**The Bias in Measuring Vertical Specialization**

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**Abstract:** Most of China's exports are processing exports, which largely depend on imported intermediate inputs. Measuring—within an input-output framework—vertical specialization as the import content of the exports, one would expect to find strong vertical specialization for China. Using the ordinary input-output table, however, this is not the case. Because the production of processing exports is only a small part of total production, the average input structure in the input-output table hides the typical features of processing exports. Adapting the input-output table so as to single out the processing exports, indeed reveals the expected strong vertical specialization in China.

**Keywords:** Vertical Specialization, Processing trade, China, Input-output tables

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## 1. Introduction

It is well known that China's foreign trade has developed very rapidly since the reforms and the country's opening-up to the outside world, and in particular after its entry to the WTO in 2001. For example, between 2001 and 2006, the trade volume (i.e. the total value of imports and exports) showed an average annual growth rate of 28.1%, and exports grew annually by 29.5% on average. The ratio between China's trade volume and its GDP, raised from 38.7% in 1995 to 69.1% in 2006. Yet, this huge trade dependence is somewhat misleading in the sense that the contribution of Chinese exports in generating GDP is relatively modest. The most important reason is that processing trade accounts for about 50% of China's foreign trade. Processing trade refers to importing (all or part of the) raw and auxiliary materials, parts and components, accessories, and packaging materials from abroad free of duty, and re-exporting the finished products after processing or assembly by enterprises within Mainland China.[1] Processing exports (which constituted 54.7% and 52.7% of total exports in 2005 and 2006, see NBS, 2007) induce much less domestic economic activity than ordinary (non-processing) exports do. The value added generated by processing exports is therefore much lower than that of non-processing exports. Lau *et al*. (2006) estimated for 2002 that the value added generated by one million RMB of processing exports was only 38% of the value added generated by one million RMB of non-processing exports.

Vertical specialization (or international fragmentation) is characterized by

[1] The imported goods involved in processing trade (usually called processing imports) can only be used to produce goods for processing exports. According to the regulations, processing imports are not allowed to be used for other purposes.

"increasing interconnectedness of production processes in a vertical trading chain that stretches across many countries, with each country specializing in particular stages of a good's production sequence" (Hummels *et al*., 2001, p. 76). Given that a large part of China's exports are processing exports and given that these processing exports rely heavily on imports, China's exported goods are indirectly "made" by many countries. China's processing trade can thus be seen as an exemplary case of vertical specialization.

As a measure for vertical specialization, Hummels *et al*. (2001) propose to use the imported input content of exports. In order to take not only the direct but also the indirect requirements into consideration, they adopt an input-output framework. When applied to the case of China, one would expect the exports to have a high import content. The reason is that the production of processing exports uses only little domestic inputs and relies strongly on imported inputs. In contrast, the production processes of goods for domestic consumption and for non-processing exports depend much more on domestic inputs and much less on imported inputs. Because processing exports are a major part of the total exports, Chinese exports should have a high import content.

This, however, is not confirmed by the calculations. Although processing exports are an important part of total exports, the production of these goods is only a very minor part of total production. The input-output tables do not reflect the typical nature of producing the processing exports. Instead, they reflect the average production structure in which producing processing exports plays only a minor role. This means that while China's trade is characterized by a large degree of vertical specialization, the

input-output measure for vertical specialization will not indicate this. The reason is that the typical production structure corresponding to vertical specialization is "hidden" by the input-output table. The present paper uses a unique input-output table for China that distinguishes between three types of production, one of them corresponding to processing exports. Applying this table allows for a quantification of the bias in measuring vertical specialization.

## 2. Methodology

In measuring vertical specialization, we will follow the approach proposed by Hummels *et al*. (2001). Starting point is an input-output table with $n$ industries. Let matrix $\mathbf{Z}$ denote the domestic interindustry flows $z_{ij}$ from industry $i$ to industry $j$, $\mathbf{e}$ the vector of exports $e_i$, $\mathbf{f}$ the vector of domestic final demands $f_i$ (including household and government consumption, and gross fixed capital formation), $\mathbf{x}$ the vector of industry gross outputs $x_i$, and $\mathbf{M}$ the matrix with imports $m_{ij}$ of product $i$ by industry $j$.[2] Matrix $\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1}$ gives the direct requirement for domestic input $i$ per unit of output $j$ (i.e. $a_{ij} = z_{ij} / x_j$). Matrix $\mathbf{B} = \mathbf{M}\hat{\mathbf{x}}^{-1}$ gives the direct requirement for imported input $i$ per unit of output $j$ (i.e. $b_{ij} = m_{ij} / x_j$). The direct import multiplier for industry $j$ is given by the $j$th column sum of $\mathbf{B}$, i.e. the $j$th element of the row vector $\boldsymbol{\lambda}' = \mathbf{u}'\mathbf{B}$

[2] Matrices are indicated by boldfaced capital letters (e.g. **A**), vectors are columns by definition and are indicated by boldfaced lowercase letters (e.g. **x**), and scalars (including elements of matrices or vectors) are indicated by italicized lowercase letters (e.g. $c$ or $\alpha$). A prime indicates transposition (e.g. $\mathbf{x}'$) and a hat (or circumflex) indicates a diagonal matrix (e.g. $\hat{\mathbf{x}}$) with the elements of a vector (i.e. **x**) on its main diagonal and all other entries equal to zero.

where **u** is the summation vector consisting of ones. $\lambda_j$ thus gives the total imports value required to produce one unit of good *j*. The export-weighted average of the direct import multipliers yields the direct vertical specialization share (*DVS*),

$$DVS = \frac{\Sigma_j \lambda_j e_j}{\Sigma_j e_j} = \frac{\boldsymbol{\lambda}'\mathbf{e}}{\mathbf{u}'\mathbf{e}} = \frac{\mathbf{u}'\mathbf{B}\mathbf{e}}{\mathbf{u}'\mathbf{e}} \qquad (1)$$

Producing a product for exports (or domestic consumption) requires imported inputs but also domestic inputs, whose production requires imported inputs. The first is the direct effect (which is covered by $\lambda_j$), the second is an indirect effect. The total effect takes the direct and all indirect effects into consideration and is obtained from the so-called Leontief inverse $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$. Its typical element $l_{ij}$ gives the domestic production of good *i* that is necessary to satisfy one unit of exports (or domestic consumption) of good *j*. This implies that one unit of exports of good *j* requires $\lambda_i l_{ij}$ of imports that run through industry *i*. Since this holds for all *i*, we have that the total amount of imports that is required per unit of exports of good *j* equals $\mu_j = \Sigma_i \lambda_i l_{ij}$. This is the total import multiplier for industry *j* and is—using matrix notation—given by the *j*th element of the row vector $\boldsymbol{\mu}' = \boldsymbol{\lambda}'\mathbf{L}$. The export-weighted average of the total import multipliers yields the total vertical specialization share (*TVS*),

$$TVS = \frac{\Sigma_j \mu_j e_j}{\Sigma_j e_j} = \frac{\boldsymbol{\mu}'\mathbf{e}}{\mathbf{u}'\mathbf{e}} = \frac{\boldsymbol{\lambda}'\mathbf{L}\mathbf{e}}{\mathbf{u}'\mathbf{e}} = \frac{\mathbf{u}'\mathbf{B}\mathbf{L}\mathbf{e}}{\mathbf{u}'\mathbf{e}} \qquad (2)$$

## 3. A Closer Look at China's Processing Trade

Processing trade is the main body of China's foreign trade and more than 80% (83.7% in 2005 and 84.8% in 2006) of processing trade in China is done by foreign-invested enterprises (FIEs).[3] At the same time, we may distinguish two types of processing trade in China: processing with imported materials (PIM) and processing with customer's materials (PCM). PIM is the main form, accounting for more than 70% of the processing trade value (e.g. 73.6% in 2002). Under PIM, the business enterprise in China makes a foreign exchange payment for imported raw and auxiliary materials, parts and components, accessories, and exports the finished products after processing or assembly. Under PCM, however, the business enterprise does not have to make a foreign exchange payment for the imports. The imported materials and parts are supplied by the foreign party that is also responsible for selling the finished products. The business enterprise charges the foreign party a processing fee. Concerning the imported material content of the finished products, PCM is higher than PIM.

Table 1 gives the import dependency ratio for processing trade with imported

[3] In China there are three types of FIEs within the territory of China: Sino-Foreign Equity Joint Ventures (EJV); Sino-Foreign Co-operative Joint Ventures (CJV); and Wholly Foreign-Owned Enterprises (WFOE). An EJV is a limited liability company (i.e. the investor or partner is not personally liable for the debts that the company might make) and has the status of a Chinese legal person. Currently, an EJV is still the most used type in China. It can e.g. buy land, hire Chinese employees independently, and construct buildings. In a CJV, the Chinese company usually provides the labour, land use rights and factory buildings, while the foreign company brings in the necessary technology and key equipment, as well as the capital. This joint venture is based on a contract in which matters such as the terms of co-operation, the division of earnings, the ownership of property upon the termination of the contract term, and the sharing of risks and losses are laid down. A WFOE is a limited liability company established within the territory of China in accordance with relevant Chinese laws, with foreign investment only. A WFOE has the status of a Chinese legal person, taking all risks and possessing all profits.

materials (PIM) by FIEs. Due to lack of data not all trade could be included, but the table still provides an adequate sketch of a large part of China's exports. The import dependency ratio is obtained from dividing the import value by the export value. It should be mentioned that the ratios shown in Table 1 slightly underestimate the actual situation. This is because the production of the goods involved in processing exports also uses other imports indirectly. These are products imported through other channels (i.e. not directly by the FIEs), such as cotton, crude oil, and iron ore.

**INSERT TABLE 1**

The results show a declining trend in the import dependency ratio, from more then 90% in the early 1990s to a constant 65-70% for the years after 1997. With respect to commodities, it turns out that the more capital-intensive the commodities are, the higher is the import dependency ratio. High-tech FIEs, for instance, import most of the raw materials, accessories and components they require. In a survey for 2000, Jiang *et al*. (2001) found that 73.9% of the high-tech FIEs in Beijing rely mainly on imported materials (and 56.0% in Shanghai). The reason for this is twofold. On the one hand, the technology and quality of domestic products could not meet the requirements of FIEs. On the other hand, before 2007, the Chinese tax policy worked against the use of domestic accessories. Imported materials for processing trade were exempted from taxes, while enterprises were not reimbursed for the taxes they paid on domestic products. It should be stressed though that the situation started changing recently. Some

FIEs point out that for part of the accessories they require, both the quality and the price of domestic products have become very competitive. If the preferential tax policy can be extended so as to cover also domestic intermediate inputs, the domestic accessory ratio will increase and might at the same time reduce the cost of FIEs' exported commodities.

## 4. Adapting the Input-Output Table

The results in Table 1 convincingly showed that a large part of China's exports relies on imports and has a production structure that is very different from industries that produce for the domestic market or for non-processing exports. The import dependency of the non-processing exports is substantially lower than that of the processing exports. The input-output table for China, however, does not reflect this. Therefore, we will use a table that has been adapted so as to make a distinction possible between processing exports, non-processing exports and domestic production.

In the same way as input-output tables have been constructed that make a distinction between rural industries and urban industries, or interregional input-output tables that distinguish several regions, the table used in this paper distinguishes according to destination of the product (see Lau *et al*., 2006, 2007). Chinese statistics allow for distinguishing between industries whose production is for domestic use, for

processing exports and for non-processing exports. The table is based on China's input-output table for 2002 and has 42 industries, which have been aggregated to 27 (highlighting the industries that play an important role in processing trade). The structure of the input-output table is given in Table 2.

**INSERT TABLE 2**

With regard to the destination of the products, China's domestic production is divided into three types. The first type produces for domestic use only and is denoted by *D*, the second type that produces processing exports and is denoted by *P*, and the third type, denoted by *N*, contains the production of non-processing exports and also contains "other production of FIEs". In particular the last group requires additional explanation. A large percentage of the products by FIEs is directly exported (45.1% of its sales revenue in 2002, 46.3% in 2005). The other part of their production, however, is used as domestic intermediate input or is for domestic final demand.[4] Yet, this other production of FIEs is in Table 2 not listed under production for domestic use, but taken together with non-processing exports. The reason for doing so is twofold. First, the prime reason is that the inputs for most of the other production of FIEs are imported components, parts, or materials. The input structure is thus quite different from the input structure of production for domestic use and more similar to that of non-processing exports

[4] For FIEs, the main interests of the foreign parties are different. Western and Japanese investors primarily have a market-orientation, targeting to sell more products in the Chinese market. The investors from Hongkong, Macao and Taiwan (in the Chinese literature and statistics indicated as overseas China, versus mainland China) mainly have an export-orientation, considering China as a low-cost production base and export-platform (Xu and Tan, 2003; Buckley and Meng, 2005).

production (Lau *et al*., 2006, 2007). Second, some of the other production of FIEs is used to produce commodities that are exported and is thus indirectly exported. This is because some FIEs—in order to lower their costs—do not use their processing imports directly to produce export goods. Instead, they transfer the imported goods to other FIEs who re-process or assemble them, after which they export the finished products. These exports are classified in the statistics as non-processing exports.

The details of the construction of the input-output table as outlined in Table 2 are given by Chen *et al*. (2005) and Lau *et al*. (2007). When summarized, the following three issues have been key. First, concordance between international trade statistics and input-output classification was required. China's trade statistics provide detailed data for processing and for non-processing exports as well as for their corresponding imports, all by commodity. The definitions, conventions and method of measurements of these trade statistics, however, differ from those used in input-output analysis. Therefore, a "concordance table" between the trade statistics and the input-output classification had to be constructed. Using this table, the trade data (which are classified according to the Harmonized System Code) could be regrouped into the industry classification used for input-output tables.[5]

Second, conversion of the valuation used in international trade statistics into that in input-output analysis was required. In the trade statistics, China's exports are measured on a FOB (free on board) basis while its imports are on a CIF (cost, insurance and

[5] The Harmonized System Code is an international method of classifying products for trading purposes. The classification is used by customs officials around the world to determine the duties, taxes and regulations that apply to the products.

freight) basis. Input-output tables, however, valuate the products in producer's prices. All trade data had therefore to be re-valued in producer's prices.

Third, the estimation of the input coefficients for each of the three categories (*D*, *P*, and *N*) of production. China Custom Statistics did not only provide total imports by commodity, but also imports used for processing exports by commodity. The reason that such data are available is that the imports used for processing exports are free of duty and there are special rules to ensure that these processing imports are only used for processing exports. On the basis of these data (and other related sources), the transaction table of imported intermediate inputs for the production of processing exports (i.e. $\mathbf{M}^P$) could be estimated. Unfortunately, the data available for estimating $\mathbf{M}^D$ and $\mathbf{M}^N$ were limited. Therefore it was assumed that the rate of imported inputs for non-processing exports is less than that for processing exports but higher than that of production for domestic use. For the estimation, the proportional import assumption was adopted and a modified RAS procedure was used to reconcile the import matrices with the margins (that were known from the statistics).

## 5. Adapting the Methodology

Whereas we had *n* industries in Section 2, we now have 3*n* industries according to Table 2. In its partitioned form, the $3n \times 3n$ matrix **A** with the direct requirements for domestic inputs per unit of output now becomes

$$\mathbf{A} = \begin{bmatrix} \mathbf{A}^{DD} & \mathbf{A}^{DP} & \mathbf{A}^{DN} \\ 0 & 0 & 0 \\ \mathbf{A}^{ND} & \mathbf{A}^{NP} & \mathbf{A}^{NN} \end{bmatrix}$$

where $\mathbf{A}^{IJ} = \mathbf{Z}^{IJ}(\hat{\mathbf{x}}^{J})^{-1}$, with *I* = *D*, *N*, and *J* = *D*, *P*, *N*. The matrices with the direct requirements for imported inputs per unit output are given by $\mathbf{B}^{D}$, $\mathbf{B}^{P}$, and $\mathbf{B}^{N}$, where $\mathbf{B}^{J} = \mathbf{M}^{J}(\hat{\mathbf{x}}^{J})^{-1}$ with *J* = *D*, *P*, *N*. The direct import multipliers for industry *j* are again obtained as the *j*th column sum of the direct import requirements matrices, now distinguishing between the destination of the production. That is, $(\boldsymbol{\lambda}^{D})' = \mathbf{u}'\mathbf{B}^{D}$, $(\boldsymbol{\lambda}^{P})' = \mathbf{u}'\mathbf{B}^{P}$, and $(\boldsymbol{\lambda}^{N})' = \mathbf{u}'\mathbf{B}^{N}$, and for industry *j* we have $\lambda_j^{D}$, $\lambda_j^{P}$, and $\lambda_j^{N}$, respectively. The direct vertical specialization share for processing exports ($DVS^{P}$) is given by the weighted average of the corresponding direct import multipliers, using the processing exports as weights. This yields

$$DVS^{P} = \frac{\Sigma_j \lambda_j^{P} e_j^{P}}{\Sigma_j e_j^{P}} = \frac{(\boldsymbol{\lambda}^{P})'\mathbf{e}^{P}}{\mathbf{u}'\mathbf{e}^{P}} = \frac{\mathbf{u}'\mathbf{B}^{P}\mathbf{e}^{P}}{\mathbf{u}'\mathbf{e}^{P}} \qquad (3)$$

For the non-processing exports we have $DVS^{N} = \mathrm{u}'\mathrm{B}^{N}\mathrm{e}^{N} / \mathrm{u}'\mathrm{e}^{N}$. For the type producing only for domestic use, we will also calculate an average direct import multiplier, using the domestic final demands as weights. It is given by $\overline{DIM}^{D} = \mathbf{u}'\mathbf{B}^{D}\mathbf{f}^{D} / \mathbf{u}'\mathbf{f}^{D}$. It should be stressed that the average import multiplier can, in this case, not be interpreted as a direct vertical specialization share, because the type does not export. Still, it will be useful to compare the average amount of imports (in RMB) required per RMB of

production across the three types, because it indicates the production's import dependence.

The national direct vertical specialization share is obtained as the weighted average of $DVS^P$ and $DVS^N$

$$DVS = \frac{\Sigma_j \lambda_j^P e_j^P + \Sigma_j \lambda_j^N e_j^N}{\Sigma_j e_j^P + \Sigma_j e_j^N} = \frac{DVS^P \times \mathbf{u}'\mathbf{e}^P + DVS^N \times \mathbf{u}'\mathbf{e}^N}{\mathbf{u}'\mathbf{e}^P + \mathbf{u}'\mathbf{e}^N} \tag{4}$$

In a similar fashion also the total import multipliers are obtained. For the partitioned form of the Leontief inverse, we have

$$\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} = \begin{bmatrix} \mathbf{L}^{DD} & \mathbf{L}^{DP} & \mathbf{L}^{DN} \\ 0 & \mathbf{I} & 0 \\ \mathbf{L}^{ND} & \mathbf{L}^{NP} & \mathbf{L}^{NN} \end{bmatrix}$$

This yields

$$(\boldsymbol{\mu}^D)' = (\boldsymbol{\lambda}^D)'\mathbf{L}^{DD} + (\boldsymbol{\lambda}^N)'\mathbf{L}^{ND}$$

$$(\boldsymbol{\mu}^P)' = (\boldsymbol{\lambda}^D)'\mathbf{L}^{DP} + (\boldsymbol{\lambda}^P)' + (\boldsymbol{\lambda}^N)'\mathbf{L}^{NP}$$

$$(\boldsymbol{\mu}^N)' = (\boldsymbol{\lambda}^D)'\mathbf{L}^{DN} + (\boldsymbol{\lambda}^N)'\mathbf{L}^{NN}$$

The *j*th element of each of these vectors gives the total amount of imports that is directly and indirectly used for one RMB of final demand for product *j*, no matter whether the final product is exported or is for domestic use. The total vertical

specialization share for processing exports ($TVS^P$) is given by the weighted average of the corresponding total import multipliers, using the processing exports as weights. That is

$$TVS^P = \frac{\Sigma_j \mu_j^P e_j^P}{\Sigma_j e_j^P} = \frac{(\boldsymbol{\mu}^P)'\mathbf{e}^P}{\mathbf{u}'\mathbf{e}^P} \tag{5}$$

For the non-processing exports we have $TVS^N = (\boldsymbol{\mu}^N)'\mathbf{e}^N / \mathbf{u}'\mathbf{e}^N$. The average total import multiplier for the type producing only for domestic use is given by $\overline{TIM}^D = (\boldsymbol{\mu}^D)'\mathbf{f}^D / \mathbf{u}'\mathbf{f}^D$. Again, it indicates the average total import dependence of the final products by this group of industries, but cannot be interpreted as a measure of vertical specialization because the type does not export.

The national total vertical specialization share is again obtained as the weighted average of $TVS^P$ and $TVS^N$

$$TVS = \frac{\Sigma_j \mu_j^P e_j^P + \Sigma_j \mu_j^N e_j^N}{\Sigma_j e_j^P + \Sigma_j e_j^N} = \frac{TVS^P \times \mathbf{u}'\mathbf{e}^P + TVS^N \times \mathbf{u}'\mathbf{e}^N}{\mathbf{u}'\mathbf{e}^P + \mathbf{u}'\mathbf{e}^N} \tag{6}$$

## 6. Empirical Analysis

### *6.1. The Vertical Specialization Shares*

Based on the adapted input-output table for China in 2002, the vertical specialization

(VS) shares have been calculated and the results are listed in Table 3. The findings show a clear distinction between the three types of production. Per 100 RMB of gross output, the value of the direct imports amounts (on average) to 67 RMB for processing exports, to 24 RMB for non-processing exports, and to 1 RMB when producing for domestic use. Similar differences are found when also the indirect import requirements are taken into account. Per 100 RMB of final product (no matter whether exported or for domestic use) the average import values are 71, 36 and 2 RMB, respectively. The national direct and total VS shares according to (4) and (6) yield that per 100 RMB of exports on average 48 RMB of direct imports and 56 RMB of direct and indirect imports are required.[6] This average VS share is substantially larger than the results reported in Hummels *et al*. (2001) for ten OECD countries.[7] Our own calculation for the U.S. in 2002 yields a direct VS share of 0.067 and a total VS share of 0.103.

Another remarkable outcome is the difference between the direct and the total VS shares for the three categories. For processing exports, the (average) share of direct imports in total imports is no less than 93%, indicating that imports are primarily direct. For non-processing exports we have a 66% share, indicating that these exports require other domestic products as input, which—in their turn—require imports. The role of imports through such indirect effects is the strongest in the case of production for domestic use only, i.e. the average share of direct imports in total imports being only 39%.

[6] Processing exports in 2002 amount to 179.9 billion US$ (55.3% of the total exports) and non-processing exports are 145.7 billion US$ (44.7%).
[7] In addition, they find an indication "that smaller countries have higher VS shares." (Hummels *et al.*, 2001, p. 83).

**INSERT TABLE 2**

At the level of separate industries, Petroleum and (nuclear) fuel processing, and coking (industry 8) shows a very large dependence on imports that is primarily direct. The difference between processing and non-processing exports in terms of import dependence is remarkably small. On the other hand, the difference between production for exports and production for domestic use only is extremely large. It underlines that domestic petroleum is essentially used for domestic use.[8] Another industry that exhibits a large import dependence is Telecommunication and computer manufacturing (industry 16, which includes electronic equipment). For many high-technology goods, China is actually an assembly base instead of a manufacturing place. According to the OECD's trade statistics for ICT goods,[9] China surpassed the United States in 2004 and became the biggest ICT exporter. The breakdown of China's trade in ICT goods shows that China mainly imports electronic components (65% of its total ICT imports) to assemble and export computer and related equipment, audio and video equipment, and telecommunications equipment (summing to 80% of China's total ICT exports).

Note that—for the processing and non-processing exports—the industries with a VS share that is above average are essentially in the manufacturing sector (i.e. industries 3-18). Agriculture, mining and extraction and almost all service industries exhibit VS shares that are below average. Finally, observe that Finance and insurance (industry 25)

[8] Although China's petroleum import is just 6% of the world's trade volume, China's dependency ratio of imported petroleum has increased in the past several years. The ratio of imported petroleum to China's total petroleum consumption rose from 29.1% in 2001 to 47.3% in 2006.

[9] See http://www.oecd.org/document/8/0,2340,en_2649_201185_35833096_1_1_1_1,00.html. The definition of ICT goods by the OECD comprises five categories: Telecommunication equipment, Computer & related equipment, Electronic components, Audio & video equipment, and Other ICT goods.

in non-processing exports has no direct imports, but does have 19 RMB of indirect imports per 100 RMB of its exports.

*6.2. The Bias in the Vertical Specialization Shares*

The last two columns in Table 3 are obtained from the "ordinary" input-output table for China in 2002. That is, the table where no distinction is made between the specific types of production (processing exports, non-processing exports, and production for domestic use only). The result is that the national direct VS share reduced to 0.149, and the total VS share to 0.245. These outcomes are somewhat larger than the findings in Hummels *et al*. (2001) for large countries, but substantially smaller than our findings in the previous subsection (0.476 and 0.556, respectively). The results from the "ordinary" input-output table seriously underestimate the vertical specialization in China. The reason is that the characteristic feature of VS (i.e. production for exports is highly import dependent) is no longer visible in the "ordinary" input-output table, because producing export goods is a relatively minor part of the production (in particular for a large country such as China).

The "ordinary" input-output table is obtained from Table 2 by aggregating over the sectors *D*, *P*, and *N*. For example, for the import matrix we have $M = M^{\mathrm{D}} + M^{\mathrm{P}} + M^{\mathrm{N}}$ and the gross output vector yields $\mathbf{x} = \mathbf{x}^{D} + \mathbf{x}^{P} + \mathbf{x}^{N}$. According to (1), the national direct VS share is given by $DVS = \mathbf{u}'\mathbf{B}\mathbf{e} / \mathbf{u}'\mathbf{e}$, which is a weighted average of the direct import multipliers $\lambda_j$, with $\boldsymbol{\lambda}' = \mathbf{u}'\mathbf{B}$. For these import multipliers

we have

$$\boldsymbol{\lambda}' = \mathbf{u}'\mathbf{B} = \mathbf{u}'\mathbf{M}\hat{\mathbf{x}}^{-1} = \mathbf{u}'(\mathbf{M}^D + \mathbf{M}^P + \mathbf{M}^N)(\mathbf{x}^D + \mathbf{x}^P + \mathbf{x}^N)^{-1}$$

$$= \mathbf{u}'(\mathbf{B}^D\hat{\mathbf{x}}^D + \mathbf{B}^P\hat{\mathbf{x}}^P + \mathbf{B}^N\hat{\mathbf{x}}^N)(\mathbf{x}^D + \mathbf{x}^P + \mathbf{x}^N)^{-1}$$

$$= (\boldsymbol{\lambda}^D)'\hat{\boldsymbol{\omega}}^D + (\boldsymbol{\lambda}^P)'\hat{\boldsymbol{\omega}}^P + (\boldsymbol{\lambda}^N)'\hat{\boldsymbol{\omega}}^N \qquad (7)$$

where $\hat{\boldsymbol{\omega}}^J = \hat{\mathbf{x}}^J\hat{\mathbf{x}}^{-1}$ or $\omega_i^J = x_i^J / x_i$, with $J$ = $D$, $P$, $N$. That is, the direct import multiplier for industry $i$ is a weighted average of the direct import multiplier for the processing exports industry $i$, the non-processing exports industry $i$, and the industry $i$ that produces only for domestic use. The weights are the shares of gross output of each of these three types in the total gross output of industry $i$.

In contrast, the national direct VS share calculated in (4) yields $DVS = \boldsymbol{\lambda}'\mathbf{e} / \mathbf{u}'\mathbf{e}$ with

$$\boldsymbol{\lambda}' = (\boldsymbol{\lambda}^P)'\hat{\boldsymbol{\upsilon}}^P + (\boldsymbol{\lambda}^N)'\hat{\boldsymbol{\upsilon}}^N \qquad (8)$$

where $\hat{\boldsymbol{\upsilon}}^J = \hat{\mathbf{e}}^J\hat{\mathbf{e}}^{-1}$ or $\upsilon_i^J = e_i^J / e_i$, with $J = P, N$ and $e_i = e_i^P + e_i^N$.

Comparing the expressions (7) and (8), we see that in deriving the direct VS share from the detailed input-output table adopts the shares of processing and non-processing exports as weights, while using the "ordinary" input-output table adopts the output shares as weights and includes the production for domestic use only. The

same applies to the total VS shares approximately.[10] In (8), the total of all processing exports are 55.3% of the total exports (and non-processing exports' share is thus 44.7%). In (7), the total output of the processing exports is 4.8% of total gross output, the output share for non-processing is 12.8%, and for industries producing for domestic use only it is 82.4%.

## 7. Conclusions

An important part of China's trade is processing trade. That is, goods are imported from abroad, assembled in China and returned as export goods. This is exactly what has been coined vertical specialization (VS), outsourcing, or slicing the global value chain. Hummels *et al*. (2001) have proposed to measure VS as the import content of a country's exports. Given the fact that around 55% of China's exports are processing exports (with a huge import dependency), one would expect that China's VS share is much larger than the VS shares of countries with a comparable size. The results obtained from the ordinary input-output table for China cannot substantiate this hypothesis. Per 100 RMB of exports, on average 25 RMB of imports are required.

In this paper, we have shown that the strong import dependence that is so characteristic for processing exports is hidden in the ordinary input-output table. The input-output table gives for each industry the average structure of domestic and

[10] The total VS share includes the inverse of the matrix (**I** – **A**). Because this is a non-linear operation an aggregation bias will occur, in the sense that the inverse of the aggregate matrix differs from the aggregate of the original inverse.

imported inputs. Most production (over 80%), however, takes place in industries that focus on domestic use only, while only a small part (5%) of production occurs in industries involved in processing exports. Therefore, the production structure of the Chinese economy as sketched by the input-output table largely resembles the structure of the industries aiming at the domestic market only.

The typical feature of processing exports can be made visible when this type of production is singled out. This paper has used an adapted input-output table that for each industry distinguishes between the production for processing exports, for non-processing exports and for domestic final use only. It turns out that the total VS share of processing exports is no less than 0.71, that of non-processing exports is much lower, 0.36, while the overall total VS share is 0.56. As was hypothesized, this is a formidable difference with, for example, the U.S. that has a total VS share of 0.10 in 2002.

Using the ordinary input-output table thus seriously underestimates the measurement of VS. Although our results were obtained for China, it should be emphasized that it is likely to hold also for other countries with much processing trade (e.g. Mexico, Indonesia, Vietnam). Whereas processing trade may be very important for the exports (and thus a dominant factor in measuring VS), the corresponding production is relatively unimportant when compared to the production for domestic use. In such cases, the ordinary input-output table cannot reflect the role of processing trade adequately and will yield an underestimation of VS. The case of China is rather unique, because data exist that allowed us to quantify the extent of underestimation. Such data

exist due to China's regulations, which state that producers involved in processing trade were exempted from taxes on imported goods and that processing imports can only be used for producing processing exports. Monitoring such regulations necessitates that customs and tax authorities gather very specific information, which exactly fulfils the requirements to adapt the input-output table. Whereas China's case is not unique and is likely to hold for other countries as well, it will be difficult to verify because the Chinese data are unique.

As a final remark, we would like to speculate on the developments over time. Although full data sets are lacking, we have been able to estimate that the direct VS share for processing exports in 2000 was 0.698. Compared with the 0.666 in 2002, this implies a 4.6% decrease. There are two possible explanations. First, due to the quality improvement of domestic (i.e. Chinese) accessories, FIEs have increased their domestic accessories ratio. For instance, for Japan-invested enterprises, the domestic accessory ratio in China increased from only 20.0% in 1992 to 49.6% in 2002 (Jiang, 2002). Second, China's policy on processing trade has recently been adjusted in an effort to strengthen environmental protection as well as to reduce China's trade surplus with large trade partners. The adjustments include export restrictions on certain products of several labor-intensive or energy-intensive industries (including textiles, chemicals, plastic materials and furniture) and the removal or decline of tax rebates for certain export products.

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**Table 1.** Import dependency ratio of processing trade with imported materials (PIM) by foreign-invested enterprises (FIEs)

| Year | Export value (million USD) | Import value (million USD) | Import dependency ratio (%) |
|---|---|---|---|
| 1990 | 6368 | 5741 | 90.15 |
| 1991 | 9879 | 9143 | 92.55 |
| 1992 | 14446 | 13279 | 91.92 |
| 1995 | 39177 | 34409 | 87.83 |
| 1996 | 48595 | 37757 | 77.70 |
| 1997 | 57663 | 42898 | 74.39 |
| 1998 | 61958 | 43211 | 69.74 |
| 1999 | 64161 | 45283 | 70.58 |
| 2000 | 84100 | 58894 | 70.03 |
| 2001 | 92252 | 59541 | 64.54 |
| 2002 | 117963 | 81523 | 69.11 |
| 2003 | 169219 | 115697 | 68.37 |
| 2004 | 236415 | l57039 | 66.43 |

Source: Calculated by the authors from data in Wang and Lv (2005)

**Table 2.** China's expanded input-output table for analyzing processing trade

| | Intermediate use | | | Final use | | |
|---|---|---|---|---|---|---|
| | *D* | *P* | *N* | *DFD* | *EXP* | *TOT* |
| *D* | $\mathbf{Z}^{DD}$ | $\mathbf{Z}^{DP}$ | $\mathbf{Z}^{DN}$ | $\mathbf{f}^{D}$ | 0 | $\mathbf{x}^{D}$ |
| *P* | 0 | 0 | 0 | 0 | $\mathbf{e}^{P}$ | $\mathbf{x}^{P}$ |
| *N* | $\mathbf{Z}^{ND}$ | $\mathbf{Z}^{NP}$ | $\mathbf{Z}^{NN}$ | $\mathbf{f}^{N}$ | $\mathbf{e}^{N}$ | $\mathbf{x}^{N}$ |
| *IMP* | $\mathbf{M}^{D}$ | $\mathbf{M}^{P}$ | $\mathbf{M}^{N}$ | $\mathbf{f}^{M}$ | 0 | $\mathbf{x}^{M}$ |
| *VA* | $(\mathbf{v}^{D})'$ | $(\mathbf{v}^{P})'$ | $(\mathbf{v}^{N})'$ | | | |
| *TOT* | $(\mathbf{x}^{D})'$ | $(\mathbf{x}^{P})'$ | $(\mathbf{x}^{N})'$ | | | |

Notes: *D* = industries producing for domestic use; *P* = industries producing processing exports; *N* = industries producing non-processing exports and other production of FIEs; *DFD* = domestic final demand; *EXP* = exports; *TOT* = gross industry outputs (and total imports in the column *TOT*); *IMP* = imports; and *VA* = value added.

**Table 3. VS shares for China, 2002**

| | Industry | Processing Exports (P) | | Non-processing Exports (N) | | Production for Domestic Use (D)[1] | | Using the aggregated table | |
|---|---|---|---|---|---|---|---|---|---|
| | | Direct | Total | Direct | Total | Direct | Total | Direct | Total |
| 01 | Agriculture | 0.439 | 0.494 | 0.094 | 0.174 | 0.001 | 0.007 | 0.004 | 0.047 |
| 02 | Mining and oil and gas extraction | 0.490 | 0.565 | 0.163 | 0.285 | 0.008 | 0.017 | 0.023 | 0.084 |
| 03 | Food and tobacco manufacturing | 0.507 | 0.566 | 0.111 | 0.190 | 0.001 | 0.008 | 0.033 | 0.089 |
| 04 | Textile goods | 0.639 | 0.697 | 0.199 | 0.272 | 0.002 | 0.012 | 0.107 | 0.209 |
| 05 | Apparel, leather and related products | 0.593 | 0.661 | 0.198 | 0.282 | 0.002 | 0.011 | 0.175 | 0.280 |
| 06 | Wood product manufacturing and furniture | 0.583 | 0.651 | 0.180 | 0.317 | 0.003 | 0.013 | 0.087 | 0.182 |
| 07 | Paper and products, and printing | 0.540 | 0.616 | 0.206 | 0.345 | 0.003 | 0.013 | 0.089 | 0.182 |
| 08 | Petroleum and fuel processing, and coking | 0.730 | 0.775 | 0.684 | 0.734 | 0.055 | 0.070 | 0.164 | 0.235 |
| 09 | Chemicals | 0.628 | 0.710 | 0.349 | 0.510 | 0.007 | 0.022 | 0.091 | 0.196 |
| 10 | Non-metallic mineral products manufacturing | 0.551 | 0.627 | 0.248 | 0.397 | 0.004 | 0.017 | 0.057 | 0.145 |
| 11 | Metals smelting and pressing | 0.692 | 0.737 | 0.281 | 0.482 | 0.006 | 0.022 | 0.056 | 0.157 |
| 12 | Metal products | 0.738 | 0.775 | 0.232 | 0.462 | 0.003 | 0.018 | 0.107 | 0.211 |
| 13 | General and special equipment manufacturing | 0.694 | 0.746 | 0.371 | 0.530 | 0.007 | 0.021 | 0.116 | 0.226 |
| 14 | Transportation equipment manufacturing | 0.690 | 0.754 | 0.326 | 0.537 | 0.007 | 0.021 | 0.092 | 0.215 |
| 15 | Electric equipment manufacturing | 0.724 | 0.771 | 0.344 | 0.519 | 0.008 | 0.022 | 0.184 | 0.289 |
| 16 | Telecommunication and computer manufacturing | 0.822 | 0.842 | 0.511 | 0.621 | 0.006 | 0.020 | 0.307 | 0.451 |
| 17 | Instruments and office machinery manufacturing | 0.606 | 0.640 | 0.363 | 0.512 | 0.049 | 0.063 | 0.531 | 0.564 |
| 18 | Other manufacturing products | 0.620 | 0.678 | 0.124 | 0.214 | 0.002 | 0.009 | 0.073 | 0.137 |
| 19 | Electricity, gas, and water (production and supply) | 0.366 | 0.458 | 0.167 | 0.273 | 0.015 | 0.025 | 0.058 | 0.119 |
| 20 | Construction | 0.659 | 0.719 | 0.252 | 0.426 | 0.013 | 0.028 | 0.016 | 0.129 |
| 21 | Transport, warehousing and post | 0.456 | 0.536 | 0.164 | 0.334 | 0.003 | 0.017 | 0.031 | 0.109 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 22 | Information and computer services and software | 0.571 | 0.603 | 0.262 | 0.366 | 0.025 | 0.033 | 0.039 | 0.138 |
| 23 | Wholesale and retail trade | 0.410 | 0.483 | 0.172 | 0.268 | 0.003 | 0.010 | 0.056 | 0.113 |
| 24 | Accommodation, eating and drinking places | 0.433 | 0.500 | 0.100 | 0.193 | 0.001 | 0.008 | 0.020 | 0.075 |
| 25 | Finance and insurance | 0.265 | 0.352 | 0.000 | 0.192 | 0.008 | 0.014 | 0.009 | 0.054 |
| 26 | Renting and commercial service | 0.632 | 0.669 | 0.327 | 0.436 | 0.004 | 0.014 | 0.080 | 0.201 |
| 27 | Other services | 0.494 | 0.561 | 0.139 | 0.235 | 0.007 | 0.015 | 0.020 | 0.081 |
| | **Total Average** | **0.666** | **0.713** | **0.241** | **0.363** | **0.007** | **0.018** | **0.149** | **0.245** |
| | **National average for all exports** | **Direct: 0.476** | | **Total: 0.556** | | | | **0.149** | **0.245** |

Note: For D, the total averages are calculated using the domestic final demands in $\mathbf{f}^D$ as weights.