o = \tilde{x}^o - \tilde{q}^o - \tilde{e}^o$. Next these domestic sales are distributed over the regions of origin, using the regional distribution of domestic sales in the IRIO table, i.e. $\bar{d}_r = \bar{x}_r - \bar{q}_r - \bar{e}_r$. This then yields the estimate for $d_r^o$, after which the regional outputs in the IRIO table are given by $x_r^o = d_r^o + q_r^o + e_r^o$. 

4.3.3.2 Step 2: imported final demands

This step estimates the vectors of imported final consumption \( (c^M_r) \), imported fixed capital formation \( (f^M_r) \), and imported inventory changes \( (q^M) \). We distinguish between imports that are only used for producing processing exports (which we call processing imports) and imports for other purposes (which we call non-processing imports). We also distinguish between merchandise goods (sectors 1-15) and services (sectors 16 and 17). By definition, only the non-processing imports can be used as final demand. Therefore, for merchandise goods, the revised BEC (‘broad economic categories’) method proposed by Dietzenbacher et al. (2013) is adopted to allocate the region-commodity-specific non-processing imports from China’s Customs statistics to three use categories: ‘final consumption’, ‘fixed capital formation’, and ‘intermediates’.\(^{19}\)

We then aggregate the data into the 17 IO sectors and scale them to match with the imported final demands from the NIOP table. We thus obtain the regional imports used for consumption \( (c^M_{rt}) \) and for fixed capital formation \( (f^M_{rt}) \). In addition, we also obtain the total imports that are used as intermediate inputs in ordinary production \( (\Sigma_j z^{MO}_{rrij}) \) in the IRIOP table.

Processing imports are, by definition, exclusively used as intermediate input in the production of processing exports. We aggregate the region-commodity-specific processing imports from China’s customs statistics into the 17 IO sectors and scale them to match the processing imports from the NIOP table. For merchandise goods, this yields the region-commodity-specific processing imports in the IRIOP table (i.e. the totals \( \Sigma_j z^{MP}_{rrij} \)). For services, we distribute the sector-level total imports data from the NIOP table over the regions using the allocation of merchandise imports. The imported inventory changes \( (q^M_t) \) are directly obtained from the NIOP table.

\(^{19}\) A major advantage of this revised BEC method is that it allows a good to go into more than one category.
4.3.3.3 Step 3: value added

The values added for sector \( j \) in region \( s \) are obtained by using the RAS approach. The initial estimates follow from the value added ratios from the NIOP tables (i.e. \( \bar{v}_j^P \) and \( \bar{v}_j^O \)). These are combined with region-sector outputs from step 1 (i.e. \( x_{sj}^P \) and \( x_{sj}^O \)). The column constraints follow directly from the NIOP table, i.e. \( \sum_s v_{sj}^P = \bar{v}_j^P \) and \( \sum_s v_{sj}^O = \bar{v}_j^O \). For the row constraints, we have used the REAs. They provide the value added at the regional level (not distinguishing between \( P \) and \( O \)), but only for five broad sectors. One of these broad sectors is manufacturing, which covers the input-output sectors 2 – 14. Its total value added is \( \bar{v}_{s,\text{manufacturing}} \), which is split into values added at IO sector level. For this, we use the region-sector-specific value added from the IRIO table (\( \bar{v}_{sj} \)). We thus arrive at the values added \( \bar{v}_{sj} \) for all 17 IO sectors. This would give us the national value added for industry \( j \) as \( \bar{v}_j^P + \bar{v}_j^O \) (using the NIOP table), but also as \( \sum_s \bar{v}_{sj} \) (using REA data). Given the inconsistency between the REAs and the NIOP tables, and given our preference for NIOP data, we split \( \bar{v}_j^P + \bar{v}_j^O \) over the regions using \( \bar{v}_{sj} \). This gives the row constraints \( v_{sj}^P + v_{sj}^O = (\bar{v}_j^P + \bar{v}_j^O)(\bar{v}_{sj}/ \sum_r \bar{v}_{rj}) \). Finally, the RAS procedure is applied, using the initial estimates and the set of given row and column sums. Subsequently, also the value added components (i.e. compensation of labor, fixed asset depreciation, net production tax, and operating surplus) are estimated for all industries, for all regions, and for both types of production (production of processing exports and ordinary production).

4.3.3.4 Step 4: estimating the import matrices

We use the RAS approach again and initial values for import matrices are assigned by using information from the NIOP tables. We assume that for the same production type (e.g., processing exports \( P \)), the input structure of imported intermediates is the same in all regions and is identical to the national structure. The import levels, however, vary across regions. The initial import matrices in the IRIOP table are given by \( z_{sij}^{M_O} = \).
Chapter 4

\[ z_{ij}^{MP} \left[ (x_{sj}^P - v_{sj}^P) / (x_{ij}^P - v_{ij}^P) \right], \] where \( x_{sj}^P \) and \( v_{sj}^P \) are from the IRIOP table and have been estimated at an earlier stage and \( z_{ij}^{MP} \) is from the NIOP table.

Further there are three constraints that should be satisfied by \( z_{sij}^{MP} \) and \( z_{sij}^{MO} \). First, aggregating \( z_{sij}^{MP} \) and \( z_{sij}^{MO} \) over the regions should yield the corresponding import matrix in the NIOP table. That is, \( \sum_s z_{sij}^{MP} = z_{ij}^{MP} \) in case of production of processing exports. Second, aggregating \( z_{sij}^{MP} \) and \( z_{sij}^{MO} \) over the destination sectors (e.g. \( \sum_j z_{sij}^{MP} \)) yields the total imports of product \( i \) by region \( s \) for intermediate use. These totals were obtained in step 2 above. Third, for each region-sector the sum of imported inputs cannot be larger than the total amount of inputs that is required. In other words, the domestic intermediate inputs cannot be negative. The RAS procedure then results in estimates for \( z_{sij}^{MP} \) and \( z_{sij}^{MO} \).

4.3.3.5 Step 5: estimating the domestic intermediate deliveries and final demands

In the last step, we estimate the matrices with domestic intermediate deliveries (\( Z_{rs}^{DO} \) with elements \( z_{rsij}^{DO} \) and \( Z_{rs}^{OP} \) with elements \( z_{rsij}^{OP} \)) and the domestic final demand vectors (\( c_{rs}^{O} \) with elements \( c_{rsi}^{O} \) and \( f_{rs}^{O} \) with elements \( f_{rsi}^{O} \)). To this end, we adopt a hierarchical estimation method. It includes three parts, each of which uses the RAS procedure.

In part 5.1, we estimate the total intermediates and the total final demands of each product \( i \), provided by each origin region \( r \). The total is taken by summing over the destination regions. The estimation is done by splitting the total region-sector-specific domestic sales that we obtained in Step 1 (i.e. \( d_{rli}^{O} \)) into the three use categories: total intermediate use (\( y_{rli}^{O} \)), total final consumption (\( c_{rli}^{O} \)), and total fixed capital formation (\( ft_{rli}^{O} \)). To start the RAS procedure, initial values are assigned by splitting the sector-level national intermediate use (or national final consumption, or national fixed capital formation) from the NIOP tables among origin regions using information from the IRIO tables. Meanwhile, \( y_{rli}^{O} \), \( c_{rli}^{O} \), \( ft_{rli}^{O} \) are subject to two constraints. First, aggregating \( y_{rli}^{O} \), \( c_{rli}^{O} \), and \( ft_{rli}^{O} \) across origin regions should exactly yield the
corresponding elements at national level in the NIOP table. Second, the sum of \( y_{ri}^O \), \( ct_{ri}^{O} \), and \( ft_{ri}^{O} \) must equal \( d_{ri}^{O} \) for any \( r \) and \( i \).

In part 5.2, we estimate the domestic final demands \((c_{rsi}^{O}, f_{rsi}^{O})\) by using RAS again. The initial values for \( c_{rsi}^{O} \) and \( f_{rsi}^{O} \) are obtained from the IRIO tables. Meanwhile, the \( c_{rsi}^{O} \) and \( f_{rsi}^{O} \) are subject to two constraints. First, aggregating \( c_{rsi}^{O} \) and \( f_{rsi}^{O} \) over the destination regions \( s \) gives the totals that were estimated previously in part 5.1 (i.e. \( ct_{ri}^{O} \) and \( ft_{ri}^{O} \)). Second, aggregating \( c_{rsi}^{O} \) (\( f_{rsi}^{O} \)) over the origin regions and adding the imported final consumption \( c_{st}^{M} \) (imported fixed capital formation \( f_{st}^{M} \)) must yield the total consumption (fixed capital formation) consumed by each region, which is obtained by adapting NIOP data with information from the REAs.

In part 5.3, we estimate the domestic intermediate deliveries \((z_{rsij}^{OP} \text{ and } z_{rsij}^{OO})\). To this end, we first allocate the intermediate deliveries from the NIOP table over the destination regions (that is, we first estimate \( z_{sij}^{OP} = \sum_r z_{rsij}^{OP} \) and \( z_{sij}^{OO} = \sum_r z_{rsij}^{OO} \)). Then, we further allocate these estimates over the origin regions.

From previous steps, the IRIO tables contain estimates for the total intermediate inputs used by each region \( s \) and sector \( j \). That is, \( x_{sj}^{P} = \sum_i z_{sij}^{MP} - v_{sj}^{P} \) and \( x_{sj}^{O} = \sum_i z_{sij}^{MO} - v_{sj}^{O} \). These are further split over sectors of origin using the input structure in the IRIO tables. This yields the initial values for \( z_{sij}^{OP} \) and \( z_{sij}^{OO} \). Further, \( z_{sij}^{OP} \) and \( z_{sij}^{OO} \) are subject to two constraints. First, aggregating \( z_{sij}^{OP} \) (\( z_{sij}^{OO} \)) over regions should give the national intermediates deliveries in the NIOP tables. Second, aggregating \( z_{sij}^{OP} \) (\( z_{sij}^{OO} \)) over the origin sectors should equal to \( x_{sj}^{P} = \sum_i z_{sij}^{MP} - v_{sj}^{P} \) (or \( x_{sj}^{O} = \sum_i z_{sij}^{MO} - v_{sj}^{O} \)). Based on the initial values and constraints, the solution for \( z_{sij}^{OP} \) and \( z_{sij}^{OO} \) is obtained from the RAS procedure.

Then we estimate \( z_{rsij}^{OP} \) and \( z_{rsij}^{OO} \) by allocating \( z_{sij}^{OP} \) and \( z_{sij}^{OO} \) over the origin regions. For the initial values we use the IRIO tables for this allocation. Meanwhile, \( z_{rsij}^{OP} \) and \( z_{rsij}^{OO} \) are subject to two constraints. First, aggregating \( z_{rsij}^{OP} \) and \( z_{rsij}^{OO} \) over destination regions \( s \) and destination sectors \( j \) should yield the total intermediates supplied by each region-sector \( y_{ri}^{O} \) (obtained in part 5.1). Second, aggregating \( z_{rsij}^{OP} \) (\( z_{rsij}^{OO} \)) over origin regions should yield the sector-level intermediates consumed.
by each region-sector \(zt_{sij}^{OP} (zt_{sij}^{00})\). Finally, the RAS procedure results in the estimate of the domestic intermediate deliveries matrix.

The outcome of conducting all the procedures in this section are the IRIOP tables for 2002, 2007, and 2012. They include 17 sectors, cover 8 regions and distinguish in each region between production of processing exports and ordinary production. The constraints we imposed during the construction ensure that the IRIOP tables are balanced, are perfectly in line with the NIOP tables, and are maximally consistent with the information in the official statistics and the IRIO tables.

### 4.4 Separating processing exports from ordinary production matters

When analyzing phenomena such as the exports of domestic value added, disregarding processing trade leads to serious estimation biases. At the national level, this has been well documented in the literature (Chen et al., 2012; Dietzenbacher et al., 2012; Koopman et al., 2012; Pei et al., 2012). In this section we study whether—and to what extent—this is also the case at the regional level. To this end, we compare the results based on the IRIOP tables with the results based on IRIO tables (which do not separate production of processing exports from ordinary production). For our calculations, we aggregate the IRIOP tables by taking the production of processing exports and ordinary production together (for each region and each sector). The format of this aggregated IRIOP table is exactly the same as the format of the published IRIO tables (see Table A4.1.2 in Appendix 4.1).\(^{20}\) Then we compare the results obtained with the IRIOP tables with the results obtained with the aggregated IRIOP tables.

Given China’s high involvement in globalization and given the serious regional inequality, the question how globalization has affected regions within China has attracted ample attention. A general conclusion is that China’s interior regions are also

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\(^{20}\) An alternative is to compare the results based on the IRIOP tables with the results based on the IRIO tables that have been published by the State Information Center (SIC). The SIC tables were the IRIO tables that have been used in the construction of the IRIOP tables. However, because our IRIOP tables are consistent with the NIOP tables and because the NIOP tables and the SIC IRIO tables are not consistent with each other (as mentioned in Section 4.3.2), inconsistencies also exist between the aggregated IRIOP tables and the published SIC IRIO tables. Appendix 4.5 lists the average differences. These differences are actually a mix of differences caused by disregarding processing trade and differences due to inconsistencies.
deeply involved in the globalization by providing intermediates to the export production in coastal regions (Meng et al., 2017; Pei, et al., 2017). However, the existing studies ignore the prevalence of processing trade. We argue that they overestimate the role of trade \((i)\) for economic growth in the coastal regions and \((ii)\) for regional inequality. Neglecting processing trade yields these overestimation, because the production of processing exports is mainly concentrated in coastal regions and because this production relies heavily on imported materials. To check this hypothesis, we investigate the role of processing trade when measuring the contribution of exports to China’s regional economic growth.

4.4.1 Methodology

We start with a description of the methodology in the case of the aggregated IRIOP tables and for simplicity (but without loss of generality) we assume that China consists of two regions \((r \text{ and } s)\) only. Let \(Z_{rs}\) indicate the flows of intermediate deliveries from region \(r\) to region \(s\), \(x_s\) the vector of sectoral outputs in region \(s\), \(v_s\) the vector of sectoral values added in region \(s\), and \(e_s\) the vector of sectoral exports by region \(s\). The matrix \(A_{rs} = Z_{rs}(\hat{x}_s)^{-1}\) gives the amounts of intermediate inputs provided by \(r\) that are directly used per unit of production in \(s\), with \(\hat{x}_s\) the diagonal matrix of \(x_s\). At the national level, we have

\[
A = \begin{pmatrix} A_{rr} & A_{rs} \\ A_{sr} & A_{ss} \end{pmatrix} \quad \text{and} \quad L = (I - A)^{-1} = \begin{pmatrix} L_{rr} & L_{rs} \\ L_{sr} & L_{ss} \end{pmatrix}
\]

The elements of the matrix \(L_{rs}\), for example, give the amounts of production that are necessary in region \(r\) to satisfy one unit of final demand (e.g. domestic final consumption, domestic fixed capital formation, exports) for products from region \(s\). Define \(\mu'_s = v'_s(\hat{x}_s)^{-1}\) as the row vector with value added coefficients in region \(s\). Using input-output techniques (see Miller and Blair, 2009), the total value added of region \(r\) that is embodied in the exports of region \(s\) is calculated as:
\[ t_{rs}^{\text{IRIOP}} = \mu_s' L_{rs} e_s \]  

(4.1)

where the superscript IRIOPA is used to indicate that this is for the aggregated IRIOP tables with the production of processing exports and ordinary production aggregated together for each region.

The methodology is very much the same in case of the full IRIOP tables. The key difference is that the size of the matrices and vectors is doubled, because we now have two types of production. The relevant matrices and vectors are

\[ Z = \begin{pmatrix} 
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 
\end{pmatrix}, \quad x_r = \begin{pmatrix} x_r^P \\
0 \\
0 \\
0 
\end{pmatrix}, \quad e_s = \begin{pmatrix} e_s^P \\
e_s^O \end{pmatrix}, \quad v_r = \begin{pmatrix} v_r^P \\
v_r^O \end{pmatrix} \]

The coefficients then become

\[ A = \begin{pmatrix} 
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 
\end{pmatrix}, \quad L = (I - A)^{-1} \begin{pmatrix} 1 & 0 & 0 & 0 \\
0 & L_{rr}^P & L_{rt}^P & L_{rs}^P \\
0 & L_{sr}^P & L_{ss}^P & L_{ss}^P \\
0 & 0 & 1 & 0 
\end{pmatrix}, \quad \mu_s = \begin{pmatrix} \mu_s^P \\
\mu_s^O \end{pmatrix} = \begin{pmatrix} (\hat{x}_s^P)^{-1} v_s^P \\
(\hat{x}_s^O)^{-1} v_s^O \end{pmatrix} \]

The total value added of region \( r \) that is embodied in the exports of region \( s \) is now calculated as:

\[ t_{rs}^{\text{IRIOP}} = ((\mu_r^P)' \quad (\mu_r^O)')( \begin{pmatrix} 0 & 0 & 0 & 0 \\
L_{rs}^P & L_{rs}^O 
\end{pmatrix} \begin{pmatrix} e_s^P \\
e_s^O \end{pmatrix}) = (\mu_r^P)' L_{rs}^P e_s^P + (\mu_r^O)' L_{rs}^O e_s^O \]  

(4.2)

where the first item on the right-hand side gives the value added of region \( r \) embodied in region \( s \)’s processing exports and the second term gives the embodiment in region \( s \)’s ordinary exports. Note that if \( r = s \), we have \( t_{rr}^{\text{IRIOP}} = (\mu_r^P)' e_r^P + (\mu_r^O)' L_{rr}^O e_r^O \).
4.4.2 Empirical results

Value added in region $r$ induced by exports of region $s$ is measured with Equations 4.1 and 4.2. We summarize our results by looking at the aggregate level, which yields two perspectives. On the one hand, the national value added generated by the exports of region $s$ ($\sum_r t_{rs}^{1RIOP}$ with the IRIOP tables and $\sum_r t_{rs}^{1RIOPA}$ with the aggregated IRIOP tables). This reflects the domestic part of the value chains to which the export production in region $s$ contributes. On the other hand, the value added generated in region $r$ by national exports ($\sum_s t_{rs}^{1RIOP}$ and $\sum_s t_{rs}^{1RIOPA}$). This reflects region $r$ benefits from China’s participation in globalization.

4.4.2.1 Value chain activities by regions in the production of exports

We calculate the national value added generated by “an average 1000 rmb” of exports in region $s$. That is, the exports—$e_s$ in (4.1) and $e^p_s + e^o_s$ in (4.2)—are rescaled such that the elements sum to 1000 rmb and their shares remain the same. The results are given in Table 4.3. For example, we calculate that 1000 rmb of (extra) exports in Northeast in 2002 would have led to 710 rmb of (extra) value added at the national level (i.e. GDP). This is the answer—given in the top panel of Table 4.3—if the calculation is based on the IRIOP table. That is, if we distinguish between the production of processing exports and ordinary production. These tables were not available and have been developed for this chapter. To mimic the standard calculation, we have used the aggregated version of the IRIOP table. In that case, we find that 1000 rmb of (extra) exports would have generated 857 rmb of (extra) GDP. This is the answer given in the middle panel of Table 4.3. Neglecting processing trade thus implies that the GDP in 1000 rmb of exports by Northeast is overestimated by $(857 - 710 =) 147$ rmb, which is 20.8%. This is the bias given in the bottom panel of Table 4.3. Several observations follow from Table 4.3.

First, as expected, calculations with ordinary IRIO tables (which neglect the special role of processing trade) overestimate the contribution of regional exports to
GDP. To show the effect of separating processing exports from ordinary production, the calculations with ordinary IRIO tables are mimicked by using the aggregated IRIOP tables. The largest bias is found for South Coast in 2002 (32.2%).

Table 4.3 National value added embodied in 1000 rmb of regional exports: a comparison between using the IRIOP table and the aggregated IRIOP table

<table>
<thead>
<tr>
<th></th>
<th>NE</th>
<th>NM</th>
<th>NC</th>
<th>EC</th>
<th>SC</th>
<th>CR</th>
<th>NW</th>
<th>SW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Original IRIOP table (rmb)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2002</td>
<td>710</td>
<td>627</td>
<td>691</td>
<td>654</td>
<td>466</td>
<td>874</td>
<td>872</td>
<td>865</td>
</tr>
<tr>
<td>2007</td>
<td>708</td>
<td>675</td>
<td>718</td>
<td>575</td>
<td>497</td>
<td>814</td>
<td>887</td>
<td>803</td>
</tr>
<tr>
<td>2012</td>
<td>717</td>
<td>592</td>
<td>741</td>
<td>677</td>
<td>580</td>
<td>751</td>
<td>861</td>
<td>747</td>
</tr>
<tr>
<td><strong>Aggregated IRIOP table (rmb)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>857</td>
<td>711</td>
<td>866</td>
<td>759</td>
<td>615</td>
<td>924</td>
<td>901</td>
<td>923</td>
</tr>
<tr>
<td>2007</td>
<td>804</td>
<td>697</td>
<td>820</td>
<td>631</td>
<td>597</td>
<td>879</td>
<td>884</td>
<td>870</td>
</tr>
<tr>
<td>2012</td>
<td>758</td>
<td>596</td>
<td>828</td>
<td>733</td>
<td>672</td>
<td>875</td>
<td>880</td>
<td>858</td>
</tr>
<tr>
<td><strong>Bias (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>20.8</td>
<td>13.3</td>
<td>25.3</td>
<td>16.0</td>
<td>32.2</td>
<td>5.7</td>
<td>3.4</td>
<td>6.7</td>
</tr>
<tr>
<td>2007</td>
<td>13.6</td>
<td>3.3</td>
<td>14.2</td>
<td>9.7</td>
<td>20.3</td>
<td>8.0</td>
<td>-0.3</td>
<td>8.3</td>
</tr>
<tr>
<td>2012</td>
<td>5.7</td>
<td>0.8</td>
<td>11.7</td>
<td>8.3</td>
<td>15.8</td>
<td>16.4</td>
<td>2.3</td>
<td>14.9</td>
</tr>
</tbody>
</table>

Notes: Bias = 100×(IRIOPA – IRIOP)/IRIOP, where IRIOP is the result with the IRIOP table and IRIOPA is the result with the aggregated IRIOP table.

This widespread overestimation is not surprising. The value added (VA) coefficients for the production of processing exports are much smaller than for ordinary production. The IRIOPA results are obtained by using average VA coefficients. Because the amount of ordinary production is much larger than the amount of production of processing exports, these average VA coefficients are similar to (but a bit smaller than) the VA coefficient for ordinary production before aggregation. When calculating the GDP in processing exports, the (small) VA coefficients for the production of processing exports are now replaced by much larger average VA.21 This also implies that the overestimation is expected to be larger if the share of processing exports in regional exports is larger.

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21 Note that Northwest is the exception to the widespread overestimation. It shows a small underestimation in 2007. It appears that exports of Northwest include much non-processing exports. The VA coefficients for other production (which includes non-processing exports) are for the IRIOPA results replaced by the somewhat smaller average VA coefficients. Underestimation is then the probable consequence.
Second, the degree of the bias differs across regions and it seems closely related to the share of processing exports in each region’s exports. To check this, Figure 4.1 plots the bias for each region versus the corresponding shares of processing exports in the three years. It is observed that a higher share of processing exports is usually accompanied with a more serious bias. Two typical cases are South Coast and North West. The former usually has a high share of processing exports (65.9% in 2002) and ignoring the role of processing trade therefore leads to a large overestimation (32.2% in 2002) of the GDP content of its exports. In contrast, Northwest has small shares of processing exports (13.9% in 2002) and shows only a small bias of 3.4% in 2002. This clearly indicates the necessity to distinguish processing trade at the regional level. Moreover, the more a region depends on processing trade the larger is this necessity.

**Figure 4.1 The bias versus the share of processing exports**

![Graph showing bias versus share of processing exports]

*Notes: The labels indicate the region and year, e.g. “SC02” indicates the values of South Coast in 2002. The dashed line gives the regression line, Bias = (IRIOPA – IRIOP)/IRIOP, with t-values =5.27 and R² = 0.56.*

Third, the bias generated by using the aggregated IRIOP tables generally decreased over time for coastal regions (NC, EC, SC) and increased for central and
western regions (CR, NW, SW). These changes are closely related to the changes in the shares of processing exports. These shares declined for most of the coastal regions but increased for central and western regions. Given the fact that the share of China’s processing exports continuously declined since 2004, it is expected that the bias generated by using ordinary IRIOP tables will also decline. A consequence is that for countries with only little processing trade, using ordinary (regional) input-output tables—i.e. tables that do not separate ordinary production from the production of processing exports—is expected to lead to correct empirical results.

4.4.2.2 The regional benefits of globalization

In this section, we calculate how much value added is created in each region due to the entire national exports. This is also termed regional value added exports. The results are shown in Table 4.4. For example, we find that the national exports generated 117 billion rmb of value added in Northeast in 2002 (see top panel). This is the outcome obtained with the IRIOP table. If the aggregated IRIOP table is used though (to mimic the use of ordinary IRIIO tables), we find 142 billion rmb (see middle panel). This is an overestimation of 21.3% (see bottom panel).

<table>
<thead>
<tr>
<th>Table 4.4. Regional value added generated by national exports: a comparison between using the IRIOP table and the aggregated IRIOP table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>Original IRIOP table (billion rmb)</td>
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<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td>Aggregated IRIOP table (billion rmb)</td>
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<td></td>
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<tr>
<td>Bias (%)</td>
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</tbody>
</table>

Notes: Bias = 100(IRIOPA – IRIOP)/IRIOP, where IRIOP is the result with the IRIOP table and IRIOPA the result with the aggregated IRIOP table.
It follows from Table 4.4 that the income that each region generates from exports (reflecting the benefits of globalization) is seriously overestimated when ordinary IRIO tables are used. The overestimation for inland regions is slightly higher than it is for coastal regions. The consequence is that the effect of exports on regional inequality is likely to be underestimated when ordinary IRIO tables are used. IRIO tables report that exports generate more value added in coastal regions than in inland regions but IRIO tables overstate the true (i.e. IRIO) answer. The bias is larger for inland regions than for coastal regions. This implies that the true gap between the effects for coastal and inland regions is larger than the gap reported when using IRIO tables. Over time, the overestimations have become smaller because the share of processing exports decreased.

We further decompose the value added exports of each region into two parts: value added induced by the region’s own exports (i.e. the self-effect) and value added induced by the exports from all the other regions (i.e. the spillover effect). Table 4.5 presents the results. For example, using the IRIO table for 2002 we found in Table 4.4 that China’s exports generated 117 billion rmb of value added in the Northeast. 95 billion rmb was due to the exports of NE itself. The remaining 22 billion rmb was the spillover effect (see the top panel of Table 4.5), which indicates NE’s value added due to the exports by other regions. Using the aggregated IRIO table we found a spillover effect of 28 billion rmb (see the middle panel of Table 4.5). The overestimation in Table 4.4 for NE’s value added due to all exports is 25 billion rmb. The overestimation in Table 4.5 for NE’s value added due to other regions’ exports is 5 billion rmb, which is 21.6% (see the bottom panel) of the total overestimation.

The contributions to the bias as reported in Table 4.5 shows large differences between the coastal and the inland regions. For the coastal regions, the bias in their value added exports is largely caused by the self-effect (i.e. the bias in their value added due to their own exports). This holds in particular for South Coast and East Coast, to a lesser extent for North Coast. For South Coast, for example, 98.7% of the overestimation generated by using the aggregated IRIO table in 2012, is sourced from the overestimation of the value added generated by its own exports. The coastal regions have much exports and a high share of processing exports. This leads to a large bias in
the region’s value added due to their own exports. In contrast, for inland regions, the bias originates primarily from the spillover effect. For Northwest, for example, 93.6% of the overestimation is sourced from the overestimation of its value added generated by exports of other regions. In inland regions like Northwest a large part of the value added generated by exports, is generated by exports in other regions.\(^{22}\) It turns out that also a large part of the overestimation of the value added generated by exports is due to the overestimation of the value added generated by exports in other regions. The results suggest that the effect of globalization in coastal regions for the value added in inland regions is significantly overestimated by ordinary IRIO tables. This finding is consistent with the conclusion of Brun et al. (2002), who demonstrate that the linkage between Chinese regions via exports is only limited. To some extent, this also explains the failure of China’s “ladder-step strategy” to boost the economies in western areas with spillovers from the opening up of the coastal regions.\(^{23}\)

| Table 4.5 Regional value added from spillover effects of other regions’ exports: a comparison between using the IRIOP table and the aggregated IRIOP table. |
|---|---|---|---|---|---|---|---|---|
| Original IRIOP table (billion rmb) | NE | NM | NC | EC | SC | CR | NW | SW |
| 2002 | 22 | 21 | 61 | 46 | 25 | 65 | 21 | 19 |
| 2007 | 135 | 59 | 260 | 163 | 115 | 412 | 169 | 132 |
| 2012 | 151 | 135 | 261 | 176 | 122 | 578 | 310 | 195 |
| Aggregated IRIOP table (billion rmb) | 2002 | 28 | 26 | 72 | 59 | 26 | 84 | 27 | 43 |
| 2007 | 156 | 70 | 292 | 181 | 115 | 488 | 202 | 193 |
| 2012 | 175 | 156 | 297 | 208 | 125 | 676 | 366 | 237 |
| Contribution to the bias (%) | 2002 | 21.6 | 23.5 | 24.9 | 13.6 | 0.6 | 78.8 | 77.9 | 86.1 |
| 2007 | 39.7 | 42.6 | 32.8 | 10.7 | -0.2 | 79.2 | 95.0 | 83.2 |
| 2012 | 45.1 | 79.7 | 26.6 | 17.3 | 1.3 | 63.8 | 93.6 | 48.9 |

Notes: Contribution to the bias = 100(IRIOPA5 – IRIOP5)/(IRIOPA4-IRIOP4), where IRIOP4 (IRIOP5) is the result with the IRIOP table reported in Table 4.4 (5) and IRIOPA4 (IRIOPA5) the result with the aggregated IRIOP table reported in Table 4.4 (5).

\(^{22}\) Using the information from Tables 4.4 and 4.5, of the value added in Northwest in 2012 that was due to exports, 73.2% was due to exports in other regions. For South Coast this was only 4.9%.

\(^{23}\) The ladder-step strategy was launched in China by Deng Xiaoping. Higher priorities were given to the coastal areas because of their location close to the seashore and because of their overseas connections. The development of coastal region was expected to gradually spillover to inland areas (Wei and Hao, 2010).
4.5 Conclusions

Processing trade is an important characteristic of the Chinese economy that is unevenly distributed across domestic regions. A good analysis at the regional level requires adequate data. In this chapter we therefore constructed a new interregional input-output table for China, which explicitly distinguishes the production of processing exports from ordinary production. The new tables contain 17 sectors, include eight regions, and were constructed for 2002, 2007, and 2012. After describing the available data, we detailed how the information from the different data sources was harmonized and reconciled. Then we explained the construction procedure step by step. The compilation method that we have used is not only applicable to China. It may also be adopted for countries like Mexico, with much processing trade that is unevenly distributed across regions.

We expected that failing to separate processing exports will lead to misleading conclusions, also at the regional level. As an illustration of the use of the new table, we investigated whether the separation of production of processing exports from ordinary production mattered when studying the contribution of exports to regional value added. To this end, we compared the empirical results derived from the new tables with the results derived from an aggregated version of the new tables. The aggregation combined the two types of production again in order to mimic the results as would have been derived from ordinary interregional input-output tables (i.e. without singling out processing trade). We found that the contribution of regional exports to China’s GDP is significantly overestimated if processing trade is not properly included in the models. For example, a bias of 32.2% is observed in case of South Coast’s exports.

Another result was with respect to the interregional income spillovers of exports by coastal regions. The prevailing opinion is that they generate a considerable amount of value added in inland regions. We found that this effect is seriously overestimated. To simulate the economic growth in interior regions, direct involvement in exports—instead of indirect involvement through the exports of the coastal regions—is preferred.

Next to providing more accurate empirical results, the IRIOP tables have other advantages. That is, the tables can answer questions that cannot be answered by using the ordinary IRIO tables. For example, how is the value added generated by processing
exports distributed over regions and how much does processing trade contribute to regional growth, regional inequality, as well as the regional environment changes?
Appendix

Appendix 4.1

Available data for the construction of the IRIOP table

The variables in the NIOP table are noted with an overbar. Also, we will use ‘ordinary products’ for the goods and services made by ordinary production. \( \overline{z}_{ij}^{op} \) (as typical element of the matrix \( \overline{Z}^{op} \)) gives the intermediate deliveries of ordinary product \( i \) used to produce processing exports in industry \( j \); \( \overline{z}_{ij}^{oo} \) gives the intermediate deliveries of ordinary product \( i \) used for ordinary production in industry \( j \); \( \overline{z}_{ij}^{mp} \) gives the intermediate deliveries of imported product \( i \) used to produce processing exports in industry \( j \); \( \overline{z}_{ij}^{mo} \) gives the intermediate deliveries of imported product \( i \) used for ordinary production in industry \( j \); \( \overline{v}_{ij}^{p} \) is the value added in industry \( j \)’s processing exports production; \( \overline{v}_{ij}^{o} \) is the value added of industry \( j \)’s ordinary production; \( \overline{x}_{ij}^{o} \) is the gross output of industry \( j \)’s ordinary production; \( \overline{c}_{ij}^{o} \) is the value of ordinary product \( i \) used as final consumption; \( \overline{f}_{ij}^{o} \) is the value of ordinary product \( i \) used as fixed capital formation; \( \overline{q}_{ij}^{o} \) gives the inventory changes of ordinary product \( i \); \( \overline{c}_{ij}^{m} \) is the value of imported product \( i \) used as final consumption; \( \overline{f}_{ij}^{m} \) is the value of imported product \( i \) used as fixed capital formation; \( \overline{q}_{ij}^{m} \) gives the inventory changes of imported product \( i \); \( \overline{e}_{ij}^{p} \) is the processing exports of product \( i \), which makes up the total output (\( \overline{x}_{ij}^{p} \)) of this sector; \( \overline{e}_{ij}^{o} \) is the ordinary exports of product \( i \); and \( \overline{m}_{i} \) gives the total imports of product \( i \).
### Table A4.1.2 Schematic outline of the interregional input-output (IRIO) table with two regions

<table>
<thead>
<tr>
<th>Intermediate use</th>
<th>Final use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region r</td>
<td>Region s</td>
</tr>
<tr>
<td></td>
<td>DFC</td>
</tr>
<tr>
<td>Region r</td>
<td>( \tilde{z}_{rr} )</td>
</tr>
<tr>
<td>Region s</td>
<td>( \tilde{z}_{sr} )</td>
</tr>
<tr>
<td>IMP</td>
<td>( \tilde{z}_M^r )</td>
</tr>
</tbody>
</table>

Notes: DFC = domestic final consumption; FCF = fixed capital formation; INV = inventory changes; EXP = exports; TOT = gross sector outputs or total imports; IMP = imports; VA = value added.

The variables in the IRIO table are noted with a tilde. The variables that are used in the construction of the IRIO table are: \( \tilde{z}_{rsij} \) (as typical element of the matrix \( \tilde{z}_{rs} \)), which gives the intermediate deliveries of product \( i \) from region \( r \) to industry \( j \) in region \( s \); \( \tilde{v}_{sj} \), which gives the value added of industry \( j \) in region \( s \); \( \tilde{c}_{rsi} \), which gives the value of product \( i \) from region \( r \) used as final consumption in region \( s \); \( \tilde{f}_{rsi} \), which gives the value of product \( i \) from region \( r \) used as fixed capital formation in region \( s \); \( \tilde{q}_{ri} \), which gives the inventory changes in all regions of product \( i \) produced in region \( r \); \( \tilde{c}_{si}^M \), which gives the value of the import of product \( i \) used as final consumption in region \( s \); and \( \tilde{f}_{si}^M \), which gives the value of the import of product \( i \) used as fixed capital formation in region \( s \).
### Appendix 4.2

**Classification of China’s eight regions**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Eight Regions</th>
<th>Provinces</th>
<th>Macro-regions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE</td>
<td>North East</td>
<td>Heilongjiang, Jilin, Liaoning</td>
<td>Inland</td>
</tr>
<tr>
<td>NM</td>
<td>North Municipality</td>
<td>Beijing, Tianjin</td>
<td>Coastal</td>
</tr>
<tr>
<td>NC</td>
<td>North Coast</td>
<td>Hebei, Shandong</td>
<td>Coastal</td>
</tr>
<tr>
<td>EC</td>
<td>East Coast</td>
<td>Jiangsu, Shanghai, Zhejiang</td>
<td>Coastal</td>
</tr>
<tr>
<td>SC</td>
<td>South Coast</td>
<td>Fujian, Hainan, Guangdong</td>
<td>Coastal</td>
</tr>
<tr>
<td>CR</td>
<td>Central Region</td>
<td>Anhui, Jiangxi, Henan, Hubei, Hunan, Shanxi</td>
<td>Inland</td>
</tr>
<tr>
<td>NW</td>
<td>North West</td>
<td>Gansu, Inner Mongolia, Ningxia, Xinjiang, Shaanxi</td>
<td>Inland</td>
</tr>
<tr>
<td>SW</td>
<td>South West</td>
<td>Chongqing, Guizhou, Guangxi, Qinghai, Sichuan, Tibet, Yunnan</td>
<td>Inland</td>
</tr>
</tbody>
</table>

Notes: We focus on mainland China and exclude Chinese Taiwan, Hong Kong, and Macao. The Coastal areas include Liaoning, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan, and Guangxi.
Appendix 4.3
The correspondence of industry classification

The table below gives the correspondence of the 5-sector classification in the Regional Economic Accounts (REAs), the 17-sector classification of the IRIO table, and the 42-sector classification used by the NBS.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Code 1 Agriculture</td>
<td>Agriculture</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2 Mining</td>
<td></td>
<td>2-5</td>
<td>2-5</td>
</tr>
<tr>
<td>3 Food products</td>
<td></td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>4 Textile and wearing apparel</td>
<td></td>
<td>7, 8</td>
<td>7, 8</td>
</tr>
<tr>
<td>5 Wooden products</td>
<td></td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>6 Paper and printing</td>
<td></td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>7 Chemical products</td>
<td></td>
<td>11, 12</td>
<td>11, 12</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Code 8 Non-metallic mineral</td>
<td></td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>9 Metal products</td>
<td></td>
<td>14, 15</td>
<td>14, 15</td>
</tr>
<tr>
<td>10 Machinery</td>
<td></td>
<td>16</td>
<td>16, 17</td>
</tr>
<tr>
<td>11 Transport equipment</td>
<td></td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>12 Electronic products</td>
<td></td>
<td>18, 19</td>
<td>19, 20</td>
</tr>
<tr>
<td>13 Other manufacturing products</td>
<td></td>
<td>20-22</td>
<td>21-24</td>
</tr>
<tr>
<td>14 Electricity, gas and water supply</td>
<td></td>
<td>23-25</td>
<td>25-27</td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>15 Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trade and transport</td>
<td></td>
<td>27, 30</td>
<td>29, 30</td>
</tr>
<tr>
<td>16 Trade and transport</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other services</td>
<td></td>
<td>28, 29, 31-42</td>
<td>31-42</td>
</tr>
<tr>
<td>17 Other services</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Further details of the 42 IO industries are given in NBS (2009, 2016).
Appendix 4.4

The construction of the IRIOP table

In this appendix, we describe the construction procedure of the IRIOP tables in detail. Recall that the procedure is in 5 steps, where each step estimates a set of variables. Data from different data sources are used. To indicate the source from which the data are taken, we use an overbar (e.g. \( \bar{x} \)) to indicate variables from the NIOP tables, a tilde (e.g. \( \tilde{x} \)) for variables from the IRIO tables, and a diaeresis (i.e. two dots, e.g. \( \ddot{x} \)) for variables from the REAs and China’s Customs statistics. We also distinguish between merchandise goods produced by industries 1 – 15 and services produced by industries 16 and 17.

A4.4.1 Variables in Step 1

We start the construction with determining the vectors for the exports \( e_r^p \) and \( e_r^o \), the outputs \( x_r^p \) and \( x_r^o \), and the domestic inventory changes \( q_r^o \) in the IRIOP tables. These variables are used in later steps to determine the other variables.

(1) Exports

First, for mechanize goods, the data for processing exports \( \bar{e}_{ri}^p \) and ordinary exports \( \tilde{e}_{ri}^o \) for each region are obtained by aggregating the China’s Customs statistics. These data are scaled to match the export data in the NIOP table (i.e. \( \bar{e}_{ri}^p \) and \( \tilde{e}_{ri}^o \)), which we take as our benchmark table. This yields for \( i = 1, \ldots, 15 \)

\[
e_{ri}^p = \frac{\bar{e}_{ri}^p}{\sum_r e_{rit}^p} e_{rit}^p \quad \text{and} \quad e_{ri}^o = \frac{\tilde{e}_{ri}^o}{\sum_r e_{rit}^o} e_{rit}^o \quad (A4.4.1)
\]

For the processing exports of services, data limitations imply that the distribution of the processing exports of merchandise goods is adopted to distribute the processing services exports from the NIOP tables over the eight regions. It needs to be noted that
processing trade is principally only for merchandise trade. However, in the IO tables, processing exports are also non-zero for services. This refers to the commercial margins or the other services used for the processing exports of merchandise goods. We therefore assume that the regional distribution of processing exports is the same for merchandise goods and services. For \( i = 16, 17 \), we have

\[
e_r^p = \frac{\sum_{j=1}^{15} e_{rj}^p}{\sum_s \sum_{j=1}^{15} e_{sj}^p} \bar{e}_r^p \quad (A4.4.2)
\]

For ordinary services exports, the only information that is available at the regional level is in the IRIO tables (i.e. \( \bar{e}_{ri} \)). Adapting (A4.4.1) according to data availability, we distribute the ordinary exports of services from the NIOP tables over the regions as follows. For \( i = 16, 17 \), we have

\[
e_r^o = \frac{\bar{e}_{ri}}{\sum_s \bar{e}_{si}} \bar{e}_i^o \quad (A4.4.3)
\]

(2) Domestic inventory changes

Data on domestic inventory changes exist at different levels. The IRIO tables show the sectoral inventory changes provided by each region (\( \bar{q}_{si} \)). The REAs give the total inventory changes in products delivered by each region (\( \bar{q}_s \)). The NIOP tables provide the national inventory changes at sector level (\( \bar{q}_i \)). It should be noted that a region’s inventory changes are the inventory changes in the whole of China regarding products delivered by that particular region.

Based on the principle that data from the NIOP tables have the highest priority, followed by data from the REAs and then the IRIO tables, a two-step procedure is developed to estimate the domestic region-industry-specific inventory changes in the IRIOP tables (\( \bar{q}_{ri}^o \)). The first step ensures that \( \bar{q}_{ri}^o \) is in line with the REAs and the second step makes it consistent with the NIOP tables.

We distribute the regional totals of the domestic inventory changes from the REAs (\( \bar{q}_r \)) over the sectors, using \( \bar{q}_{ri} \) from the IRIO tables. This yields the initial estimate of \( \bar{q}_{ri}^o \). However, because inventory changes can be both positive and negative, applying the proportionality method straightforwardly may ‘blow up’ the numbers and cause
sizable swings. To avoid such swings, the proportionality method has been adapted following Dietzenbacher et al. (2013).

$$\tilde{q}_{ri}^0 = \bar{q}_{ri} + \frac{|\bar{q}_{ri}|}{\sum_j |\bar{q}_{rj}|} (\bar{q}_r - \sum_j \bar{q}_{rj}), \quad (A4.4.4)$$

where \(\bar{q}_{ri}^0\) gives the initial estimate (indicated by a double overbar) of the inventory changes of good \(i\) produced in region \(r\). To make the estimates in the IRIOP table consistent with the NIOP table, we distribute the \(\bar{q}_i\) from the NIOP table over the regions using the initial estimates (i.e. \(\bar{q}_{ri}^0\)). This yields

$$q_{ri}^0 = \bar{q}_{ri} + \frac{|\bar{q}_{ri}|}{\sum_s |\bar{q}_{sri}|} (\bar{q}_i - \sum_s \bar{q}_{sri}). \quad (A4.4.5)$$

(3) Outputs

By definition, the output of processing exports production is just the exports themselves (i.e. \(x_r^p = e_r^p\)). To estimate the regional output of ordinary production \((\bar{x}_r^0)\), we can follow two routes. This is because in any IO table the output of an industry always equals the sum of the inputs in that industry. Estimating the outputs can thus be approached by looking at the columns or by looking at the rows. Because we have already estimates for the exports and the domestic inventory changes, we have chosen to use the row-wise approach.

We first estimate the domestic sales of regional ordinary production \((d_{ri}^0 = x_{ri}^0 - q_{ri}^0 - e_{ri}^0)\). At the national level, the domestic sales are obtained from subtracting the ordinary exports and inventory changes from the output of ordinary production in the NIOP tables, i.e. \(\bar{d}_i^0 = \bar{x}_i^0 - \bar{q}_i^0 - \bar{e}_i^0\). Next, these domestic sales are distributed over the regions of origin, using the regional distribution of domestic sales in the IRIO table, i.e. \(\bar{d}_{ri} = \bar{x}_r - \bar{q}_{ri} - \bar{e}_{ri}\). This yields

$$d_{ri}^0 = \frac{\bar{d}_{ri}}{\sum_s \bar{d}_{si}} \bar{q}_{si}^0 = \frac{(\bar{x}_{ri} - \bar{q}_{ri} - \bar{e}_{ri})}{\sum_s (\bar{x}_{sri} - \bar{q}_{sri} - \bar{e}_{sri})} (\bar{x}_i - \bar{q}_i^0 - \bar{e}_i^0) \quad (A4.4.6)$$

Then the output is given by \(x_{ri}^0 = d_{ri}^0 + q_{ri}^0 + e_{ri}^0\). 

A4.4.2 Variables in Step 2

This part focuses on estimating the imported final demands in the IRIOP tables. Included are: imported consumption ($c_{ri}^{M}$), imported fixed capital formation ($f_{ri}^{M}$), and imported inventory changes ($q_{i}^{M}$). In addition, we obtain estimates for the total imported intermediates for processing exports production and ordinary production in each region. These totals are not shown in the IRIOP table (Table 4.2 in the main text), but are necessary for the estimation of other variables.

Comparing Table 4.2 in the main text and Table A4.1.1 in Appendix 4.1, we see that the total imports ($m_{i}$) and the inventory change of imports ($q_{i}^{M}$) in the IRIOP tables can be directly obtained from the NIOP tables. That is, $m_{i} = \bar{m}_{i}$ and $q_{i}^{M} = q_{i}^{M}$.

Next, we estimate $c_{ri}^{M}$ and $f_{ri}^{M}$. Imports are used either for producing processing exports only or for other purposes. We shall term them processing imports and non-processing imports. The non-processing imports are used as intermediate inputs for ordinary production and as final demands. We first focus on the non-processing imports and follow three steps.

(1) Non-processing imports

First, the regional non-processing imports of merchandise goods are at a very detailed commodity level given in China’s Customs statistics. Using the revised BEC (‘broad economic categories’) method proposed by Dietzenbacher et al. (2013), the regional ordinary import of each commodity is split into three categories. These are ‘intermediate inputs’, ‘final consumption’, and ‘fixed capital formation’, based on a refinement of the well-known BEC codes.24 The resulting region-commodity-specific imports for the three categories are aggregated over the commodities so as to arrive at the 15 IO sectors producing merchandise goods. These are the initial estimates for the imports used as final consumption ($c_{ri}^{M}$), as fixed capital formation ($f_{ri}^{M}$), and as intermediate inputs of ordinary products ($\bar{z}_{ri}^{MO}$, with $\bar{z}_{ri}^{MO} = \sum_{j} \bar{z}_{rij}^{MO}$).

Second, we assume that the imports of each region can only be used either as final

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24 A major advantage of this revised BEC method is that it allows that a good is used by more than one category.
demand or intermediate use in the own region, i.e. no re-exports to other regions. This assumption is reasonable since the imports from China’s Customs statistics are calculated using the principle of destination. Therefore, the vectors obtained in first step are matched to the NIOP table. This yields for the estimates in the IRIOP table, for \( i = 1, \ldots, 15 \)

\[
c^M_{r_1} = \frac{z^M_{r_1} c^M_i}{\sum_s z^M_{r_1} c^M_i}, f^M_{r_1} = \frac{z^M_{r_1} f^M_i}{\sum_s z^M_{r_1} f^M_i}, z^MO_{r_1i} = \frac{z^MO_{r_1i}}{\sum_s z^MO_{r_1i}} (\sum_j z^MO_{r_1j}) \tag{A4.4.7}
\]

The variable \( z^MO_{r_1i} \) gives the total value of imports \( i \) used as intermediate input in ordinary production in region \( r \). It will be used in Section A4.4.4 to estimate the import matrix for ordinary production (\( Z^MO_r \)).

Third, for the non-processing imports of services, we assume – due to data limitations – that their regional allocation is (for each category) identical with the regional allocation of imports of merchandise goods. For \( i = 16, 17 \), we have

\[
c^M_{r_1} = \frac{\sum_{j=1}^{15} z^M_{r_1j} c^M_i}{\sum_j z^M_{r_1j} c^M_i}, f^M_{r_1} = \frac{\sum_{j=1}^{15} z^M_{r_1j} f^M_i}{\sum_j z^M_{r_1j} f^M_i}, z^MO_{r_1i} = \frac{\sum_{j=1}^{15} z^MO_{r_1j}}{\sum_j z^MO_{r_1j}} (\sum_j z^MO_{r_1j}) \tag{A4.4.8}
\]

(2) Processing imports

The estimation of total processing imports of product \( i \) for intermediate use (i.e. \( z^MP_{r_1i} \)) is not necessary in this step. However, because it is very similar to the estimation of the total \( z^MO_{r_1i} \) for ordinary imports in Equation A4.4.7, we do it at this stage. The totals in \( z^MP_{r_1i} \) are crucial in determining later the import matrix of processing imports (i.e. matrix \( Z^MP_r \) with elements \( z^MP_{r_1ij} \)).

According to the regulations of China’s Customs, all processing imports should be used exclusively in the production of processing exports.\(^{25}\) We further assume that the processing imports of each region are only used within this region.

For merchandise goods, we first obtain the region-commodity-specific processing imports (\( z^MP_{r_1i} \)) by aggregating data from China’s customs statistics. Then, we scale

\(^{25}\) Due to the tax-exemption policy for processing imports, processing exporters use almost only processing imports in producing their processing exports.
these totals to match them with the national processing imports in the NIOP table (i.e. $\Sigma_j z_{ij}^{MP}$). This yields the region-commodity-specific processing imports in the IRIOP table, for $i = 1, \ldots, 15$

$$ z_{r_{i*}}^{MP} = \frac{z_{r_{i*}}^{MP}}{\sum_s z_{s_{i*}}^{MP}} \left( \Sigma_j z_{ij}^{MP} \right) \quad (A4.4.9) $$

Due to data limitations, we assume that the allocation of processing imports across regions is the same for services as it is for merchandise goods. For $i = 16, 17$, we have

$$ z_{r_{i*}}^{MP} = \frac{\Sigma_{j=15} z_{r_{i*}}^{MP}}{\Sigma_{j=15} z_{s_{j*}}^{MP} \left( \Sigma_j z_{ij}^{MP} \right)} \quad (A4.4.10) $$

**A4.4.3 Variables in Step 3**

In this step, we estimate the vectors with values added. Different from steps 1 and 2, the value added vectors cannot be obtained directly from existing data sources. Therefore, a more complicated procedure is followed. The general idea is that (i) initial values are assigned to the values added based on a combination of official statistics and some reasonable assumptions, (ii) row and column constraints are determined from official data, and (iii) the RAS procedure is applied on the initial values to ensure a balanced IO table that satisfies the constraints.

1. *Initial estimates for the values added*

   For industry $j$ in region $s$, we need to estimate $v_{s_{ij}}^P$ and $v_{s_{ij}}^O$. For the initial estimates ($v_{0s_{ij}}^P$ and $v_{0s_{ij}}^O$), we take the value added ratios from the NIOP table (i.e. \( v_{ij}^P / \bar{x}_j^P \) and \( v_{ij}^O / \bar{x}_j^O \)), assume that they apply to each region, and multiply them with the output of industry $j$ in region $s$ (which was obtained in step 1). That is,

$$ v_{0s_{ij}}^P = \frac{v_{ij}^P}{\bar{x}_j^P} x_{s_{ij}}^P \quad \text{and} \quad v_{0s_{ij}}^O = \frac{v_{ij}^O}{\bar{x}_j^O} x_{s_{ij}}^O \quad (A4.4.11) $$
(2) Constraints and the RAS procedure

The NIOP table—which is our preferred data source—provides information on the national values added $v_j^P$ and $v_j^O$. Requiring that our regional estimates $v_{sj}^P$ and $v_{sj}^O$ are consistent with the NIOP table yields the column constraints

$$\sum_s v_{sj}^P = v_j^P \quad \text{and} \quad \sum_s v_{sj}^O = v_j^O \quad \text{(A4.4.12)}$$

The REAs provide the value added at the regional level (not distinguishing between $P$ and $O$), but only for the broad sector classification (see Appendix 4.3). For agriculture ($j = 1$), construction ($j = 15$), trade and transport ($j = 16$), and other services ($j = 17$), we thus have $\bar{v}_{sj}$. The broad sector manufacturing covers the input-output sectors $2 - 14$ and its total value added is $\bar{v}_{s,manufacturing}$. To split the broad sector value added into value added at IO sector level, we use the region-sector-specific value added from the IRIO table ($\bar{v}_{sj}$). That is, for $j = 2, \ldots, 14$, $\bar{v}_{sj} = \frac{\bar{v}_{sj}}{\sum_{i=2}^{14} \bar{v}_{si}} \bar{v}_{s,manufacturing}$.

In principle, the national value added for industry $j$ can be obtained as $\bar{v}_j^P + \bar{v}_j^O$ (using the NIOP table), but also as $\sum_s \bar{v}_{sj}$ (using REA data). Given the inconsistency between the REAs and the NIOP tables, and given our preference for NIOP data, we split $\bar{v}_j^P + \bar{v}_j^O$ over the regions using $\bar{v}_{sj}$. This gives the row constraints.

$$v_{sj}^P + v_{sj}^O = \frac{\bar{v}_{sj}}{\sum_{r} \bar{v}_{rj}} (\bar{v}_j^P + \bar{v}_j^O) \quad \text{(A4.4.13)}$$

Next, the RAS procedure is applied to the initial estimates in Equation A4.4.11, taking the column sums in Equation A4.4.12 and the row sums in A4.4.13 into account. This yields the information as sketched in Table A4.4.1.
Table A4.4.1. RAS data for the value added of industry \( j \) in the IRIOP table

<table>
<thead>
<tr>
<th>( \ldots )</th>
<th>Production of processing exports</th>
<th>Ordinary production</th>
<th>Row sums</th>
</tr>
</thead>
<tbody>
<tr>
<td>region ( r )</td>
<td>( v_{rj}^p )</td>
<td>( v_{rj}^o )</td>
<td>((\bar{v}<em>{rj}/\Sigma \bar{v}</em>{rj}) (\bar{v}<em>{j}^p + \bar{v}</em>{j}^o))</td>
</tr>
<tr>
<td>region ( s )</td>
<td>( v_{sj}^p )</td>
<td>( v_{sj}^o )</td>
<td>((\bar{v}<em>{rj}/\Sigma \bar{v}</em>{rj}) (\bar{v}<em>{j}^p + \bar{v}</em>{j}^o))</td>
</tr>
<tr>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
</tr>
</tbody>
</table>

Column sums

| \( \bar{v}_{j}^p \) | \( \bar{v}_{j}^o \) |

(3) Estimates of value added components

Value added in input-output tables includes four components: compensation of labor (index \( c \)), fixed asset depreciation (\( d \)), net production tax (\( t \)), and operating surplus (\( q \)). For industry \( j \) in region \( s \) in the IRIOP tables, we thus need to estimate \( v_{sj}^{cp} \), \( v_{sj}^{dp} \), \( v_{sj}^{tp} \), and \( v_{sj}^{qp} \) for the production of processing exports, and \( v_{sj}^{co} \), \( v_{sj}^{do} \), \( v_{sj}^{to} \), and \( v_{sj}^{qo} \) for ordinary production.

Before we describe the estimation procedure, we indicate the availability of data. First, the NIOP table provides the value added items at the national level. That is, \( \bar{v}_{j}^{cp} \), \( \bar{v}_{j}^{dp} \), \( \bar{v}_{j}^{tp} \), and \( \bar{v}_{j}^{qp} \) for the production of processing exports, and \( \bar{v}_{j}^{co} \), \( \bar{v}_{j}^{do} \), \( \bar{v}_{j}^{to} \), and \( \bar{v}_{j}^{qo} \) for ordinary production. These data are used for the national controls of the estimation. Second, the IRIOP table provides the value added items at the level of sector-regions (\( \bar{v}_{sj}^{c} \), \( \bar{v}_{sj}^{d} \), \( \bar{v}_{sj}^{t} \), and \( \bar{v}_{sj}^{q} \)) but not making a distinction between type of production (\( P \) or \( O \)). These data are used for determining the initial estimates. Thirdly, the REA provides the totals of each value added item across industries for each region (\( \bar{v}_{s}^{c} \), \( \bar{v}_{s}^{d} \), \( \bar{v}_{s}^{t} \), and \( \bar{v}_{s}^{q} \)).

The initial estimates split the region-sector-specific value added in the IRIOP table (i.e., \( v_{sj}^{p} \) and \( v_{sj}^{o} \)) into the four components. This is done with proportions from the IRIOP table. For example, the initial estimate for \( v_{sj}^{cp} \) is given by

\[
v0_{sj}^{cp} = v_{sj}^{p} \frac{v_{sj}^{c}}{v_{sj}}
\]  
(A4.4.14)
where \( \tilde{v}_{sj} = \tilde{v}_{sj}^c + \tilde{v}_{sj}^d + \tilde{v}_{sj}^t + \tilde{v}_{sj}^q \). Initial estimates for the other seven variables 
\( (v_{0sj}^p, v_{0tp}, v_{0q}, v_{0s}^d, v_{0s}^q, v_{0s}^{tq}, v_{0s}^{dq}) \) are obtained in the same way.

There are three types of constraints for the value added components. First, regional aggregation of the IRIOP variables must yield the national values from the NIOP table. For example,

\[
\sum_s v_{sj}^{cp} = \bar{v}_{j}^{cp} \quad \text{(A4.4.15)}
\]

Second, the four components must sum to the estimates for the value added (i.e. \( v_{sj}^p \) and \( v_{sj}^o \)) as obtained in Section A4.4.3.(2). That is,

\[
v_{sj}^{cp} + v_{sj}^{dp} + v_{sj}^{tp} + v_{sj}^{q} = v_{sj}^p \quad \text{and} \quad v_{sj}^{co} + v_{sj}^{do} + v_{sj}^{to} + v_{sj}^{qo} = v_{sj}^o \quad \text{(A4.4.16)}
\]

Finally, the regional totals of the value added items are equal to the NIOP totals that have been regionally adapted using the REA data. The procedure is similar to A4.4.13 and for the compensation of labor it yields

\[
\sum_j (v_{sj}^{cp} + v_{sj}^{co}) = \frac{\bar{v}_s}{\sum_r \bar{v}_r} \sum_j (\bar{v}_j^{cp} + \bar{v}_j^{co}) \quad \text{(A4.4.17)}
\]

Finding a solution that satisfies constraints A4.4.15 – A4.4.17 cannot be done with the standard bi-proportional method. Instead, we use a multi-proportional method that is based on the ideas underlying TRAS (Gilchrist and St Louis, 1999). This yields a nested RAS method. That is, a RAS procedure that is nested into another bi-proportional adjustment procedure. Consider Table A4.4.2, for the value added items involved in regional production of processing exports by industry \( j \). We have a similar table for the ordinary production. This means that we have a three-dimensional estimation problem. Equation A4.4.15 gives the row sums (summing over the eight regions), Equation A4.4.16 gives the column sums (summing over the four value added categories), and Equation A4.4.17 gives the “layer” sums (summing over the two types of production, \( P \) and \( O \)).

First, RAS-using the initial estimates—given A4.4.15 and A4.4.16 as
constraints—gives the first round estimates \( v^{1cp}_{s_j} \) and \( v^{1co}_{s_j} \). Next these first round estimates are adapted in order to make them satisfy constraint A4.4.17, which yields

\[
v^{2cp}_{s_j} = v^{1cp}_{s_j} \frac{\tilde{v}_s}{\sum_r \tilde{v}_r \sum_i (v^{1cp}_{r_j} + v^{1co}_{r_j})} \quad \text{and} \quad v^{2co}_{s_j} = v^{1co}_{s_j} \frac{\tilde{v}_s}{\sum_r \tilde{v}_r \sum_i (v^{1cp}_{r_j} + v^{1co}_{r_j})}
\]  

(A4.4.18)

Probably, the estimates \( v^{2cp}_{s_j} \) and \( v^{2co}_{s_j} \) violate constraints A4.4.15 and A4.4.16, after which the RAS procedure is applied again. This yields \( v^{3cp}_{s_j} \) and \( v^{3co}_{s_j} \), which are adapted again so as to match constraint A4.4.17. This is done similar to A4.4.18 and gives \( v^{4cp}_{s_j} \) and \( v^{4co}_{s_j} \). This process is repeated until convergence is reached, implying that the estimates satisfy all three constraints.

Table A4.4.2 RAS data for the value added items of industry \( j \)'s production of processing exports in the IROP table

<table>
<thead>
<tr>
<th></th>
<th>...</th>
<th>Region ( r )</th>
<th>Region ( s )</th>
<th>...</th>
<th>Row sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor compensation</td>
<td>...</td>
<td>( v^{cp}_{r_j} )</td>
<td>( v^{cp}_{s_j} )</td>
<td>...</td>
<td>( \tilde{v}^{cp}_j )</td>
</tr>
<tr>
<td>Fixed asset depreciation</td>
<td>...</td>
<td>( v^{dp}_{r_j} )</td>
<td>( v^{dp}_{s_j} )</td>
<td>...</td>
<td>( \tilde{v}^{dp}_j )</td>
</tr>
<tr>
<td>Net production tax</td>
<td>...</td>
<td>( v^{ip}_{r_j} )</td>
<td>( v^{ip}_{s_j} )</td>
<td>...</td>
<td>( \tilde{v}^{ip}_j )</td>
</tr>
<tr>
<td>Operating surplus</td>
<td>...</td>
<td>( v^{op}_{r_j} )</td>
<td>( v^{op}_{s_j} )</td>
<td>...</td>
<td>( \tilde{v}^{op}_j )</td>
</tr>
<tr>
<td>Column sums</td>
<td>...</td>
<td>( v^{p}_{r_j} )</td>
<td>( v^{p}_{s_j} )</td>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

A4.4.4 Variables in Step 4

After the estimation in previous steps of the output \( (x^{p}_{s_j}) \) and the value added \( (v^{p}_{s_j}) \), the total amount of intermediate input use can be obtained as the residual \( (x^{p}_{s_j} - v^{p}_{s_j}) = \sum_r \sum_i \tilde{z}^{op}_{r_s i} + \sum_i \tilde{z}^{MP}_{s_j} \). In this sub-section, we estimate the import matrices \( \tilde{z}^{MP}_{s_j} \) in the case of production of processing exports and \( \tilde{z}^{MO}_{s_j} \) in the case of ordinary production.
(1) The constraints

The elements of the import matrices in the IRIOP table ($z_{sij}^{MP}$ and $z_{sij}^{MO}$) are subject to several constraints. This is to ensure that the IRIOP table is balanced and consistent with the NIOP table and the trade statistics.

First, the IRIOP table should be in line with the bipartite table. We thus have:

$$\sum_s z_{sij}^{MP} = \bar{z}_{ij}^{MP} \quad \text{and} \quad \sum_s z_{sij}^{MO} = \bar{z}_{ij}^{MO} \quad \quad \quad \text{(A.4.19)}$$

Next, the IRIOP table should accord with the trade statistics. Recall that in Section A4.4.2 we have estimated the variables $z_{sij}^{MP}$ and $z_{sij}^{MO}$. They give the total value of imports $i$ used as intermediate input in production of processing exports ($P$) or in ordinary production ($O$) in region $s$. It gives the totals over all destination sectors. Hence,

$$\sum_j z_{sij}^{MP} = z_{sij}^{MP} \quad \text{and} \quad \sum_j z_{sij}^{MO} = z_{sij}^{MO} \quad \quad \quad \text{(A.4.20)}$$

Finally, the sum of imported inputs cannot be larger than the total amount of inputs that is required. In other words, the domestic intermediate inputs cannot be negative. This yields

$$\sum_i z_{sij}^{MP} \leq x_{sij}^p - v_{sij}^p \quad \text{and} \quad \sum_i z_{sij}^{MO} \leq x_{sij}^o - v_{sij}^o \quad \quad \quad \text{(A.4.21)}$$

These inequalities can also be written as $\sum_r \sum_i z_{rsij}^{OP} \geq 0$ and $\sum_r \sum_i z_{rsij}^{OO} \geq 0$.

(2) The estimation of the import matrices

To estimate $z_{sij}^{MP}$ and $z_{sij}^{MO}$, we apply the RAS procedure. Consider the imports of product $i$, then the problem is depicted in Table A4.4.3. Note that the link to the NIOP table (also in Section A4.4.2) implies that $\sum_j z_{ij}^{MP} = \sum_s z_{sij}^{MP}$, so that the sum of the column sums equals the sum of the row sums.
Table A4.4.3 RAS data for the imports of product $i$ for production of processing exports

<table>
<thead>
<tr>
<th></th>
<th>…</th>
<th>Sector $j$</th>
<th>Sector $k$</th>
<th>…</th>
<th>Row sums</th>
</tr>
</thead>
<tbody>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>Region $r$</td>
<td>…</td>
<td>$z_{r1j}^{MP}$</td>
<td>$z_{r1k}^{MP}$</td>
<td>…</td>
<td>$z_{r1}^{MP}$</td>
</tr>
<tr>
<td>Region $s$</td>
<td>…</td>
<td>$z_{s1j}^{MP}$</td>
<td>$z_{s1k}^{MP}$</td>
<td>…</td>
<td>$z_{s1}^{MP}$</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>Column sums</td>
<td>…</td>
<td>$z_{1j}^{MP}$</td>
<td>$z_{1k}^{MP}$</td>
<td>…</td>
<td>…</td>
</tr>
</tbody>
</table>

To assign initial values, we can use the structure of imported inputs either from the NIOP table (i.e. Table A4.2.1) or from the IRIO table (i.e. Table A4.2.2). The IRIO table only provides the total imports by each sector and region without information on whether they are used for production of processing exports ($P$) or ordinary production ($O$). Moreover, recall that the trade data in IRIO tables—which are crucial to the import matrices—are not consistent with other data sources. We have therefore chosen to use the information in the NIOP table to assign initial values for the import matrices in the IRIO table.

We assume that for the same production type (e.g., processing exports), the input structure of imported intermediates is the same in all regions and is identical to the national structure. The import levels, however, vary across regions. The initial import matrices in the IRIO table are given by

$$
z_{0_{stij}}^{MP} = z_{ij}^{MP} \frac{x_{ij}^{P} - v_{ij}^{P}}{x_{ij}^{P} - \bar{v}_{ij}^{P}} \tag{A4.4.22}
$$

where $x_{ij}^{P}$ and $v_{ij}^{P}$ are from the IRIO table and have been estimated at an earlier stage.

Next, we apply the RAS procedure (with the constraints as depicted in Table A4.3.3) and this yields the first-round estimate of the import matrix ($z_{1_{stij}}^{MP}$). For every $i, j$ and $s$, we check whether $z_{1_{stij}}^{MP}$ satisfies the constraint A4.4.21. If A4.4.21 holds for all $i, j$ and $s$, we are done and have $z_{stij}^{MP} = z_{1_{stij}}^{MP}$. If Equation A4.4.21 is not satisfied
by all $i, j$ and $s$, we define second-round estimates. For combinations $i, j$ and $s$ that do satisfy A4.4.21 we define $z_{slj}^{2MP} = z_{slj}^{1MP}$ for the second-round estimate. Otherwise, for combinations $i, j$ and $s$ for which $\sum_i z_{slj}^{TT} > x_{sji}^T - v_{sji}^T$, we adjust the first-round estimate and obtain the second-round estimate as follows:

$$z_{slj}^{2MP} = z_{slj}^{1MP} \frac{x_{sji}^P - v_{sji}^P}{\sum_i z_{slj}^{1MP}} \quad (A4.4.23)$$

Next, the RAS procedure is applied to the second-round estimates ($z_{slj}^{2MP}$), which yields third-round estimates ($z_{slj}^{3MP}$). If they satisfy constraint A4.4.21, we are done. If not, another round of estimates is needed. This process continues until condition A4.4.21 is satisfied for all $i, j$ and $s$.

**A4.4.5 Variables in Step 5**

In the last step, we estimate the matrices with domestic intermediate deliveries ($Z_{rs}^{0O}$ with elements $z_{rsij}^{0O}$ and $Z_{rs}^{0P}$ with elements $z_{rsij}^{0P}$) and the domestic final demand vectors ($c_{rs}^O$ with elements $c_{rsij}^O$ and $f_{rs}^O$ with elements $f_{rsij}^O$). To this end, we adopt a hierarchical estimation method. It includes three steps, each of which uses the RAS procedure. First, the total regional domestic sales ($d_{si}^O$)—which were obtained in Equation A4.4.6 in Section A4.4.1—are split into total intermediate use, total final consumption, and total fixed capital formation. Second, the domestic final demands are determined by applying the RAS procedure. Finally, RAS is also used to estimate the domestic intermediate deliveries ($z_{rsij}^{OP}, z_{rsij}^{OO}$).

(1) **Total intermediates and total final demands**

In this sub-section, we allocate the total region-sector-specific domestic sales into the three use categories: intermediates use, final consumption, and fixed capital formation. Let $y_{ri}^O$, $c_{ri}^O$ and $f_{ri}^O$ denote the total value of ordinary production by
sector $i$ in region $r$ that is used for intermediate use, for final consumption and for fixed capital formation. That is,

$$y_{ri}^0 \equiv \sum_s \sum_j (z_{rsi j}^{0p} + z_{rsi j}^{00}), \quad c_{ri}^0 \equiv \sum_s c_{rsi}^0, \quad f_{ri}^0 \equiv \sum_s f_{rsi}^0$$  \hspace{1cm} (A4.4.24)

For the IRIOP table we have

$$y_{ri}^0 + c_{ri}^0 + f_{ri}^0 = d_{ri}^0$$  \hspace{1cm} (A4.4.25)

where $d_{ri}^0$ has been determined earlier in Equation A4.4.6 and where $y_{ri}^0$, $c_{ri}^0$ and $f_{ri}^0$ are the unknown variables to be estimated in this sub-section.

One of our principles was that the IRIOP table should match with the NIOP table. Aggregating $y_{ri}^0$, $c_{ri}^0$, and $f_{ri}^0$ over the regions should therefore yield the corresponding totals at the national level as given in the NIOP table. We thus have

$$\sum_r y_{ri}^0 = \sum_j (\tilde{z}_{ij}^{0p} + \tilde{z}_{ij}^{00}), \quad \sum_r c_{ri}^0 = \tilde{c}_i^0, \quad \sum_r f_{ri}^0 = \tilde{f}_i^0$$  \hspace{1cm} (A4.4.26)

Equations A4.4.25 and A4.4.26 provide the constraints that must be satisfied by the IRIOP table. This is illustrated in Table A4.4.4. The uncolored cells are the variables to be estimated ($y_{ri}^0$, $c_{ri}^0$, and $f_{ri}^0$), and the last column and the last row respectively provide the row sums and column sums that are given. Using Equation A4.4.6, we can prove that the sum of row sums equals the sum of column sums. Therefore, the RAS procedure can be used for estimation.
Table A4.4.4 RAS data for total use of ordinary production by industry \(i\) as domestic intermediates and as domestic final demands

<table>
<thead>
<tr>
<th></th>
<th>Total domestic intermediates</th>
<th>Total domestic final consumption</th>
<th>Total domestic fixed capital formation</th>
<th>Row sums</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region (r)</td>
<td>(y_{rl}^0)</td>
<td>(c_{rl}^0)</td>
<td>(f_{rl}^0)</td>
<td>(d_{rl}^0)</td>
</tr>
<tr>
<td>Region (s)</td>
<td>(y_{si}^0)</td>
<td>(c_{si}^0)</td>
<td>(f_{si}^0)</td>
<td>(d_{si}^0)</td>
</tr>
<tr>
<td>Column sums</td>
<td>(\sum_j(z_{ij}^{0P} + z_{ij}^{0O}))</td>
<td>(\bar{c}_i^0)</td>
<td>(\bar{f}_i^0)</td>
<td>(\ldots)</td>
</tr>
</tbody>
</table>

The initial values for the RAS procedure are obtained by distributing the given column sums over the regions of origin. The distribution is based on the regional shares from the IRIO tables. That is,

\[
y_{0rl}^0 = \left( \sum_j(z_{ij}^{0P} + z_{ij}^{0O}) \right) \frac{\sum_r \sum_s z_{rsij}}{\sum_r \sum_s \sum_j z_{rsij}^0}, \quad c_{0rl}^0 = \frac{\sum_r \sum_s c_{rsi}^0}{\sum_r \sum_s \sum_j z_{rsij}^0}, \quad f_{0rl}^0 = \frac{\sum_r \sum_s f_{rsi}^0}{\sum_r \sum_s \sum_j z_{rsij}^0}
\]

(A4.4.27)

(2) Domestic final demands

In last sub-section, we obtained the total domestic final use of products provided by industry \(i\) in region \(r\) (\(c_{rl}^0\) and \(f_{rl}^0\)). In this sub-section, we will split these totals according to region of destination. That is, we estimate \(c_{rsi}^0\) and \(f_{rsi}^0\), using the RAS procedure again.

The final consumption (\(c_{rsi}^0\)) and the fixed capital formation (\(f_{rsi}^0\)) in the IRIOP table are each subject to two constraints. Their row sums (summing over the destination regions \(s\)) and their column sums (summing over the origin regions \(r\)) are given. First, the row sums are given in Equation A4.4.24, i.e. \(\sum_s c_{rsi}^0 = c_{rl}^0\) and \(\sum_s f_{rsi}^0 = f_{rl}^0\). Second, for the column sums we start from the NIOP table, which gives the national total of final use of product \(i\) (i.e. \(\bar{c}_i^0 + \bar{f}_i^0\) for final consumption and \(\bar{c}_i^0 + \bar{f}_i^0\) for fixed capital formation). These totals are split over the regions in which the final use takes place (i.e. destination regions), using information from the REAs (i.e. \(\bar{c}_s\) and \(\bar{f}_s\)). This yields
\[
\sum_r c^O_{rsi} + c^M_{sli} = \frac{\bar{c}_s}{\sum_s \bar{c}_s} (c^O_i + c^M_i), \quad \sum_r f^O_{rsi} + f^M_{sli} = \frac{\bar{f}_s}{\sum_s \bar{f}_s} (f^O_i + f^M_i)
\]  
(A4.4.28)

from which the columns sums can be obtained (subtracting \( c^M_{sli} \) on both sides and the same for \( f^M_{sli} \)). The constraints for the RAS procedure are depicted by the shaded ells in Tables A4.4.5 and A4.4.6. Note that \( r \) and \( w \) indicate origin regions and \( s \) and \( l \) destination regions.

**Table A4.4.5 RAS data for final consumption in region \( s \) of product \( i \) produced in region \( r \).**

<table>
<thead>
<tr>
<th></th>
<th>Region ( s )</th>
<th>Region ( l )</th>
<th>Row sums</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
</tr>
<tr>
<td>Region ( r )</td>
<td>( \cdots )</td>
<td>( c^O_{rsi} )</td>
<td>( c^O_{rii} )</td>
</tr>
<tr>
<td>Region ( w )</td>
<td>( \cdots )</td>
<td>( c^O_{wsi} )</td>
<td>( c^O_{wii} )</td>
</tr>
<tr>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
</tr>
<tr>
<td>Column sums</td>
<td>( \frac{\bar{c}_s}{\sum_s \bar{c}<em>s} (c^O_i + c^M_i) - c^M</em>{sli} )</td>
<td>( \frac{\bar{c}_l}{\sum_s \bar{c}<em>s} (c^O_i + c^M_i) - c^M</em>{lil} )</td>
<td>( \cdots )</td>
</tr>
</tbody>
</table>

**Table A4.4.6 RAS data for fixed capital formation in region \( s \) of product \( i \) produced in region \( r \).**

<table>
<thead>
<tr>
<th></th>
<th>Region ( s )</th>
<th>Region ( l )</th>
<th>Row sums</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
</tr>
<tr>
<td>Region ( r )</td>
<td>( \cdots )</td>
<td>( f^O_{rsi} )</td>
<td>( f^O_{rli} )</td>
</tr>
<tr>
<td>Region ( w )</td>
<td>( \cdots )</td>
<td>( f^O_{wsi} )</td>
<td>( f^O_{wli} )</td>
</tr>
<tr>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
</tr>
<tr>
<td>Column sums</td>
<td>( \frac{\bar{f}_s}{\sum_s \bar{f}<em>s} (f^O_i + f^M_i) - f^M</em>{sli} )</td>
<td>( \frac{\bar{f}_l}{\sum_s \bar{f}<em>s} (f^O_i + f^M_i) - f^M</em>{lil} )</td>
<td>( \cdots )</td>
</tr>
</tbody>
</table>

Next, we have to assign initial values to the domestic final demands. Because production of processing exports does not deliver domestically, the final use in the IRIOP table that we need to estimate is other (or ordinary) production. Therefore, the deliveries of product \( i \) from region \( r \) to region \( s \) for final consumption (or fixed capital
formation) in the IRIOP table are just the deliveries from region \( r \) to region \( s \) that are listed in the IRIO table. We thus take the domestic final demands in the IRIO table as the initial values for domestic final demands in the IRIOP table. That is:

\[
c^0_{rsl} = \tilde{c}_{rsl}, \quad f^0_{rsl} = \tilde{f}_{rsl}
\]  

(A4.4.29)

(3) Domestic intermediate deliveries

In this sub-section, we estimate the domestic intermediate deliveries in the IRIOP table \( (z^0_{rslij} \text{ and } z^0_{rslij}) \). This is the key part of the IRIOP table and reflects the interdependence amongst regions and sectors. The estimation takes place in two steps, starting from the NIOP table \( (\tilde{z}^0_{ij} \text{ and } \tilde{z}^0_{ij}) \). First, the national deliveries are split according to destination regions. Second, the results of the first step are split according to origin regions.

(a) Allocation of the intermediate deliveries over the regions of destination

In this first step, we estimate

\[
z^0_{tij} = \sum_r z^0_{rslij}, \quad z^0_{tij} = \sum_r z^0_{rslij}
\]  

(A4.4.30)

For the RAS procedure, we will use two constraints. Summing over the (destination) regions \( s \) should give us the national total from the IOP table. That is,

\[
\sum_s z^0_{tij} = \tilde{z}^0_{ij}, \quad \sum_s z^0_{tij} = \tilde{z}^0_{ij}
\]  

(A4.4.31)

The other constraint is based on the column sums of the IRIOP table. The sum (taken over origin sectors and origin regions) of the intermediate deliveries is given by \( \sum_l \sum_r z^0_{rslij} = \sum_l z^0_{tij} \). This equals the output of sector \( j \) in region \( s \) minus the total imported inputs and the value added \( (x^0_{sj} - \sum_i z^0_{slij} - v^0_{sj}) \). The second constraint thus becomes

\[
\sum_l z^0_{tslij} = x^0_{sj} - \sum_l z^0_{slij} - v^0_{sj}, \quad \sum_l z^0_{tslij} = x^0_{sj} - \sum_l z^0_{slij} - v^0_{sj}
\]  

(A4.4.32)
The RAS procedure and its constraints is illustrated in Table A4.4.7. The shaded cells give the row sums—from Equation A4.4.31—and the columns sums—from Equation A4.4.32. Note that the row sums are taken directly from the NIOP table and the column sums can be calculated from IRIOP variables that have been estimated in an earlier stage. Also, it can be shown that \( \sum_i z_{ij}^{OP} = \sum_i \sum_s z_{stij}^{OP} = \sum_s (x_{sj}^p - \sum_l z_{stlj}^{MP} - v_{sj}^p) \), implying that the sum of row sums equals the sum of column sums.

Table A4.4.7 RAS data for domestic intermediate inputs to produce sector \( j \)’s processing exports.

<table>
<thead>
<tr>
<th></th>
<th>( \ldots )</th>
<th>Region ( s )</th>
<th>Region ( l )</th>
<th>( \ldots )</th>
<th>( \ldots )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product ( i )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
</tr>
<tr>
<td></td>
<td>( \ldots )</td>
<td>( z_{tiij} )</td>
<td>( z_{tij} )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
</tr>
<tr>
<td>Product ( k )</td>
<td>( \ldots )</td>
<td>( z_{skj} )</td>
<td>( z_{tkj} )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
</tr>
<tr>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
</tr>
<tr>
<td>Column sums</td>
<td>( \ldots )</td>
<td>( x_{sj}^p - \sum_l z_{stlj}^{MP} - v_{sj}^p )</td>
<td>( x_{lj}^p - \sum_l z_{stlj}^{MP} - v_{lj}^p )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
</tr>
</tbody>
</table>

To start the RAS procedure, an initial value should be assigned to \( zt_{siij}^{OP} \) and \( zt_{siij}^{OO} \). We could take the national input structure in the NIOP table as the starting point. In that case, we would distribute \( \bar{z}_{ij}^{OP} \) and \( \bar{z}_{ij}^{OO} \) over the destination regions. Alternatively, we could take the regional input structures of sector \( j \) from the IRIIO table as the starting point. In that case, we would distribute sector \( j \)’s totals \( x_{sj}^p - \sum_l z_{stlj}^{MP} - v_{sj}^p \) over the different region-specific inputs. We have chosen for the latter option. This is because Chinese regions differ considerably in terms of endowments and production technologies.\(^{26}\) Therefore, we think that it matters more to have detailed information of the regional intermediate input structure than to have separate structures for types of production (i.e. \( P \) or \( O \), as in the former option). We thus estimate the initial value

\(^{26}\) To illustrate this point, production in China’s North East (where agriculture is well-developed) tends to use more agricultural products than production in other regions, according to the 2007 IRIIO table. In contrast, production in Northern Municipalities (where China’s cultural, commercial and political center is located and which has thriving service industries) depends more on services than production elsewhere. For example, one unit of food products used 0.41 units of agricultural products and 0.04 units of services in the North East, and 0.17 units of agricultural products and 0.11 units of services the Northern Municipalities.
by using the IRIO tables. That is:

\[
z_{t0}^{op}_{sij} = (x_{sj}^{p} - \sum z_{sij}^{MP} - v_{sj}^{p}) \frac{\Sigma r z_{rsij}}{\Sigma r z_{rsij}}, \quad z_{t0}^{oo}_{sij} = (x_{sj}^{o} - \sum z_{sij}^{MO} - v_{sj}^{o}) \frac{\Sigma r z_{rsij}}{\Sigma r z_{rsij}}.
\]

(A4.4.33)

The RAS procedure then yields \(z_{t0}^{op}_{sij}\) and \(z_{t0}^{oo}_{sij}\).

(b) Allocation of the intermediate deliveries over the regions of origin

In previous step, we obtained the intermediate inputs that are used by the different regions (i.e. \(z_{t0}^{op}_{sij}\) and \(z_{t0}^{oo}_{sij}\)). In this sub-section, we will separate these intermediates according to the region where they originate. This will yield the domestic intermediate inputs in the IRIO table (i.e. \(z_{t0}^{op}_{rsij}\) and \(z_{t0}^{oo}_{rsij}\)).

There are two constraints again for the RAS procedure in this step. From Equation A4.4.24 we have \(\Sigma s \Sigma j (z_{t0}^{op}_{rsij} + z_{t0}^{oo}_{rsij}) = y_{ri}^{o}\). Note that \(y_{ri}^{o}\) was estimated earlier (in sub-section A4.4.5.(1)) and is therefore given in this sub-section. The other constraint follows from Equation A4.4.30 and yields \(\Sigma r z_{t0}^{op}_{rsij} = z_{t0}^{op}_{sij}\) and \(\Sigma r z_{t0}^{oo}_{rsij} = z_{t0}^{oo}_{sij}\), which we have estimated in the previous step (a). The case is illustrated by Table A4.4.8 for the input of good \(i\) from ordinary production. For the shaded cells, it follows from Equations A4.4.26 and A4.4.31 that the sum of row sums equals the sum of column sums. This implies that we can apply the RAS procedure.

<table>
<thead>
<tr>
<th>Table A4.4.8 RAS data for the input of good (i) from ordinary production.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing exports production of industry (j) in region (s)</td>
</tr>
<tr>
<td>(\ldots)</td>
</tr>
<tr>
<td>Region (r)</td>
</tr>
<tr>
<td>Region (w)</td>
</tr>
<tr>
<td>(\ldots)</td>
</tr>
<tr>
<td>Column sums</td>
</tr>
</tbody>
</table>

Our last step is to assign initial values to the domestic intermediate inputs. We
take \( zt_{stij}^{op} \) and \( zt_{stij}^{oo} \) that were obtained in the previous step (a) and distribute it over regions of origin. For this we use the origin shares of the intermediates in the IRIO table, because it is the only data source that includes these proportions. The initial value of the domestic intermediate deliveries are as follows:

\[
z0_{rstij}^{op} = zt_{stij}^{op} \frac{z_{rsij}}{\sum_r z_{rsij}}, \quad z0_{rstij}^{oo} = zt_{stij}^{oo} \frac{z_{rsij}}{\sum_r z_{rsij}} \tag{A4.4.34}
\]
### Appendix 4.5

**Differences between variables in the aggregated IRIOP table and the IRIO table published by the State Information Center, 2007**

<table>
<thead>
<tr>
<th></th>
<th>NE</th>
<th>NM</th>
<th>NC</th>
<th>EC</th>
<th>SC</th>
<th>CR</th>
<th>NW</th>
<th>SW</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value Added (%)</td>
<td>-1.3</td>
<td>-0.6</td>
<td>0.4</td>
<td>-0.6</td>
<td>2.1</td>
<td>-0.9</td>
<td>-5.5</td>
<td>4.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Output (%)</td>
<td>0.3</td>
<td>3.0</td>
<td>-0.1</td>
<td>0.0</td>
<td>5.5</td>
<td>-0.6</td>
<td>-1.7</td>
<td>-0.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Final Consumption (%)</td>
<td>-1.7</td>
<td>-20.3</td>
<td>2.8</td>
<td>-1.0</td>
<td>0.5</td>
<td>7.4</td>
<td>-5.8</td>
<td>6.7</td>
<td>-0.1</td>
</tr>
<tr>
<td>Capital Formation (%)</td>
<td>5.1</td>
<td>-0.6</td>
<td>-1.0</td>
<td>-11.3</td>
<td>-13.2</td>
<td>20.3</td>
<td>9.3</td>
<td>9.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Exports (%)</td>
<td>12.6</td>
<td>31.4</td>
<td>24.3</td>
<td>11.9</td>
<td>50.8</td>
<td>30.5</td>
<td>-18.7</td>
<td>14.4</td>
<td>24.6</td>
</tr>
<tr>
<td>Value added ratio</td>
<td>-0.6</td>
<td>-1.1</td>
<td>0.1</td>
<td>-0.2</td>
<td>-1.0</td>
<td>-0.1</td>
<td>-1.5</td>
<td>1.9</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

Notes: Final consumption and capital formation indicate the delivery by each region of goods and services that are used for domestic final consumption and capital formation. The value added ratio is the aggregate value added divided by the total output. The differences (in value added, output, final consumption, capital formation, and exports) are measured as a percentage of value in the SIC IRIO table. The differences in the value added ratio are absolute (IRIOP table outcome minus SIC IRIO table outcome).