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Measuring the Vertical Specialization in Chinese Trade

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Abstract

In recent years, two important related developments have transformed the nature of world trade: the explosive growth of Chinese trade, and the growth of vertically specialized trade due to international production fragmentation. The literature in each of these two separate topics is large and growing. However, very few papers quantitatively assess these two trends together. In this paper, we measure the degree to which Chinese trade has become vertically specialized, using a new measure adapted from Hummels, Ishii and Yi (2001). By making use of the latest Chinese input-output tables, and a new detailed Chinese trade data set which distinguishes processing trade from other forms of trade, we develop a new method of identifying intermediate goods imported into China. With this new method, we measure Chinese vertical specialization over time, and by sector, export destination, and input source. We find about 35 percent of the value of China's exports to the world is attributable to imported inputs. This vertical specialization exceeds 50% in some sectors, and is growing over time.

JEL Codes: F10, F14
Key Words: China, fragmentation, vertical specialization, trade growth

1. Introduction

In recent years, two interrelated important phenomena have occurred that transform the fundamental nature of global trade. The first phenomenon is the international fragmentation of production, where production processes are sliced thinner and thinner into many stages, and the resulting production fragments are carried out in different locations. The production of a finished product thus involves the participation of many economies, with countries specializing in different fragments of the vertical production chain. International trade is then increasingly dominated by trade in parts and components—fragments. While the international division of labor in the global economy is nothing new, the vast scope and the intricate nature of this pattern of global production sharing seems genuinely unprecedented.

The second phenomenon is the explosive growth of Chinese trade, and China's increasing importance in the global production chain. In current dollars, the value of China's exports plus imports rose from $280.9 billion in 1995 to $1422.1 billion in 2005--a growth of about 311%. China's policy regime of processing trade provides incentives for the import of intermediate goods, which are then transformed into finished goods for export. In 2005, processing trade accounted for 42 percent of China's imports from the world, and 55 percent of China's exports to the world. A similarly large proportion of China's imports from the U.S. (23 percent) and exports to the US (65 percent) were processing trade. This trade is concentrated in relatively high-tech products, and is carried out largely by foreign firms.

China's prominence in trade has raised numerous questions. How is it that China's trade can grow so rapidly? Has China's comparative advantage shifted to production of high-tech goods? How does this rapid growth and new composition of trade affect China's gains from trade? Increasingly, it appears that the answers to these questions may be found by studying the impact of international production fragmentation on China's trade. Because the splitting of the production process leads to products crossing borders many more times than in ordinary trade, production fragmentation across borders could account for rapid growth in trade (Yi, 2003). While China's final

good exports may appear far more high-tech than traditional comparative advantage would predict (Rodrik, 2006; Schott, 2006), fragmentation theory suggests that the fragments which make up the production chain are likely to be allocated across countries in a way that reflects traditional comparative advantage (Jones and Kierzkowski, 2001). Finally, the global gains from trade may be enlarged because international production fragmentation allows more finely defined production processes to be allocated across countries more efficiently (Yi, 2003).[1] Unlike intra-industry trade, this "intra-product" trade might particularly foster the growth of trade between industrial and developing countries (Jones, et al., 2005).

Yet in both the academic and policy literature, the phenomena of international production fragmentation and China's growth in trade have been studied quite separately. Much of the recent literature studying the growth of Chinese trade has focused on the role of foreign direct investment, trade liberalization, WTO accession, incentives, and the composition of China's exports.[2] Most of the recent literature on fragmentation has focused on developing and testing various theories of the firm's decision to fragment production across borders.[3] A few studies have attempted to measure the importance of trade in parts and components in global trade and East Asian trade, and found it to be large (Yeats, 2001; Ng and Yeats 2001, 2003). Athukorala and Yamashita (2006) find that parts and components accounted for about one-third of China's exports in 2003, and nearly 40% of the growth in China's exports between 1992 and 2003.[4] Baldwin (2006) documents the growing importance of China in East Asian trade in parts and components. But little work has been done exploring the degree to which China's trade has become vertically specialized due to production fragmentation.

[1] An individual country's gains from trade might also be enlarged if fragmentation lowers adjustment costs to trade liberalization, by allowing displaced workers to find new employment in a different stage of production within the same sector (Deardorff, 2001; Jones and Kierzkowski, 2001). Deardorff (2005) argues that in a world of fragmentation, the gains from trade result will likely hold. However, it is unclear if some factors of production like unskilled workers may or may not be hurt by fragmentation. See also Markusen (2005).

[2] Some recent examples include Bhattasali, et al. (2004), Dean, Lovely and Wang (2006), Wang (2003), Schott (2006), Rodrik (2006), Hammer (2006), Amiti and Javorcik (2005).

[3] Examples in the first group include Antras (2003, 2005), Antras and Helpman (2005), Grossman and Helpman (2004, 2005), McLaren (2000), Feenstra and Hanson (2005), and Feenstra and Spencer (2005). For an excellent survey of both theoretical and empirical work see Spencer (2005).

[4] See also Athukorala (2006). These studies, as well as Yeats (2001) and Ng and Yeats (2003), are confined to a limited number of SITC sectors where parts and components are easiliy identified.

This paper fills this void by measuring the vertical specialization in Chinese trade. We make three contributions. First, we use a new detailed Chinese trade dataset which distinguishes processing and ordinary imports, as well as the United Nations Broad Economic Categories (BEC) classification of capital, intermediate, and consumer goods, to more accurately identify Chinese imports of intermediate goods. Second, we combine these newly identified intermediate import data with the 1997 and 2002 Chinese benchmark IO tables, to construct an improved version of the Hummels, Ishii and Yi (2001) (HIY) measure of vertical specialization. Third, we use this new measure of vertical specialization to quantify the foreign content in Chinese global exports and bilateral exports, from 1996-2005, and disaggregate these results by source country and by firm type. We then quantify Chinese vertical specialization for 122 sectors over the same time period.

Our approach surmounts some of the technical difficulties encountered in two recent studies which examine fragmentation in China's trade. Chen, Cheng, Fung and Lau (2004) use Chinese data to measure the value of Chinese exports net of imported intermediate goods used for the production of such exports. However, their study is limited to a single year (1995) and 33 sectors. Ping (2005) uses Chinese data to calculate the HIY measure over time, by source country and by sector. However, he is only able to use one benchmark IO table (1997), which ultimately limits his results to 40 sectors.[5] In addition, he is unable to isolate processing imports and exports in measuring intermediate input use.

Our results show that in 2002, the vertical specialization share (VS share) in Chinese trade with the US and with the world was 30.8 percent and 35.9 percent, respectively. That is, imported intermediate inputs made up 30.8 cents (35.9 cents) of every dollar's worth of Chinese exports to the US (to the world) in 2002. These are significantly higher estimates of China's VS share than in

[5] The year 2000 is a non-benchmark year for the construction of the Chinese input-output table and it has only 40 sectors. In contrast, 1997 is the year with a benchmark input-output table and it has 124 sectors. In addition, Ping computes his estimates of VS shares using aggregate IO data, which tends to underestimate the actual VS share as pointed by Yi (2003).

previous studies. We also see strong evidence of the Asian network of suppliers to China studied by Baldwin (2006) and Athukorala (2006). Disaggregating VS share by source, we find Japan and the Four Dragons accounted for more than half of the value of imported inputs in China's exports, both at the beginning and the end of the ten year period. However, the US and EU together accounted for an additional 16-17%.

Our evidence also suggests that China's trade is becoming more vertically specialized over time. Between 1997 and 2002, China's VS share increased by about 23%. China's VS share with individual trading partners shows growth over time, with considerable acceleration in the VS share of exports to the US and to the EU. The most vertically specialized sectors in China's trade are plastics, steel processing, communications equipment, industrial machinery, metal products, and electronic computers. In these sectors, imported intermediate goods account for between 52 percent and 76 percent of the value of Chinese exports. Not surprisingly, we find that wholly-owned foreign firms and joint ventures have the most vertically specialized trade.

2. Methodology

2.1 The HIY measure

To measure the extent of vertical specialization of China, we begin with the method used by HIY. Consider Figure 1 for illustration.[6] In this figure, A is the amount of imported textile inputs. D is the amount of domestic sales of apparel, while E is the amount of exports of apparel to the United States. The measure of vertical specialization (VS) is given as (A/ (D+E))*E or (E/ (D+E))*A. Conceptually, this (E/ (D+E)) is the proportion of exports to total sales. When multiplied by A, the VS index measures the dollar value of imported inputs "contained" in Chinese exports. To get the share of imported inputs contained in one dollar worth of Chinese exports—VS share--we divide VS by E.

[6] Figure 1 is adapted from Hummels, Ishii and Yi (2001).

Given that we will be dealing with many inputs and many exports, we follow HIY and write our VS share index for China in matrix notation as:

$$\text{VS share} = \mathbf{u}\mathbf{A}^{\mathbf{M}}[\mathbf{I}-\mathbf{A}^{\mathbf{D}}]^{-1}\mathbf{X}/x_k \qquad (1)$$

where $\boldsymbol{u}$ is a 1 x n vector of 1's, $\boldsymbol{A^M}$ is an n x n imported coefficients matrix, $\boldsymbol{I}$ is the identity matrix, $\boldsymbol{A^D}$ is the n x n domestic coefficient matrix, $\boldsymbol{X}$ is the n x 1 export vector and x_k is a scalar that denotes the amount of exports from country k, which in our case, is China. The numerator of equation (1) measures all the imported inputs, iterated over the economy's production structure, that are needed to produce the exports of China from all n sectors. Dividing this by the amount of Chinese exports yields the total (both direct and indirect) share of Chinese exports attributable to imported inputs (VS share).

There are at least two concepts used in the literature which are related to VS share. One is the domestic content share, which is the gross value of exports minus the value of all imported intermediate goods used in their production divided by export value. A second term used is "domestic value added share", which is not often used in the academic literature, but is identical in definition to the domestic content share. It can be shown that (1-VS share) is equal to the domestic value added ratio or the domestic content ratio. We highlight this equivalence in Appendix I.[7]

2.2 A new measure of vertical specialization

To improve our ability to identify imported intermediate goods, we make use of detailed data on Chinese processing trade. In China's customs statistics, processing trade consists of two types—trade associated with processing and assembly and trade associated with processing with imported inputs. The Chinese government provides special incentives for enterprises engaged in processing trade, allowing them to import raw materials and other inputs duty free as long as these inputs are used to produce final goods or further processed inputs solely for export. Trade associated with processing and assembly means that ownership of the imported inputs is retained by the foreign

[7] The proof is first given in Chen, Cheng, Fung and Lau (2004) in their appendix 1. However, they did not realize the link between their domestic value-added measure and HIY's VS share measure.

exporting firm. Processing with imported materials means that ownership of the imported inputs is transferred to a local presence.

Processing trade is highly concentrated by sector, by origin, and by firm type. In 2005, more than two-thirds of this trade was found in 3 key sectors: Electrical Machinery (HS85), Machinery (HS84), and Optical, Medical and Precision Instruments (HS90). More than three-quarters of imported processing inputs originated in the Four Dragons, Japan, and other Southeast Asian economies. In addition, foreign-invested enterprises (FIEs) accounted for 84 percent of China's processing exports and imports.[8]

Our basic approach in measuring imported Chinese inputs is to classify all processed imports as imported intermediate goods. Within ordinary Chinese imports there may also be some amount of imported intermediate goods used for the production of exports. This is particularly true for information technology products, as China joined the Information Technology Agreement (ITA) in 2003, which provides importers with duty free imports in this category. To capture these imported intermediate goods, we apply the United Nations BEC (Broad Economic Categories) classification to all Chinese non-processed imports, and include as intermediates any goods labeled as such by the BEC. For ease of exposition, we call this two-step approach the Dean-Fung-Wang (DFW) approach.

To identify the coefficients in the A^M matrix, we use our new estimates of total sectoral imported intermediates, and assume that these imported inputs are used in each industry in the same proportion as indicated in the original input-output table. The coefficients in the A^D matrix are then obtained as residuals by subtracting the coefficients in the A^M matrix from the coefficients in the original input-output table.

All data on processing imports and exports, and on ordinary trade used in the estimates of VS share are taken from a new USITC Chinese trade database. This database was purchased from China Customs, and contains official Chinese export and import data from 1995-2005 at the HS 8-digit

[8] Throughout this paper, FIE will refer to three types of foreign-owned firms: wholly foreign-owned, equity joint venture and contractual joint venture.

level, differentiated by customs regime, region, source, destination, firm ownership, incentives, port, and transport mode. The two Chinese input-output tables that we use are from 1997 and 2002.[9] Both years are benchmark years, which means they include more detailed sectors than otherwise: 124 sectors in 1997 and 122 sectors in 2002.[10]

2.3 Alternative methods for identifying intermediate inputs

To test the robustness of our results, we will also utilize two other methods to codify imported intermediate inputs. One is to simply use the BEC identification for all Chinese imports, and single out those that are intermediate goods under this UN classification. We shall call this the BEC approach. A second alternative approach is to assume that the ratio of imported intermediate inputs to total imports is the same as the ratio of total intermediate inputs to total absorption. This is a standard method used to deduce the extent of imported inputs in the input-output literature. Both Ping (2005) and Chen, Cheng, Fung and Lau (2004) used this basic approach in their calculations.[11] We will label this alternative as the IO approach.

Essentially these are three alternative ways to identify intermediate goods from total imports for each sector. To clarify the differences, define the share of total imports (i.e. imports of intermediate goods and imports of final goods) accounted for by intermediate goods in sector i as $INTSH_i$, where the subscript denotes sector i. Then imports used as intermediate inputs, $IMPINT_i$ = $INTSH_i$*total imports. The three methods use different rules to identify $INTSH_i$.

For the DFW case, $INTSH_i$ =((Processing $imports_i$ + Intermediates identified by the BEC classification for non-processing $imports_i$) / total $imports_i$). For the BEC case:

[9] The Chinese input-output tables are of the competitive import type, which means that the tables do not differentiate between domestic intermediate goods and imported intermediate goods. To achieve the objective of our project, we need to convert the input-output tables into the non-competitive type, i.e. to separate out imported inputs and domestic inputs. As discussed earlier, the main method we used is the DFW approach.

[10] These sectors are listed in tables 3 and 4. For example, the study by Chen, Cheng, Fung and Lau (2004) used the 1995 Chinese input-output table, which had only 33 sectors.

[11] Hummels et al. (2001) also appears to use this method, but the exact method is not stated explicitly in the paper.

$INTSH_i$ = (Intermediates identified by the BEC classification from all $imports_i$ / total $imports_i$).
For the IO case: $INTSH_i$ = total intermediate use (domestic and imports) for sector i/ total absorption for sector i(both domestic and imports) as given in the conventional input-output tables.

These three methods yield significantly different estimates of the sectoral shares of imported intermediate goods. For illustration, we present two tables in Appendix II, showing these shares for Chinese imports from the world and Chinese imports from the United States for the year 2002 (the year of the most recent Chinese benchmark input-output table). In general, we can see that the BEC method yields shares that are less than or equal to the DFW method, since the DFW method counts all processing imports as imported intermediates. Since the IO method uses the average inputs to absorption ratio as the share of imported intermediate goods, it will tend to be lower (higher) than the DFW method in sectors where processed imports are high (low). Figure 2 illustrates the significant differences in the shares of imported intermediates generated by the three methods. It is clear from these simple regressions that the IO shares are very different from the other estimates while the BEC shares and the DFW shares are more closely correlated. [12]

We believe that the DFW method is conceptually and economically an improvement over the alternative methods of identifying intermediate imports. Fundamental economic principles teach us that economic agents do respond to incentives. When Chinese firms or foreign firms import intermediate goods into the country for processing, there is every incentive for these economic agents to declare that these inputs are used for processing. For sectors such as information technology, agreements like the ITA may have reduced these incentives. But it seems that there is relatively little cost for these processing firms to still declare them as such. Furthermore, even if they do not declare these imported inputs as used for processing purposes, the BEC method should still be able to catch these outliers. At worst, it seems to us that the DFW method is no better than the BEC method.[13] In

[12] Note that if we draw a 45 degree line in the graph relating the BEC and the DFW shares, we can show that the BEC shares are no higher than the DFW shares.
[13] Because of these incentives, it is possible that producers will report more imports as processing imports than is actually true, implying that China official customs statistics will overstate the amount of processing imports.

contrast, the IO method uses a very strong assumption. While this may be necessary when detailed data on processing trade are not available, it is easy to see why the two alternative methods should yield better results.

3. Results

3.1. Vertical Specialization in China's Exports to the World

3.1.1 Over time. In measuring the aggregate vertical specialization shares for China's exports to the world, we have two benchmark years, 1997 and 2002. The results for both direct VS shares and total VS shares for each year, using the DFW method of measurement are shown in Table 1. For comparison, the results for the same years, using the BEC and IO approaches are also shown. From Table 1, we can see that using the DFW method, the aggregate intermediate import content (total VS share) of China's exports was 29.3% in 1997, and 35.9% in 2002. In general, the direct shares are less than half of the total VS shares, but they show a similar large increase during this period. This increase in VS shares suggests that the fragmentation of China's exports to the world has been rising significantly. These trends are robust when we examine the results from the two alternative methods. Table 1 indicates that both the BEC method and the IO methods yield total VS share values of similar magnitude, though slightly smaller than the DFW method. Each of these three methods shows a rise in VS of about 6.5 percentage points between 1997 and 2002.

3.1.2 By Source Country. As discussed above, China's imports of intermediate inputs appear to be sourced for the most part from other Asian economies. Using the DFW method of identifying imported inputs, we can disaggregate China's total VS, to assess the extent of imported intermediate goods from the United States and other countries, for each dollar of China's exports to the world. We

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This may be one of the reasons that only about 85 percent of processing imports were identified by UN BEC classification as intermediate inputs. On the other hand, the BEC method may underestimate the portion of imported intermediates in processing trade for some double end use commodities which are entered as processing trade in Chinese Custom statistics.

again use both the 1997 and the 2002 input-output tables and extend our analysis to other years. The results for 1996 and for 2005 are shown in figure 3.[14]

In Figure 3 we can see that Japan and the Four Dragons (Hong Kong, Taiwan, South Korea, Singapore) constituted more than half of China's total VS share in 1996, with an additional 6% from the rest of Southeast Asia. Thus, these economies could be seen as an Asian supply network for China's global production-sharing. Japan was the largest single country source of inputs, accounting for 20% of China's intermediate inputs. The United States and the EU15, supplied roughly similar shares of 8% and 9%, respectively. Though much smaller than the Asian network, they still constituted important sources of intermediate inputs for China's fragmented trade. Interestingly, China's sourcing patterns do not change much by 2005. Within the Asian supply network, the focus has shifted away from Japan somewhat and more toward other Southeast Asian countries. But this network still accounts for 58% of China's aggregate VS share in 2005. Similarly, the United States and EU15 still supply about 16% of China's intermediate inputs for exports.

3.2. China's Vertical Specialization by Sector

Tables 2 and 3 show how the direct and total VS shares vary with different sectors using our own DFW methods as well as the two alternative methods. Table 2 shows sectoral results using the 1997 benchmark input-output table, and table 3 uses the 2002 benchmark input-output table. To highlight the sectors with the highest total VS shares, figures 4 and 5 show the sectors with total VS (by DFW method) of 25% or more, for 1997 and 2002 respectively.

In 1997, seventeen industrial manufacturing products had total VS shares of 25% or more (Figure 4). In three of these sectors, the value of imported inputs was greater than 50% of the value of exports: metal products (65%), steel processing (59%) and other electric machinery and equipment (53%). Cotton textiles and wearing apparel had VS shares of between 40% and 50%. Other sectors with relatively high total VS shares included plastic products, petroleum refining, other general industrial machinery , motor vehicles, and other special industrial equipment.

[14] The results in Figure 3 are estimated by using the DFW method only.

By 2002, the mix of products with the highest total VS shares had changes somewhat (Figure 5). Now a total of 21 sectors had total VS shares exceeding 25%. Six manufacturing sectors now had total VS shares exceeding 50% of exports: plastic products (76 %), steel processing (69 %), communication equipment (59%), other general industrial machinery (58 %), metal products (55 %), and electronic computers (52.1 percent). In an additional six sectors, the value of imported inputs was between 40% and 50% of the value of exports.

These results are fairly robust across the three methods, though there are some minor variations. For example, for motor vehicles for the year 2002, the IO approach, the BEC approach and the DFW approach yielded respectively total VS shares of 35.1%, 31.9% and 34.0%. We expect that the BEC method, which applies the United Nations classification of intermediate goods uniformly for processing as well as non-processing imports, would yield the lowest estimates of the VS shares, and this is borne out in figures 2 and 3. We also expect that the IO method would underestimate VS in sectors with a high level of processing trade and overestimate it in sectors with a low level of processing trade. This is borne out to some degree in the two figures.

Figure 6 shows the change in VS shares from 1997-2002 for selected sectors. It is immediately evident that in most of these sectors, VS shares have grown significantly. While imported inputs constituted 39 cents of every US dollar worth of plastic products exported by China in 1997, this nearly doubled to 76 cents of each dollar of exports by 2002. Total VS more than doubled in communication equipment and sawmills and wood products, and grew by at least one-third in electronic computers, and general industrial machinery. Interestingly, VS shares in cotton textiles and wearing apparel actually fell.

3.3. China's Vertical Specialization in Exports by Trading Partner

In measuring the vertical specialization shares of China's exports to the United States, we again utilize the two benchmark input-output tables, which provide us with two matrices of coefficients of imported intermediates, one for 1997 and one for 2002. To get results for other years, we assume these import matrices to be unchanged, but we allow China's exports to the United States

to vary. Using the 1997 matrix, we extrapolate the calculations for the years 1996 to 2001. Similarly we can measure the VS shares of China's exports to the United States using the 2002 input-output tables and extrapolate our measurements to the years 2001-2005 by changing the export vector for each year. To save space, we present only results with our DFW method. These VS shares are presented in Table 4.

From Table 4 we can see that both the direct and total VS shares are rising over time for China's exports to the United States. This suggests that China's exports to the United States contain an increasing share of imported intermediate goods over time. China appears to be increasingly enmeshed in the global network of production fragmentation, whether we consider its trade with the world or its trade with the United States. Figure 5 shows the fragmentation of China's exports to a number of trading partners over time, using the DFW measure.[15] The vertical specialization of China's exports to the United States and the EU15 show a similar trajectory, beginning a little above 25% in 1996, and rising to about 30% in 2005, with an acceleration starting in 2000. China's exports to Japan are less vertically specialized, though the pattern over time is not too different from that of the United States or the EU.

We might expect that China's exports to India would be less fragmented, since it is a country at a similar level of development. Figure 5 suggests that this is the case. China's exports to India begin with a total VS of only 20%, which does rise rapidly to about 27% at the end of the period, but remains significantly below the level of VS for the industrialized economies. Interestingly, the VS for China's exports to Singapore and Taiwan follow a similar pattern to that of the US and the EU15.

3.4. Vertical Specialization by Chinese Exporting Firms

Our rich Chinese trade data also allow us to differentiate a variety of Chinese exporting firms and we measure the degree of fragmentation in their exports as well. Table 5 shows results for 2002

[15] In the figure, the VS value for 2001 is based on the results using the 2002 matrix.

for Chinese firms exporting to the world, and for firms exporting to the United States.[16] For exports going to the world, we can see that the highest VS share was for wholly-owned foreign firms, followed by joint ventures, collectives, state-owned enterprises and others. For exports to the United States, the total VS share was highest again with the wholly-owned foreign firms, followed by collectives, joint ventures, state-owned enterprises and then others. Not surprisingly, the FIEs showed more fragmentation than state-owned firms.

5. Conclusion

While trade fragmentation and China's rapidly growing trade have been recognized as important economic phenomena, the importance of fragmentation in China's trade growth has been left unexamined until recently. In this paper, we provide the most up-to-date and comprehensive measures of the degree of vertical specialization in China's trade, using a new detailed Chinese dataset which allows us to distinguish processing imports and exports from ordinary trade. We further utilize the United Nations Broad Economic Categories (BEC) system to identify non-processed imported intermediates from imports of final goods These data are incorporated into the Hummels, et al. (2001) measure of vertical specialization, using both the 1997 and 2002 benchmark Chinese IO tables. We then quantify vertical specialization over time, by source, by trading partner, sector, and type of firm.

Our results show that the vertical specialization in China's exports to the world was more than 30% in 2002. In the sectors with the most fragmented trade--plastic products, steel processing, communication equipment, industrial machinery, metal products and computers—vertical specialization exceeded 50%. Not surprisingly, the firms with the most fragmented trade are the foreign-invested enterprises. There is strong evidence of the importance and persistence of an Asian supplier network to China. About 58% China's aggregate vertical specialization in 2002 was attributable to imports from Japan, Taiwan, South Korea and other Southeast Asian economies.

[16] Here we present only results measured by the IO approach. In future work we will include estimates using the BEC and DFW approaches.

Among bilateral partners, China's vertical specialization was high (about 30%) with not only the US, the EU 15, and Canada, but also with Taiwan and Singapore. Our evidence also suggests that the fragmentation in China's global trade is growing, particularly its trade with the US and the EU.

Our results are generally robust to the use of alternative methods of measurement. However, for some specific sectors, there can be some variations across methods. For example, in 1997, for motor vehicles, the extent of fragmentation was 34% using our own DFW method, but it was 31.9% using the BEC method and 35% using the IO approach. These variations could become important for our future work since we intend to econometrically determine the how the VS shares can vary with different variables as suggested in the theoretically literature. The alternative measures give us an opportunity to test the robustness of our future estimates.

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Figure 1

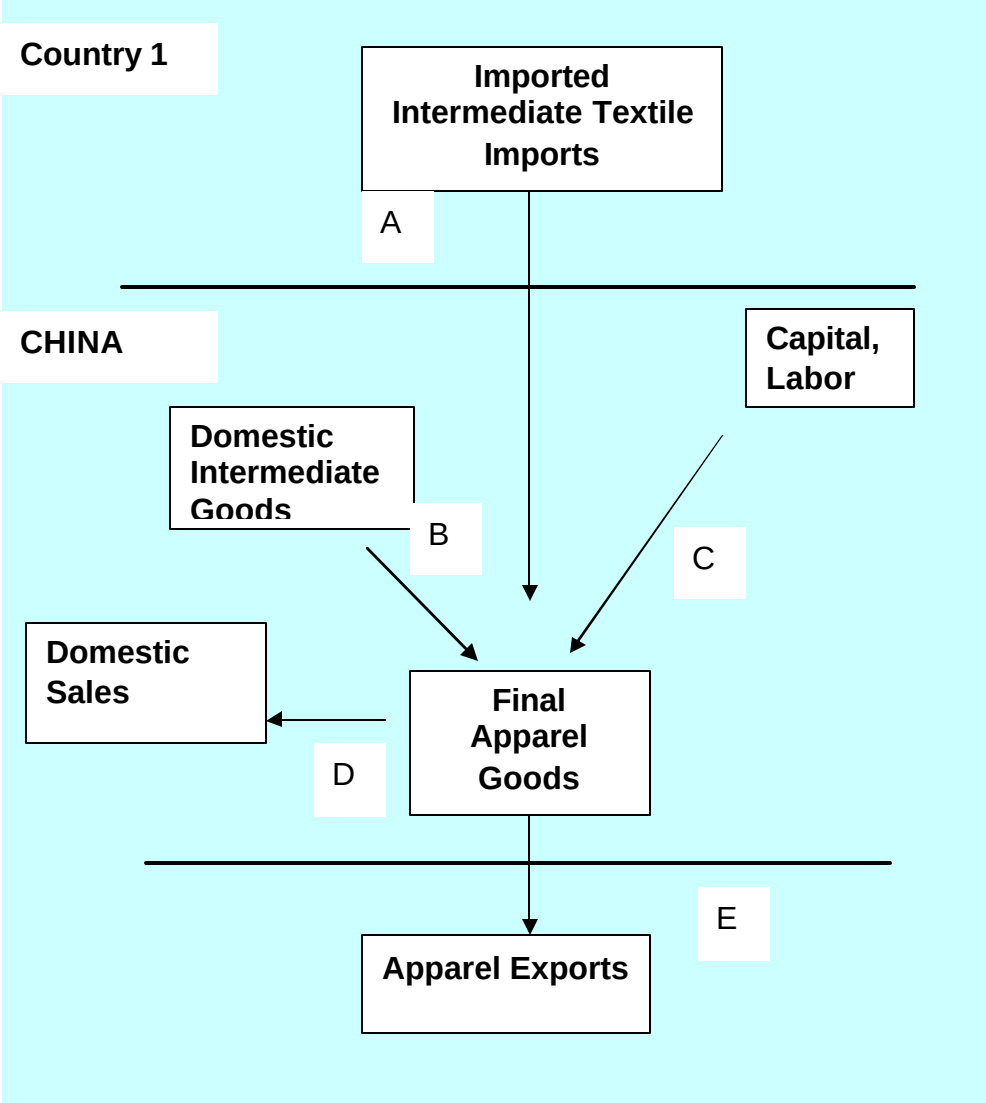
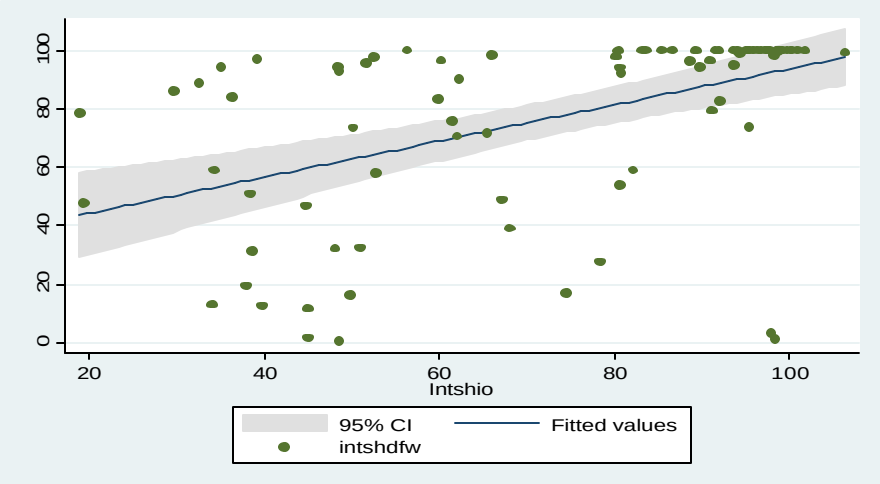
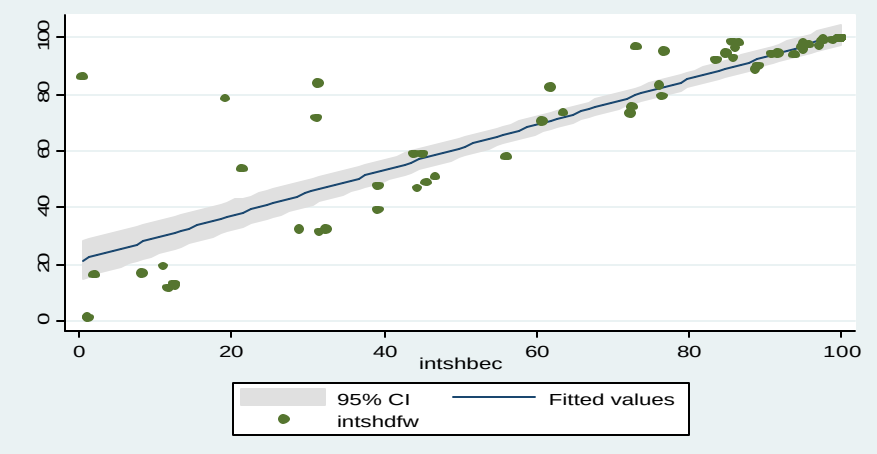

Country 1
Imported Intermediate Textile Imports
A
CHINA
Capital, Labor
Domestic Intermediate Goods
B
C
Domestic Sales
Final Apparel Goods
D
E
Apparel Exports

Figure 2. Comparing Intermediate Shares Calculated by the Three Methods for 2002:

(a) IO and DFW



(b) BEC and DFW



(c) IO and BEC

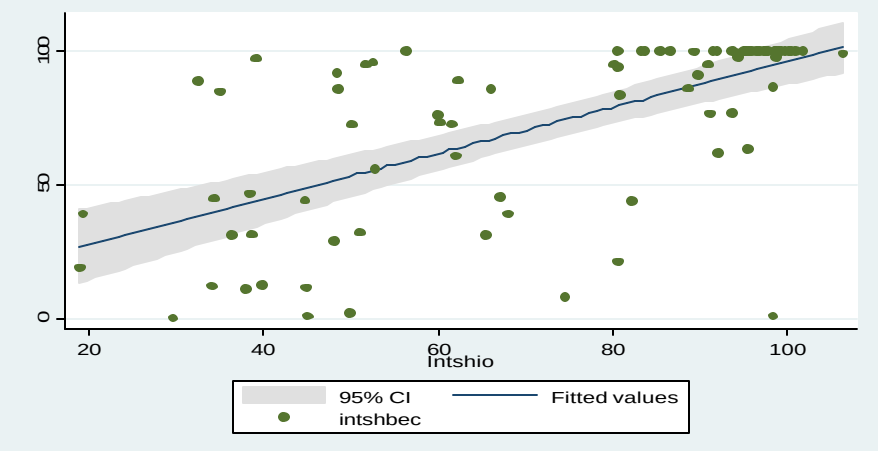


Figure 3. China's Vertical Specialization by Source Country

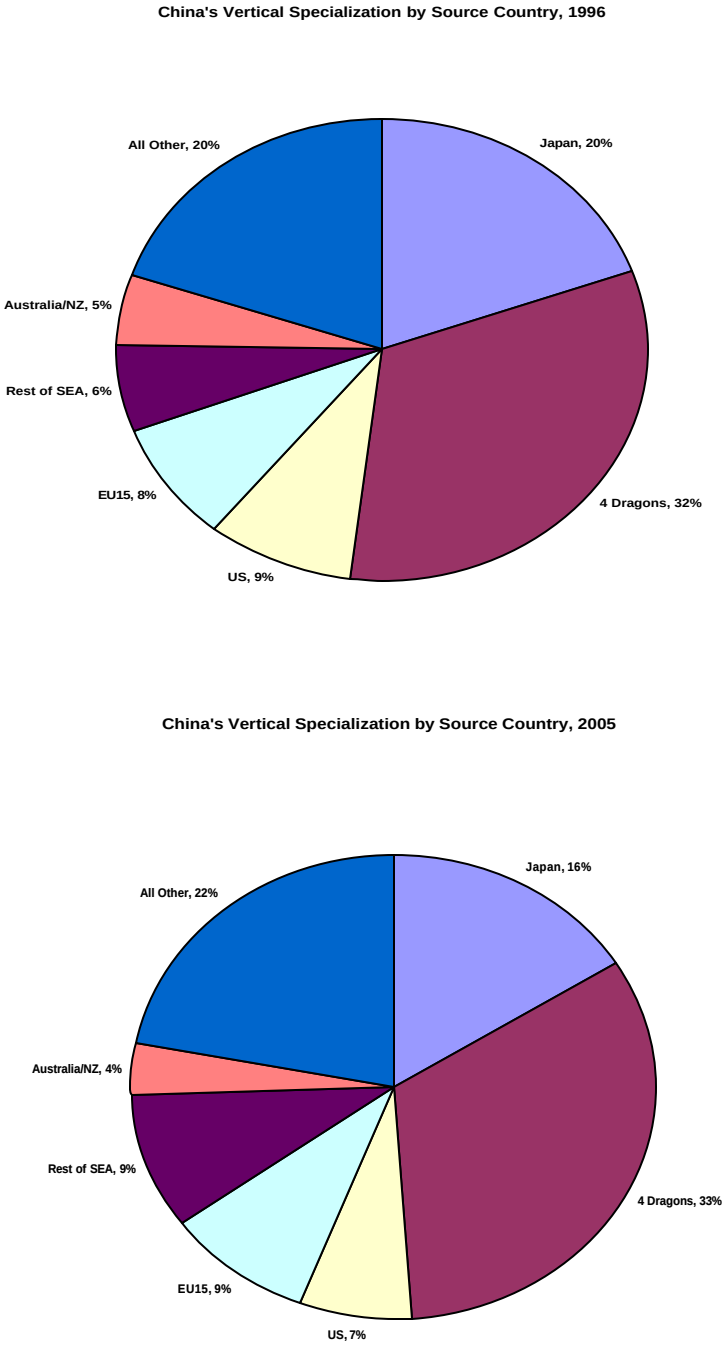


Figure 4. Total VS Shares by Selected Sectors, 1997

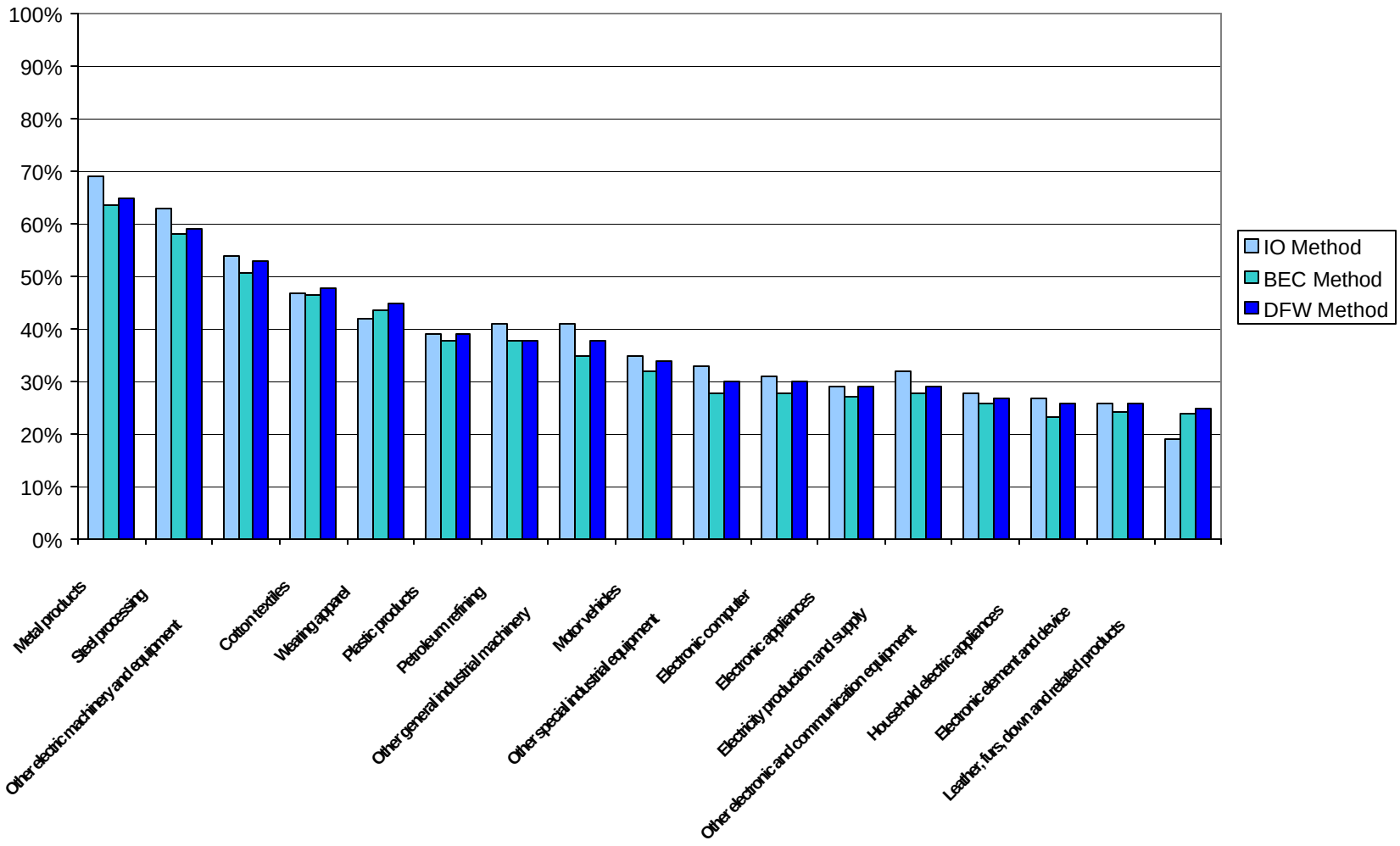


Figure 5. Total VS Shares by Selected Sectors, 2002

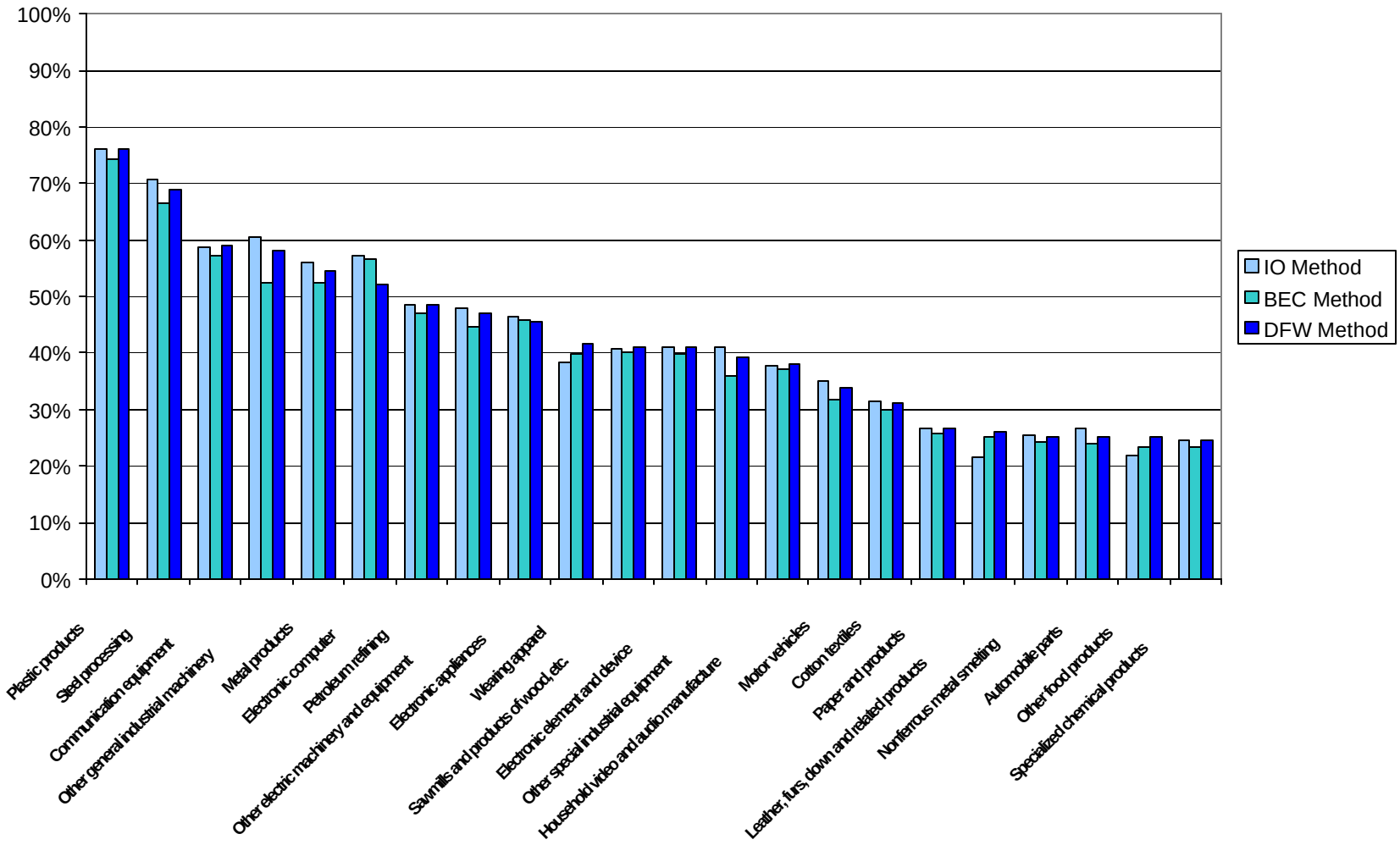


Figure 6. Change in Total Vertical Specialization, 1997-2002 (Selected Sectors)

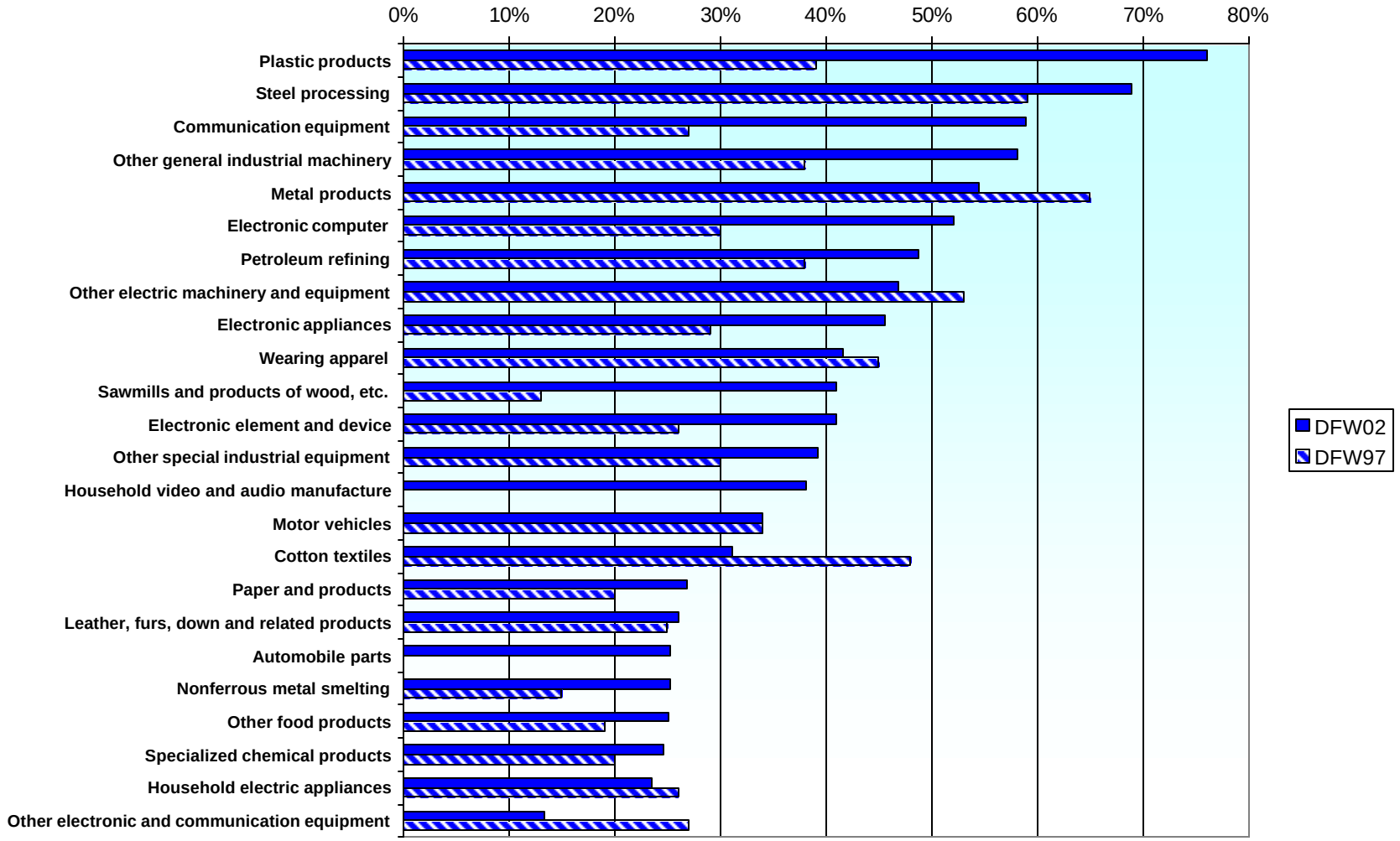


Figure 7. Vertical Specialization of China's Exports to Selected Trading Partners, 1996-2005

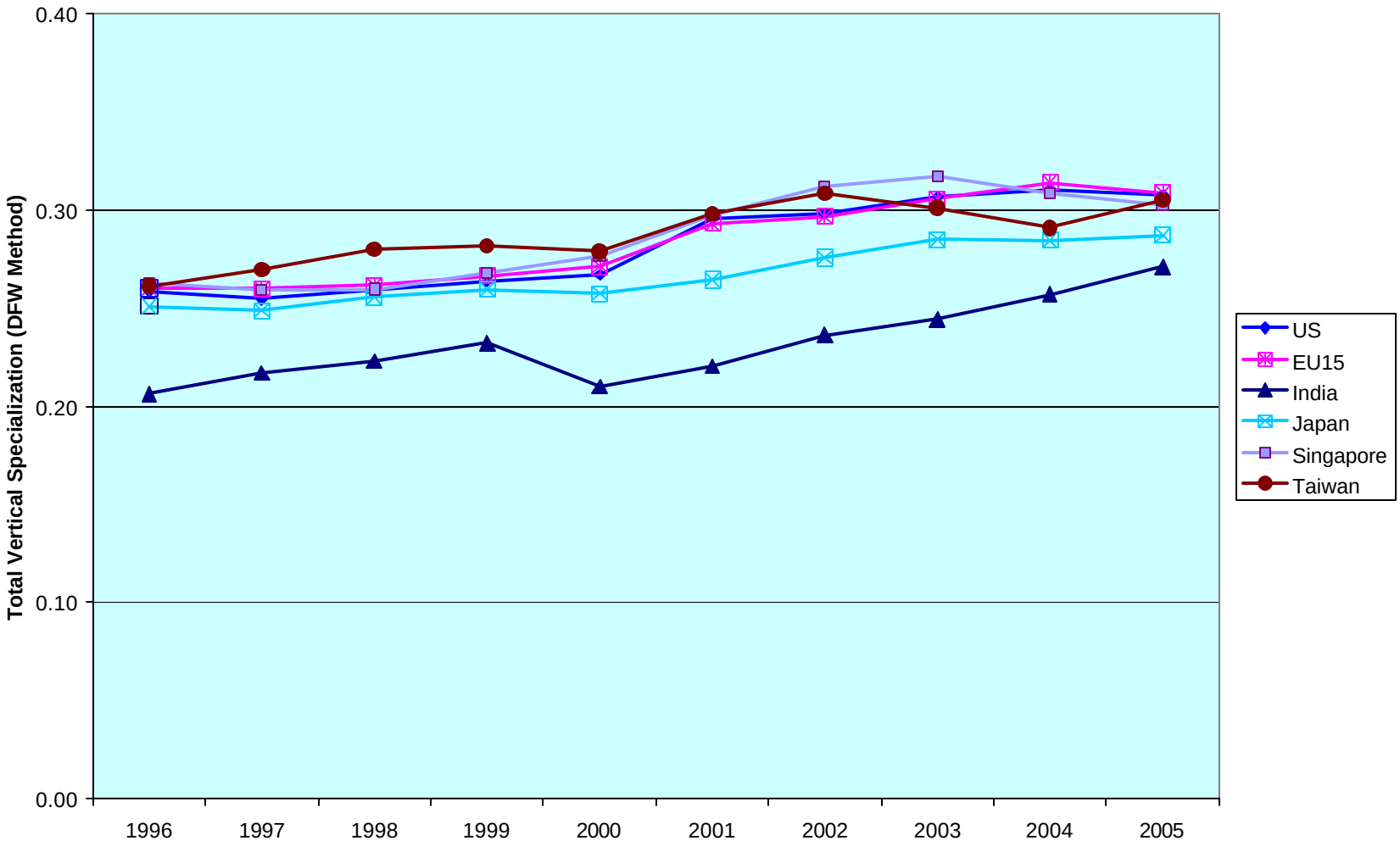


Table 1. Aggregate Vertical Specialization Shares for China's Exports to the World: DFW, BEC and IO Approaches

Year	Direct VS Share DFW	Total VS Share DFW	Direct VS Share BEC	Total VS Share BEC	Direct VS Share IO	Total VS Share IO	*Total VS Share IO Ping (2005)*
1997	12.8%	**29.3%**	12.1%	**28.1%**	12.2%	**29.2%**	15.19%
2002	17.3%	**35.9%**	16.6%	**34.6%**	17.0%	**35.7%**	21.03%

Table 2. Vertical Specialization Share Estimates Based on China's 1997 Benchmark Input-Output Table

IOCode	Description	IO Method		BEC Method		DFW Method	
		Direct	Total	Direct	Total	Direct	Total
001	Crop cultivation	0.219	0.57	0.199	0.52	0.203	0.54
002	Forestry	0.012	0.03	0.011	0.026	0.012	0.03
003	Livestock and livestock products	0.041	0.22	0.055	0.221	0.056	0.23
004	Fishery	0.034	0.1	0.025	0.086	0.028	0.09
005	Other agricultural products	0.019	0.05	0.02	0.05	0.021	0.05
006	Coal mining and processing	0.098	0.21	0.089	0.189	0.092	0.2
007	Crude petroleum products	0.029	0.07	0.022	0.058	0.024	0.06
008	Natural gas products	0.004	0.01	0.003	0.008	0.003	0.01
009	Ferrous ore mining	0.043	0.07	0.039	0.06	0.039	0.06
010	Non-ferrous ore mining	0.032	0.08	0.029	0.077	0.031	0.08
011	Salt mining	0.001	0.01	0.001	0.005	0.001	0.01
012	Non-metal minerals and other mining	0.042	0.12	0.037	0.108	0.038	0.11
013	Logging and transport of timber and bamboo	0.008	0.02	0.008	0.016	0.008	0.02
014	Grain mill products, vegetable oil and forage	0.03	0.2	0.03	0.185	0.048	0.21
015	Sugar refining	0.007	0.02	0.008	0.021	0.009	0.02
016	Slaughtering , meat processing, eggs and dairy products	0.005	0.05	0.007	0.052	0.008	0.06
017	Prepared fish and seafood	0.004	0.03	0.003	0.027	0.007	0.03
018	Other food products	0.049	0.17	0.059	0.174	0.067	0.19
019	Wines, spirits and liquors	0.023	0.1	0.024	0.092	0.025	0.1
020	Non-alcoholic beverage	0.021	0.07	0.024	0.067	0.027	0.07
021	Tobacco products	0.016	0.06	0.014	0.052	0.015	0.05
022	Cotton textiles	0.199	0.47	0.203	0.466	0.207	0.48
023	Woolen textiles	0.054	0.11	0.059	0.117	0.06	0.12
024	Hemp textiles	0.011	0.02	0.012	0.019	0.012	0.02
025	Silk textiles	0.025	0.11	0.026	0.108	0.027	0.11
026	Knitted mills	0.051	0.14	0.068	0.148	0.073	0.15
027	Other textiles	0.037	0.08	0.039	0.079	0.039	0.08
028	Wearing apparel	0.188	0.42	0.21	0.435	0.215	0.45
029	Leather, furs, down and related products	0.07	0.19	0.121	0.24	0.128	0.25
030	Sawmills and fibreboard	0.073	0.13	0.072	0.123	0.073	0.13
031	Furniture and products of wood, bamboo, cane, palm, straw, etc.	0.069	0.18	0.077	0.182	0.079	0.19
032	Paper and products	0.071	0.2	0.07	0.191	0.072	0.2
033	Printing and record medium reproduction	0.032	0.08	0.032	0.079	0.033	0.08
034	Cultural goods	0.011	0.02	0.012	0.023	0.012	0.02
035	Toys, sporting and athletic and recreation products	0.045	0.1	0.046	0.1	0.057	0.11
036	Petroleum refining	0.291	0.41	0.272	0.377	0.273	0.38
037	Coking	0.005	0.03	0.004	0.023	0.005	0.02
038	Raw chemical materials	0.028	0.1	0.025	0.089	0.026	0.09
039	Chemical fertilizers	0.047	0.14	0.042	0.133	0.044	0.14
040	Chemical pesticides	0.018	0.05	0.011	0.039	0.012	0.04
041	Organic chemical products	0.099	0.25	0.094	0.238	0.096	0.24
042	Chemical products for daily use	0.021	0.07	0.022	0.07	0.023	0.07
043	Other chemical products	0.094	0.21	0.089	0.194	0.091	0.2
044	Medical and pharmaceutical products	0.032	0.12	0.031	0.109	0.033	0.12
045	Chemical fibers	0.112	0.2	0.113	0.197	0.115	0.2
046	Rubber products	0.067	0.15	0.068	0.145	0.072	0.15
047	Plastic products	0.183	0.39	0.184	0.38	0.192	0.39

048	Cement	0.049	0.21	0.04	0.19	0.043	0.2
049	Cement and asbestos products	0.015	0.1	0.014	0.093	0.015	0.1
050	Bricks, tiles, lime and light-weight building materials	0.051	0.19	0.051	0.177	0.052	0.18
051	Glass and glass products	0.022	0.07	0.021	0.061	0.022	0.06
052	Pottery, china and earthenware	0.016	0.06	0.015	0.055	0.016	0.06
053	Fireproof products	0.013	0.05	0.013	0.045	0.013	0.05
054	Other non-metallic mineral products	0.02	0.07	0.017	0.062	0.018	0.07
055	Iron-smelting	0.082	0.12	0.079	0.116	0.079	0.12
056	Steel-smelting	0.05	0.11	0.046	0.099	0.046	0.1
057	Steel processing	0.265	0.63	0.242	0.581	0.245	0.59
058	Alloy iron smelting	0.034	0.06	0.033	0.06	0.033	0.06
059	Nonferrous metal smelting	0.062	0.16	0.061	0.149	0.061	0.15
060	Nonferrous metal processing	0.054	0.13	0.053	0.127	0.053	0.13
061	Metal products	0.224	0.69	0.203	0.636	0.208	0.65
062	Boiler, engines and turbine	0.059	0.12	0.054	0.113	0.058	0.12
063	Metalworking machinery	0.037	0.08	0.022	0.065	0.024	0.07
064	Other general industrial machinery	0.165	0.41	0.116	0.349	0.14	0.38
065	Agriculture, forestry, animal husbandry and fishing machinery	0.057	0.15	0.046	0.133	0.049	0.14
066	Other special industrial equipment	0.143	0.33	0.1	0.279	0.117	0.3
067	Railroad transport equipment	0.018	0.04	0.013	0.036	0.015	0.04
068	Motor vehicles	0.099	0.35	0.086	0.319	0.093	0.34
069	Ship building	0.028	0.06	0.02	0.049	0.023	0.05
070	Aircraft	0.144	0.16	0.112	0.126	0.112	0.13
071	Bicycle	0.016	0.05	0.035	0.074	0.035	0.08
072	Other transport machinery	0.062	0.17	0.062	0.163	0.066	0.17
073	Generators	0.046	0.09	0.032	0.073	0.04	0.08
074	Household electric appliances	0.117	0.27	0.091	0.234	0.108	0.26
075	Other electric machinery and equipment	0.25	0.54	0.227	0.507	0.237	0.53
076	Electronic computer	0.212	0.31	0.183	0.277	0.202	0.3
077	Electronic appliances	0.179	0.29	0.167	0.271	0.18	0.29
078	Electronic element and device	0.162	0.26	0.147	0.243	0.158	0.26
079	Other electronic and communication equipment	0.166	0.28	0.148	0.259	0.161	0.27
080	Instruments, meters and other measuring equipment	0.069	0.11	0.048	0.087	0.054	0.09
081	Cultural and office equipment	0.042	0.06	0.037	0.058	0.039	0.06
082	Maintenance and repair of machinery and equipment	0.111	0.17	0.086	0.137	0.088	0.14
083	Arts and crafts products	0.041	0.11	0.045	0.113	0.046	0.12
084	Other manufacturing products	0.037	0.1	0.036	0.1	0.04	0.11
085	Scrap and waste	0	0	0	0	0	0
086	Electricity production and supply	0.11	0.32	0.08	0.277	0.089	0.29
087	Steam and hot water production and supply	0.003	0.01	0.002	0.01	0.003	0.01
088	Gas production and supply	0.003	0.01	0.002	0.011	0.003	0.01
089	Water production and supply	0.005	0.02	0.004	0.02	0.005	0.02
090	Construction	0.434	1.71	0.376	1.57	0.396	1.63
091	Railway freight transport	0.016	0.05	0.015	0.048	0.015	0.05
092	Highway freight transport	0.036	0.12	0.034	0.11	0.035	0.11
093	Pipeline transport	0.001	0	0.001	0.003	0.001	0
094	Water freight transport	0.01	0.03	0.007	0.022	0.007	0.02
095	Air freight transport	0.049	0.06	0.039	0.048	0.039	0.05
096	Transportation not elsewhere classified and auxiliary body	0.017	0.05	0.015	0.046	0.016	0.05
097	Warehousing	0.002	0.01	0.002	0.005	0.002	0.01

098	Post	0.012	0.03	0.013	0.026	0.014	0.03
099	Telecommunication	0.052	0.15	0.04	0.134	0.046	0.14
100	Wholesale and retail trade	0.226	0.79	0.241	0.763	0.26	0.8
101	Eating and drinking places	0.024	0.11	0.025	0.1	0.047	0.13
102	Railway passenger transport	0.007	0.02	0.007	0.02	0.007	0.02
103	Highway passenger transport	0.007	0.02	0.007	0.023	0.008	0.02
104	Water passenger transport	0.011	0.03	0.007	0.023	0.008	0.03
105	Air passenger transport	0.345	0.39	0.27	0.315	0.271	0.32
106	Finance	0.152	0.29	0.151	0.282	0.156	0.29
107	Insurance	0.024	0.05	0.025	0.05	0.026	0.05
108	Real estate	0.022	0.07	0.023	0.066	0.024	0.07
109	Public services	0.027	0.09	0.025	0.083	0.027	0.09
110	Resident services	0.081	0.15	0.082	0.148	0.085	0.15
111	Hotels	0.02	0.05	0.021	0.047	0.024	0.05
112	Tourism	0.11	0.19	0.11	0.178	0.11	0.18
113	Recreational services	0.007	0.02	0.007	0.017	0.009	0.02
114	Other social services	0.25	0.42	0.227	0.392	0.246	0.41
115	Health services	0.034	0.12	0.026	0.111	0.028	0.12
116	Sports	0.001	0	0.001	0.003	0.002	0
117	Social welfare	0.004	0.01	0.004	0.008	0.004	0.01
118	Educational services	0.095	0.21	0.095	0.196	0.102	0.21
119	Culture and arts, radio, film and television	0.022	0.06	0.023	0.055	0.025	0.06
120	Scientific research	0.041	0.06	0.034	0.054	0.036	0.06
121	General technical services	0.031	0.06	0.028	0.051	0.03	0.05
122	Technical services for agriculture, forestry, livestock and fishing	0.006	0.02	0.006	0.016	0.006	0.02
123	Geological prospecting and water conservancy	0.01	0.04	0.01	0.033	0.01	0.03
124	Public administration and other sectors	0.217	0.51	0.218	0.482	0.226	0.5
Total		0.122	0.29	0.121	0.281	0.128	0.29

Table 3. Vertical Specialization Share Estimates Based on China's 2002 Benchmark Input-output Table

IOCode	Description	IO Method		BEC Method		DFW Method	
		Direct	Total	Direct	Total	Direct	Total
01001	Crop cultivation	0.175	0.491	0.174	0.47	0.16	0.47
02002	Forestry	0.033	0.073	0.033	0.072	0.031	0.071
02003	Livestock and livestock products	0.009	0.018	0.008	0.017	0.008	0.018
03004	Fishery	0.016	0.204	0.019	0.197	0.019	0.223
04005	Other agricultural products	0.044	0.129	0.039	0.118	0.041	0.128
05006	Technical services for agriculture, forestry, livestock and fishing	0.011	0.027	0.01	0.026	0.011	0.028
06007	Coal mining and processing	0.086	0.201	0.066	0.176	0.076	0.191
07008	Crude petroleum and natural gas mining	0.054	0.117	0.033	0.095	0.044	0.108
08009	Ferrous ore mining	0.036	0.06	0.034	0.057	0.035	0.059
09010	Non-ferrous ore mining	0.022	0.054	0.019	0.049	0.021	0.053
10011	Salt mining	0.002	0.006	0.002	0.006	0.002	0.006
10012	Non-metal minerals and other mining	0.031	0.087	0.026	0.08	0.029	0.085
13013	Grain mill products	0.007	0.053	0.008	0.052	0.009	0.053
13014	feed products	0.025	0.069	0.024	0.066	0.049	0.093
13015	vegetable oil and forage	0.017	0.064	0.028	0.074	0.029	0.075
13016	Sugar refining	0.007	0.018	0.008	0.018	0.009	0.02
13017	Slaughtering , meat processing, eggs and dairy products	0.007	0.047	0.008	0.047	0.009	0.051
13018	Prepared fish and seafood	0.01	0.043	0.01	0.04	0.019	0.052
13019	Other food products	0.08	0.22	0.098	0.234	0.11	0.251
15020	Wines, spirits and liquors	0.015	0.053	0.014	0.05	0.015	0.052
15021	Non-alcoholic beverage	0.023	0.063	0.025	0.064	0.028	0.068
16022	Tobacco products	0.005	0.022	0.007	0.023	0.007	0.024
17023	Cotton textiles	0.104	0.313	0.101	0.3	0.104	0.311
17024	Woolen textiles	0.032	0.067	0.035	0.069	0.037	0.072
17025	Hemp and silk textiles	0.022	0.065	0.024	0.066	0.025	0.068
17026	textiles products	0.042	0.083	0.046	0.086	0.047	0.088
17027	Knitted mills	0.07	0.166	0.076	0.168	0.082	0.176
18028	Wearing apparel	0.181	0.383	0.202	0.397	0.217	0.416
19029	Leather, furs, down and related products	0.096	0.216	0.136	0.251	0.142	0.26
20030	Sawmills and products of wood, bamboo, cane, palm, straw, etc.	0.242	0.406	0.243	0.403	0.246	0.41
21031	Furniture	0.081	0.171	0.084	0.172	0.085	0.176
22032	Paper and products	0.116	0.266	0.114	0.258	0.118	0.268
23033	Printing and record medium reproduction	0.049	0.141	0.047	0.136	0.049	0.141
24034	Cultural goods	0.011	0.027	0.011	0.027	0.012	0.028
24035	Toys, sporting and athletic and recreation products	0.058	0.121	0.058	0.119	0.07	0.132
25036	Petroleum refining	0.312	0.486	0.317	0.469	0.322	0.487
25037	Coking	0.008	0.03	0.008	0.028	0.008	0.03
26038	Raw chemical materials	0.113	0.218	0.105	0.201	0.111	0.214
26039	Chemical fertilizers	0.054	0.133	0.05	0.124	0.053	0.131
26040	Chemical pesticides	0.025	0.045	0.024	0.044	0.022	0.042
26041	Dye, printing oil and similar products	0.075	0.157	0.073	0.151	0.075	0.157
26042	Organic chemical products	0.099	0.193	0.096	0.185	0.099	0.192
26043	specialized chemical products	0.131	0.245	0.127	0.235	0.133	0.246
26044	Chemical products for daily use	0.039	0.089	0.041	0.089	0.042	0.092
27045	Medical and pharmaceutical products	0.07	0.172	0.065	0.164	0.07	0.172
28046	Chemical fibers	0.081	0.155	0.078	0.149	0.081	0.154
29047	Rubber products	0.057	0.129	0.056	0.124	0.058	0.129

30048	Plastic products	0.41	0.76	0.403	0.742	0.412	0.76
31049	Cement	0.045	0.142	0.038	0.129	0.042	0.137
31050	Glass and glass products	0.046	0.095	0.046	0.091	0.047	0.095
31051	Pottery, china and earthenware	0.018	0.044	0.018	0.042	0.018	0.044
31052	Fireproof products	0.018	0.047	0.017	0.045	0.018	0.047
31053	Other non-metallic mineral products	0.025	0.08	0.023	0.075	0.024	0.079
32054	Iron-smelting	0.077	0.12	0.077	0.118	0.078	0.12
32055	Steel-smelting	0.119	0.236	0.112	0.223	0.114	0.23
32056	Steel processing	0.28	0.708	0.26	0.665	0.268	0.69
32057	Alloy iron smelting	0.035	0.06	0.034	0.058	0.035	0.059
33058	Nonferrous metal smelting	0.146	0.256	0.142	0.244	0.144	0.252
33059	Nonferrous metal processing	0.076	0.205	0.075	0.197	0.076	0.203
34060	Metal products	0.189	0.561	0.173	0.525	0.179	0.545
35061	Boiler, engines and turbine	0.069	0.132	0.063	0.121	0.069	0.131
35062	Metalworking machinery	0.044	0.087	0.024	0.065	0.028	0.071
35063	Other general industrial machinery	0.243	0.604	0.18	0.525	0.223	0.581
36064	Agriculture, forestry, animal husbandry and fishing machinery	0.036	0.084	0.027	0.071	0.029	0.075
36065	Other special industrial equipment	0.175	0.41	0.132	0.358	0.156	0.392
37066	Railroad transport equipment	0.025	0.05	0.018	0.041	0.021	0.045
37067	Motor vehicles	0.112	0.351	0.094	0.319	0.105	0.34
37068	automobile parts	0.09	0.266	0.076	0.24	0.08	0.252
37069	Ship building	0.067	0.11	0.057	0.097	0.064	0.106
37071	Other transport machinery	0.107	0.211	0.099	0.198	0.104	0.208
39072	Generators	0.061	0.121	0.045	0.103	0.058	0.116
39073	Household electric appliances	0.101	0.239	0.084	0.217	0.099	0.235
39074	Other electric machinery and equipment	0.211	0.478	0.188	0.447	0.203	0.469
40075	Communication equipment	0.359	0.586	0.349	0.571	0.367	0.589
40076	Electronic computer	0.384	0.573	0.38	0.566	0.297	0.521
40077	Electronic appliances	0.341	0.465	0.335	0.457	0.323	0.455
40078	Electronic element and device	0.283	0.409	0.276	0.399	0.284	0.409
40079	Household video and audio manufacture	0.268	0.377	0.265	0.372	0.276	0.381
40080	Other electronic and communication equipment	0.104	0.128	0.105	0.128	0.11	0.133
41081	Instruments, meters and other measuring equipment	0.101	0.147	0.062	0.109	0.083	0.131
41082	Cultural and office equipment	0.146	0.185	0.153	0.189	0.156	0.192
42083	Arts and crafts products	0.04	0.105	0.047	0.109	0.049	0.114
42084	Other manufacturing products	0.028	0.066	0.027	0.063	0.032	0.07
43085	Scrap and waste	0	0	0	0	0	0
44086	Electricity, Steam and hot water production and supply	0.174	0.414	0.101	0.331	0.142	0.381
45087	Gas production and supply	0.011	0.029	0.012	0.028	0.012	0.029
46088	Water production and supply	0.017	0.035	0.015	0.032	0.016	0.034
47089	Construction	0.972	2.519	0.807	2.287	0.915	2.446
51090	Railway passenger transport	0.021	0.051	0.015	0.042	0.016	0.044
51091	Railway freight transport	0.025	0.072	0.019	0.062	0.02	0.065
52092	Highway passenger transport	0.083	0.21	0.085	0.205	0.086	0.213
53093	Highway freight transport	0.014	0.042	0.014	0.04	0.015	0.042
54094	Water passenger and freight transport	0.086	0.282	0.07	0.257	0.073	0.27
55095	Air passenger transport	0.03	0.072	0.026	0.068	0.027	0.07
55096	Air freight transport	0.008	0.022	0.007	0.021	0.007	0.022
56097	Pipeline transport	0.002	0.005	0.001	0.004	0.001	0.005
58098	Warehousing	0.012	0.039	0.009	0.036	0.011	0.038

59099	Post	0.012	0.034	0.012	0.033	0.013	0.035
60100	information transfer services	0.21	0.309	0.176	0.272	0.209	0.304
61101	computer and software services	0.085	0.196	0.081	0.188	0.071	0.183
63102	Wholesale and retail trade	0.277	0.813	0.277	0.791	0.294	0.824
66103	Hotels	0.02	0.071	0.02	0.069	0.023	0.074
67104	Eating and drinking places	0.083	0.236	0.083	0.231	0.139	0.293
68105	Finance	0.191	0.299	0.211	0.311	0.214	0.318
70106	Insurance	0.024	0.071	0.024	0.069	0.025	0.071
72107	Real estate	0.042	0.171	0.04	0.164	0.042	0.17
73108	Public services	0.003	0.008	0.003	0.008	0.003	0.008
74109	Resident services	0.125	0.396	0.123	0.387	0.091	0.368
74110	Tourism	0.013	0.03	0.013	0.029	0.013	0.03
75111	Scientific research	0.061	0.091	0.054	0.083	0.061	0.09
76112	specialized technical and other services	0.036	0.078	0.03	0.069	0.032	0.073
78113	Geological prospecting and water conservancy	0.007	0.017	0.004	0.015	0.006	0.016
79114	irrigation facility management	0.007	0.018	0.005	0.016	0.006	0.017
80115	Management of environment resource and public infrastructure	0.019	0.055	0.016	0.05	0.018	0.054
82116	household and other services	0.281	0.43	0.314	0.452	0.319	0.463
84117	Educational services	0.171	0.335	0.161	0.314	0.177	0.338
85118	Health services	0.064	0.188	0.04	0.162	0.047	0.175
86119	Social welfare	0.002	0.006	0.002	0.006	0.002	0.006
88120	Culture and arts, radio, film and television	0.033	0.076	0.032	0.073	0.036	0.079
91121	Sports	0.001	0.004	0.001	0.004	0.002	0.005
92122	Recreational services	0.008	0.023	0.008	0.023	0.011	0.026
93123	Public administration and other sectors	0.163	0.436	0.172	0.428	0.179	0.45
	Total	0.17	0.357	0.166	0.346	0.173	0.359

Table 4. Vertical Specialization Shares for China's Exports to the United States

Benchmark IO Table	Year	Direct VS Share DFW	Total VS Share DFW
1997	**1996**	12.36%	25.88%
1997	**1997**	12.30%	25.46%
1997	**1998**	12.48%	25.93%
1997	**1999**	12.69%	26.38%
1997	**2000**	12.89%	26.73%
1997	**2001**	12.96%	27.00%
2002	**2001**	15.70%	29.61%
2002	**2002**	15.99%	29.82%
2002	**2003**	16.66%	30.67%
2002	**2004**	16.85%	31.01%
2002	**2005**	16.68%	30.75%

Table 5. Total Vertical Specialization Shares by Types of Chinese Exporting Firms, 2002

Types of Firms	Total VS Share for China's Exports to The World in 2002	Total VS Share for China's Exports to the United States in 2002
State-Owned Enterprises	27.25%	28.72%
Joint-Ventures	28.68%	29.53%
Wholly-owned foreign firms	30.60%	30.34%
Collectives	28.23%	29.98%
Others	26.00%	26.63%

APPENDIX I

As Hummels, Ishii and Yi (2001) (HIY) state, "imported inputs are allowed to circulate through several stages of the domestic economy before 'exiting' as an export." The imported intermediates in the HIY definition of vertical specialization (VS) include all direct and indirect imported inputs embodied in a country's exports (HIY, page 80). They therefore describe their VS measure as "the *imported input content* of exports, or equivalently, *foreign value-added* embodied in exports" (HIY page 79, italics added).[17] It is easy to show that the *domestic content* share, or *domestic value-added* share[18] in a country's aggregate exports equals one minus the VS share measure proposed by HIY in a non-competitive import type input-output (IO) model.

The IO model can be specified as follows:

$$A^D X + Y^D = X \tag{1}$$

$$A^M X + Y^M = M \tag{2}$$

$$(A^D + A^M)' X + \hat{A}_v X = X \tag{3}$$

$$uA^D + uA^M + A_v = u \tag{4}$$

where:

$A^D = [a^D_{ij}]$ is an nxn matrix of direct input coefficients of domestic products;
$A^M = [a^M_{ij}]$ is an nxn matrix of direct inputs of imported goods;
Y^D is an $nx1$ vector of final demands for domestic products;
Y^M is an $nx1$ vector of final demands for imported goods;
X is an $nx1$ vector of gross output;
M is an $nx1$ vector of imports;
$A_v = [a^v_j]$ is a $1xn$ vector of each sector j's ratio of value-added to gross output;
$\hat{A}_v$ is an nxn diagonal matrix with A_v as its diagonal elements;
u is a $1xn$ unity vector;
superscripts D and M represent domestic and imported products, respectively;
subscripts i and j indicate sectors.

From equation (1), we have

[17] Note that HIY are referring to the value of imported intermediate goods embodied in the home country's exports. They are not referring to the returns to foreign labor or foreign capital working in the home country.
[18] The term "domestic value-added" used throughout this appendix is most often referred to in the trade literature as "domestic content."

$$X = (I - A^D)^{-1} Y^D \quad (5)$$

Substituting equation (5) into equation (2) for X, yields:

$$M = A^M (I - A^D)^{-1} Y^D + Y^M , \quad (6)$$

Suppose that there is an incremental increase in exports of *DE*. Assuming no other change in domestic final demand ($DY^D = DE$), the incremental increase in gross output induced by this change is given by

$$\Delta X = (I - A^D)^{-1} \Delta E \quad (7)$$

according to equation (5). Define the incremental increase in value-added induced by a change in gross output as:

$$\Delta V = \hat{A}_v \Delta X \quad (8)$$

Then, substituting equation (7) for *DX*, the incremental increase in value-added induced by this increase in exports is given by

$$\Delta V = \hat{A}_v \Delta X = \hat{A}_v (I - A^D)^{-1} \Delta E \quad (9)$$

where $V = \{v_j\}$ is an n_{x1} vector of sector value-added. (Miller and Jones, 1985, Chen et al 2005, and Lau et al, 2006).

Define $B_v = \{b^V_j\}$, a $1_{x}n$ vector, as the "domestic value added" generated by one unit of exports ($DE = u'$). Based on (9), we have $B_v = \Delta V = A_v (I - A^D)^{-1}$. The intuition behind B_v is as follows. When an export is produced, a first round of value-added is generated. Let us call it the *direct* domestic value-added induced by exports. In order to produce that export, however, intermediate inputs must be used. The production of these intermediate inputs creates the second-round of value-added. Let us call this the *indirect* domestic value added induced by exports. Clearly, this process of creating indirect value-added can be traced throughout the economy, as intermediate inputs are used to produce other intermediate inputs, etc. Therefore, the *total* domestic value-added induced by exports is equal to the sum

of direct domestic value-added and all indirect domestic value-added (Chen, et. al, 2004). Expressing this process mathematically using the terms defined above, we have

$$\begin{aligned} B_v &= A_v + A_v A^D + A_v A^D A^D + A_v A^D A^D A^D + ... \\ &= A_v (I + A^D + A^{D^2} + A^{D^3} + ...) \end{aligned} \tag{10}$$

It can be shown that the power series of matrix A^D is convergent and the inverse matrix $(I - A^D)^{-1}$ exists (Miller and Jones, 1985). Thus, we have

$$B_v = A_v (I - A^D)^{-1} \tag{11}$$

Now define $B_m = \{b^M_j\}$, a $1xn$ vector which represents the VS in one unit of exports. Then based on HIY's equation (3), we have:

$$B_m = uA^M (I - A^D)^{-1} \tag{12}$$

where A^M and $(I - A^D)^{-1}$ are defined as above. It is easy to show that

$$B_v + B_m = u \text{ [19]}.$$

Since $A_v = u' - u' A^D - u' A^M$ by definition from equation (4), therefore,

$$\begin{aligned} u - B_m &= u - uA^M (I - A^D)^{-1} \\ &= u(I - A^M (I - A^D)^{-1} \\ &= u[(I - A^D)(I - A^D)^{-1} - A^M (I - A^D)^{-1}] \\ &= u[(I - A^D - A^M)(I - A^D)^{-1}] \\ &= (u - uA^D - uA^M)(I - A^D)^{-1} \\ &= A_v (I - A^D)^{-1} = B_v \end{aligned} \tag{13}$$

Therefore, $B_m + B_v = u$ and B_v is the domestic value-added embodied in exports.

[19] The proof is first given in Chen, Cheng, Fung and Lau (2004) in their appendix 1. However, they did not realize the link of their domestic value-added measure and Hummels, Ishii and Yi (2001)'s VS measure.

APPENDIX II

Share of intemediate and final good identified by different methods - China's imports from the United States, 2002

ioid	IOCode	description	intshbec	finshbec	intshdfw	finshdfw	Intshio	Finshio
1	01001	Crop cultivation	95.75	4.25	96.41	3.59	62.35	37.65
2	02002	Forestry	100.00		100.00		83.65	16.35
3	02003	Livestock and livestock products	100.00		100.00		97.68	2.32
4	03004	Fishery	85.32	14.68	85.32	14.68	39.19	60.81
5	04005	Other agricultural products	94.39	5.61	94.39	5.61	50.11	49.89
6	05006	Technical services for agriculture, forestry, livestock and fishing	30.60	69.40	39.01	60.99	74.52	25.48
7	06007	Coal mining and processing	100.00		100.00		83.25	16.75
8	07008	Crude petroleum and natural gas mining	100.00		100.00		95.15	4.85
9	08009	Ferrous ore mining	100.00		100.00		97.34	2.66
10	09010	Non-ferrous ore mining	100.00		100.00		100.96	-0.96
11	10011	Salt mining	100.00		100.00		91.58	8.42
12	10012	Non-metal minerals and other mining	100.00		100.00		95.96	4.04
13	13013	Grain mill products	99.60	0.40	99.60	0.40	48.44	51.56
14	13014	feed products	1.50	98.50	1.50	98.50	98.36	1.64
15	13015	vegetable oil and forage	69.91	30.09	96.33	3.67	51.74	48.26
16	13016	Sugar refining	64.16	35.84	92.82	7.18	66.03	33.97
17	13017	Slaughtering , meat processing, eggs and dairy products	15.65	84.35	19.48	80.52	48.12	51.88
18	13018	Prepared fish and seafood	36.64	63.36	91.29	8.71	36.32	63.68
19	13019	Other food products	57.52	42.48	64.66	35.34	19.31	80.69
20	15020	Wines, spirits and liquors	6.85	93.15	15.88	84.12	49.91	50.09
21	15021	Non-alcoholic beverage	5.25	94.75	9.94	90.06	37.94	62.06
22	16022	Tobacco products	0.00	100.00	0.00	100.00	32.56	67.44
23	17023	Cotton textiles	99.98	0.02	99.98	0.02	91.91	8.09
24	17024	Woolen textiles	97.98	2.02	98.44	1.56	89.37	10.63
25	17025	Hemp and silk textiles	100.00		100.00		80.52	19.48
26	17026	textiles products	96.08	3.92	97.60	2.40	80.19	19.81
27	17027	Knitted mills	89.19	10.81	92.14	7.86	60.20	39.80
28	18028	Wearing apparel	0.32	99.68	97.04	2.96	29.63	70.37
29	19029	Leather, furs, down and related products	96.37	3.63	99.59	0.41	52.50	47.50
30	20030	Sawmills and products of wood, bamboo, cane, palm, straw, etc.	100.00		100.00		97.43	2.57
31	21031	Furniture	70.73	29.27	72.79	27.21	62.03	37.97
32	22032	Paper and products	99.72	0.28	99.78	0.22	94.09	5.91
33	23033	Printing and record medium reproduction	36.23	63.77	38.07	61.93	95.43	4.57
34	24034	Cultural goods	93.15	6.85	94.76	5.24	80.82	19.18
35	24035	Toys, sporting and athletic and recreation products	9.61	90.39	54.96	45.04	18.92	81.08
36	25036	Petroleum refining	99.99	0.01	99.99	0.01	98.51	1.49
37	25037	Coking	100.00		100.00		93.66	6.34
38	26038	Raw chemical materials	100.00		100.00		96.46	3.54
39	26039	Chemical fertilizers	100.00		100.00		100.27	-0.27
40	26040	Chemical pesticides		100.00	0.73	99.27	97.98	2.02
41	26041	Dye, printing oil and similar products	99.79	0.21	99.96	0.04	101.82	-1.82
42	26042	Organic chemical products	100.00		100.00		99.18	0.82
43	26043	specialized chemical products	76.83	23.17	98.36	1.64	98.31	1.69
44	26044	Chemical products for daily use	71.95	28.05	77.88	22.12	59.97	40.03
45	27045	Medical and pharmaceutical products	53.55	46.45	53.55	46.45	68.03	31.97
46	28046	Chemical fibers	100.00		100.00		98.69	1.31
47	29047	Rubber products	95.48	4.52	97.95	2.05	88.63	11.37
48	30048	Plastic products	82.37	17.63	93.00	7.00	93.70	6.30
49	31049	Cement	100.00		100.00		86.59	13.41
50	31050	Glass and glass products	98.27	1.73	99.21	0.79	94.34	5.66

51	31051	Pottery, china and earthenware	98.75	1.25	98.79	1.21	89.79	10.21
52	31052	Fireproof products	100.00		100.00		95.22	4.78
53	31053	Other non-metallic mineral products	99.67	0.33	99.81	0.19	106.35	-6.35
54	32054	Iron-smelting	100.00		100.00		95.11	4.89
55	32055	Steel-smelting	100.00		100.00		99.70	0.30
56	32056	Steel processing	100.00		100.00		96.77	3.23
57	32057	Alloy iron smelting	100.00		100.00		100.36	-0.36
58	33058	Nonferrous metal smelting	100.00		100.00		98.61	1.39
59	33059	Nonferrous metal processing	100.00		100.00		99.09	0.91
60	34060	Metal products	66.94	33.06	75.02	24.98	91.15	8.85
61	35061	Boiler, engines and turbine	67.96	32.04	76.95	23.05	61.53	38.47
62	35062	Metalworking machinery	12.64	87.36	12.65	87.35	44.92	55.08
63	35063	Other general industrial machinery	41.13	58.87	56.45	43.55	82.15	17.85
64	36064	Agriculture, forestry, animal husbandry and fishing machinery	6.66	93.34	6.66	93.34	39.82	60.18
65	36065	Other special industrial equipment	16.52	83.48	16.91	83.09	34.06	65.94
66	37066	Railroad transport equipment	5.35	94.65	5.35	94.65	50.99	49.01
67	37067	Motor vehicles	1.11	98.89	1.27	98.73	45.01	54.99
68	37068	automobile parts	100.00		100.00		95.49	4.51
69	37069	Ship building	46.73	53.27	46.81	53.19	67.17	32.83
70	37071	Other transport machinery	16.66	83.34	16.67	83.33	38.67	61.33
71	39072	Generators	25.77	74.23	47.89	52.11	65.44	34.56
72	39073	Household electric appliances	24.37	75.63	24.67	75.33	44.78	55.22
73	39074	Other electric machinery and equipment	55.92	44.08	65.45	34.55	92.12	7.88
74	40075	Communication equipment	45.02	54.98	45.10	54.90	38.42	61.58
75	40076	Electronic computer		100.00	0.22	99.78	48.52	51.48
76	40077	Electronic appliances		100.00	2.58	97.42	78.35	21.65
77	40078	Electronic element and device	99.59	0.41	99.74	0.26	98.71	1.29
78	40079	Household video and audio manufacture	29.20	70.80	35.66	64.34	48.56	51.44
79	40080	Other electronic and communication equipment	73.00	27.00	79.53	20.47	52.78	47.22
80	41081	Instruments, meters and other measuring equipment	14.29	85.71	15.21	84.79	80.66	19.34
81	41082	Cultural and office equipment	90.47	9.53	90.49	9.51	80.57	19.43
82	42083	Arts and crafts products	66.12	33.88	82.96	17.04	35.06	64.94
83	42084	Other manufacturing products	59.85	40.15	66.16	33.84	90.97	9.03
84	43085	Scrap and waste	100.00		100.00		97.76	2.24
86	45087	Gas production and supply	100.00		100.00		56.37	43.63
98	59099	Post		100.00		100.00	63.30	36.70
119	88120	Culture and arts, radio, film and television	44.81	55.19	45.30	54.70	34.32	65.68
	99999			100.00	98.72	1.28		
	total		59.70	40.30	63.78	36.22	74.20	25.80

Share of intemediate and final good identified by different methods - China's imports from the World, 2002

ioid	IOCode	description	intshbec	finshbec	intshdfw	finshdfw	Intshio	Finshio
1	01001	Crop cultivation	89.08	10.92	90.08	9.92	62.35	37.65
2	02002	Forestry	100.00		100.00		83.65	16.35
3	02003	Livestock and livestock products	100.00		100.00		97.68	2.32
4	03004	Fishery	97.19	2.81	97.19	2.81	39.19	60.81
5	04005	Other agricultural products	72.34	27.66	73.45	26.55	50.11	49.89
6	05006	Technical services for agriculture, forestry, livestock and fishing	8.16	91.84	16.85	83.15	74.52	25.48
7	06007	Coal mining and processing	100.00		100.00		83.25	16.75
8	07008	Crude petroleum and natural gas mining	100.00		100.00		95.15	4.85
9	08009	Ferrous ore mining	100.00		100.00		97.34	2.66
10	09010	Non-ferrous ore mining	100.00		100.00		100.96	-0.96
11	10011	Salt mining	100.00		100.00		91.58	8.42
12	10012	Non-metal minerals and other mining	100.00		100.00		95.96	4.04
13	13013	Grain mill products	91.64	8.36	94.49	5.51	48.44	51.56
14	13014	feed products	1.10	98.90	1.10	98.90	98.36	1.64
15	13015	vegetable oil and forage	95.05	4.95	95.67	4.33	51.74	48.26
16	13016	Sugar refining	85.75	14.25	98.53	1.47	66.03	33.97
17	13017	Slaughtering , meat processing, eggs and dairy products	28.89	71.11	32.30	67.70	48.12	51.88
18	13018	Prepared fish and seafood	31.29	68.71	84.11	15.89	36.32	63.68
19	13019	Other food products	39.15	60.85	47.83	52.17	19.31	80.69
20	15020	Wines, spirits and liquors	2.00	98.00	16.29	83.71	49.91	50.09
21	15021	Non-alcoholic beverage	11.07	88.93	19.39	80.61	37.94	62.06
22	16022	Tobacco products	88.71	11.29	88.77	11.23	32.56	67.44
23	17023	Cotton textiles	99.94	0.06	99.99	0.01	91.91	8.09
24	17024	Woolen textiles	99.75	0.25	99.90	0.10	89.37	10.63
25	17025	Hemp and silk textiles	99.92	0.08	99.99	0.01	80.52	19.48
26	17026	textiles products	95.00	5.00	97.92	2.08	80.19	19.81
27	17027	Knitted mills	73.10	26.90	96.71	3.29	60.20	39.80
28	18028	Wearing apparel	0.38	99.62	86.24	13.76	29.63	70.37
29	19029	Leather, furs, down and related products	95.71	4.29	97.57	2.43	52.50	47.50
30	20030	Sawmills and products of wood, bamboo, cane, palm, straw, etc.	100.00		100.00		97.43	2.57
31	21031	Furniture	60.71	39.29	70.57	29.43	62.03	37.97
32	22032	Paper and products	99.55	0.45	99.67	0.33	94.09	5.91
33	23033	Printing and record medium reproduction	63.44	36.56	73.64	26.36	95.43	4.57
34	24034	Cultural goods	83.53	16.47	92.20	7.80	80.82	19.18
35	24035	Toys, sporting and athletic and recreation products	19.07	80.93	78.60	21.40	18.92	81.08
36	25036	Petroleum refining	99.53	0.47	99.53	0.47	98.51	1.49
37	25037	Coking	100.00		100.00		93.66	6.34
38	26038	Raw chemical materials	100.00		100.00		96.46	3.54
39	26039	Chemical fertilizers	100.00		100.00		100.27	-0.27
40	26040	Chemical pesticides		100.00	3.22	96.78	97.98	2.02
41	26041	Dye, printing oil and similar products	99.87	0.13	99.97	0.03	101.82	-1.82
42	26042	Organic chemical products	100.00		100.00		99.18	0.82
43	26043	specialized chemical products	86.47	13.53	98.15	1.85	98.31	1.69
44	26044	Chemical product s for daily use	76.12	23.88	83.26	16.74	59.97	40.03
45	27045	Medical and pharmaceutical products	39.09	60.91	39.11	60.89	68.03	31.97
46	28046	Chemical fibers	100.00		100.00		98.69	1.31

47	29047	Rubber products	86.04	13.96	96.30	3.70	88.63	11.37
48	30048	Plastic products	76.71	23.29	95.05	4.95	93.70	6.30
49	31049	Cement	100.00		100.00		86.59	13.41
50	31050	Glass and glass products	97.58	2.42	98.82	1.18	94.34	5.66
51	31051	Pottery, china and earthenware	90.95	9.05	94.26	5.74	89.79	10.21
52	31052	Fireproof products	100.00		100.00		95.22	4.78
53	31053	Other non-metallic mineral products	98.94	1.06	99.23	0.77	106.35	-6.35
54	32054	Iron-smelting	100.00		100.00		95.11	4.89
55	32055	Steel-smelting	100.00		100.00		99.70	0.30
56	32056	Steel processing	100.00		100.00		96.77	3.23
57	32057	Alloy iron smelting	100.00		100.00		100.36	-0.36
58	33058	Nonferrous metal smelting	100.00		100.00		98.61	1.39
59	33059	Nonferrous metal processing	100.00		100.00		99.09	0.91
60	34060	Metal products	76.49	23.51	79.39	20.61	91.15	8.85
61	35061	Boiler, engines and turbine	72.55	27.45	75.67	24.33	61.53	38.47
62	35062	Metalworking machinery	11.66	88.34	11.68	88.32	44.92	55.08
63	35063	Other general industrial machinery	43.87	56.13	58.95	41.05	82.15	17.85
64	36064	Agriculture, forestry, animal husbandry and fishing machinery	12.52	87.48	12.55	87.45	39.82	60.18
65	36065	Other special industrial equipment	12.30	87.70	13.10	86.90	34.06	65.94
66	37066	Railroad transport equipment	32.36	67.64	32.39	67.61	50.99	49.01
67	37067	Motor vehicles	1.05	98.95	1.56	98.44	45.01	54.99
68	37068	automobile parts	100.00		100.00		95.49	4.51
69	37069	Ship building	45.51	54.49	48.84	51.16	67.17	32.83
70	37071	Other transport machinery	31.43	68.57	31.51	68.49	38.67	61.33
71	39072	Generators	31.16	68.84	71.67	28.33	65.44	34.56
72	39073	Household electric appliances	44.33	55.67	46.82	53.18	44.78	55.22
73	39074	Other electric machinery and equipment	61.88	38.12	82.59	17.41	92.12	7.88
74	40075	Communication equipment	46.70	53.30	50.95	49.05	38.42	61.58
75	40076	Electronic computer		100.00	0.57	99.43	48.52	51.48
76	40077	Electronic appliances		100.00	27.61	72.39	78.35	21.65
77	40078	Electronic element and device	97.75	2.25	99.67	0.33	98.71	1.29
78	40079	Household video and audio manufacture	85.86	14.14	92.91	7.09	48.56	51.44
79	40080	Other electronic and communication equipment	56.05	43.95	57.87	42.13	52.78	47.22
80	41081	Instruments, meters and other measuring equipment	21.33	78.67	53.78	46.22	80.66	19.34
81	41082	Cultural and office equipment	93.86	6.14	94.08	5.92	80.57	19.43
82	42083	Arts and crafts products	84.81	15.19	94.56	5.44	35.06	64.94
83	42084	Other manufacturing products	94.84	5.16	96.78	3.22	90.97	9.03
84	43085	Scrap and waste	100.00		100.00		97.76	2.24
85	44086	Electricity, Steam and hot water production and supply	100.00		100.00		85.47	14.53
86	45087	Gas production and supply	100.00		100.00		56.37	43.63
98	59099	Post		100.00		100.00	63.30	36.70
119	88120	Culture and arts, radio, film and television	45.04	54.96	59.03	40.97	34.32	65.68
	99999			100.00	57.12	42.88		
	total		73.89	26.11	80.03	19.97	74.67	25.33