

Dynamic Changes of China's Functional Specialization in Export and International Comparison under Global Value Chains

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The functional specialization in export of a country (and its sectors) in different activities, such as fabrication, R&D, management and marketing, is crucial to its governance and control on the value chains, which magnifies the shortage of the existing aggregate value added studies on our understanding of global value chains (GVCs). Considering production fragmentation at both the spatial and functional levels, this paper defines the modified functional specialization indicators at the national and sectoral levels from the forward linkage (rather than backward linkage). Based on the World Input-Output Database together with the newly compiled Labor Occupations Database, this paper re-estimates and analyzes the functional specialization and changes in China and major developed economies' exports. The results show that China's export is mainly specialized in fabrication activity, which is among the world leading level, while it is weak in headquarter activities (especially R&D and management), which is almost locked at the lowest level in the world and could not pose an export threat to the developed economies. China's manufacturing basically follows the functional development path of "relying on fabrication, entering market, targeting management and R&D", featuring the coexistence of "strong" fabrication and "weak" management and R&D. The fabrication specialization of the typical processing sector "electronic and optical equipment" has reached the international leading level. The level of functional specialization of China's service industry is generally lower than that of manufacturing and generally lags behind in the world, indicating that China still has a long way to go before becoming a major power of service in the world. Finally, this paper proposes policy implications and further researches that can be extended.

Keywords: global value chains, functional specialization, domestic value added in export, international comparison

1. Introduction

Since the 1980s, as the cost of information communications and transport reduced

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and global environment for trade and investment improved, global production chain revolution has emerged and soon become the mainstream of international trade. This is manifested by the fact that working procedures of production are constantly segmented, in which each country (region)¹ focuses on only one production procedure or step of products and value of particular products is constituted by multiple countries (Johnson and Noguera, 2012; Wang *et al.*, 2013; Koopman *et al.*, 2014; Timmer *et al.*, 2014). In the context that global value chains (GVCs) keep developing in depth, scholars and policy-makers have generally reached the consensus that the new trade accounting method based on value added can correct the misjudgment in a country's comparative advantages in export made with the traditional method of trade of gross value, and is more effective in measuring authentic international competitiveness of industries of a country (Koopman *et al.*, 2014; Timmer *et al.*, 2013). However, production division covers two dimensions of space and function (Romero *et al.*, 2009; Timmer *et al.*, 2019). As a typical example, iPhone are printed with "Designed by Apple in California Assembled in China" at the back, meaning that they are designed by Apple in California, the United States, and then assembled in China. The Report of the 19th National Congress of the CPC proposed to "move Chinese industries up to the medium-high end of the global value chain", one important area of which is to expand from processing and fabrication to areas of high value-added and high technical content at the both ends of the "Smiling Curve" such as R&D management and market services. Therefore, a pure perspective of trade of gross value-added may cover the differences among different functional activities such as R&D, management, marketing and fabrication in level of specialization. In fact, measurement of a country's functional specialization of different activities in export is the latest research progress in the field of GVCs (Chen *et al.*, 2018; Timmer *et al.*, 2019). Apparently, it is necessary to take the perspective of GVCs to measure and analyze a country (or sector)'s actual functional specialization level in activities of export and the dynamic changes more scientifically and in greater details, so as to offer some insightful references for promoting Chinese industries to move up to the medium-high end of the GVCs and helping China realize functional upgrade in export.

Existing literature on the measurement and analysis of specialization in export of a country can be divided into two development stages by their applied trade accounting framework. The first stage was analysis on export specialization under the accounting framework of trade of gross value. The representative figure was Balassa (1965), who was the first to propose the measuring method of revealed comparative advantage (RCA), and used the proportion of a country's industrial (product) export in its total export in comparison with the proportion of the global export of same industries (products) in global total export to reflect the country's specialization level in the

¹ Country in this paper sometimes refers to region.

industrial (product) export. Afterwards, RCA was widely adopted by the academic community (Balassa, 1977; Balassa, 1979; Jin *et al.*, 2006; Jin *et al.*, 2013; French, 2017) and international institutions (UNIDO, 1986; World Bank, 1994; OECD, 2011). However, what the RCA-based analysis under the framework of trade of gross value reflected was comparative advantages of a country's industries in participating in global specialization, which overlooked the domestic and global production division (Wang *et al.*, 2015). To be specific, for one thing, it neglected the fact that a country's industries (products) could be concealed in export of its other industries (products) and may realize indirect export. For another, it ignored the fact that the country's industrial (product) export might conceal part of value added of other countries, and therefore, export under the framework of trade of gross value was not necessarily the "authentic export" of the industries (products). On this account, as GVCs rapidly become the mainstream of international trade, it is difficult for the RCA-based analysis under the traditional accounting framework of trade of gross value to reflect a country (sector)'s authentic specialization in export under GVCs, which may even cause serious misjudgment (Timmer *et al.*, 2013; Wang *et al.*, 2013; Koopman *et al.*, 2014; Wang *et al.*, 2015).

In fact, the accounting method based on trade in value added can exactly overcome such limitations and reflect a country's specialization in export amid its participation in global vertical specialization. Hence the measurement and analysis on a country's specialization in export evolved to the second development stage under the accounting framework of trade in value added. This was further divided into two sub-stages by whether functional activities were classified or not. So far, the majority of literature on export specialization didn't distinguish different types of functional activities, but only improved RCA from the perspective of trade of gross value added and analyzed a country's specialization in export in the context of GVCs (Timmer *et al.*, 2019). However, the research from the perspective of trade of gross value added was incapable of value added accounting for segmented functional activities, which covered the differences among different types of activities in functional specialization. As technologies advanced and labor division was refined, the activities were increasingly segmented to R&D, fabrication, marketing and management, etc., and the relative proportion of a country's industries in engagement of different functional activities affected its influence and control on value chains and thus influenced its ability in acquiring value added. According to existing researches, compared with processing and fabrication at the bottom of the "Smiling Curve", R&D management and marketing services at the both ends had greater capability in gaining value added and had stronger control and influence on entire value chains (Meng *et al.*, 2020). On this account, accurate measurement of the value added of different functional activities in a country's industrial export and scientific analysis of the country's functional specialization in export in different types of activities are highly relevant both theoretically and realistically.

In this regard, Timmer *et al.* (2019) was among the first to make beneficial

explorations, measuring a country's functional specialization level and its changes from the perspective of labor occupation types for the first time and on such basis, estimating a country's functional specialization in export in different types of activities. However, the following aspects remained to be improved. First, the backward-linkage decomposition was adopted to measure the value added in trade of sectors of a country in different functional activities. Though the foreign value added in export was removed, domestic production division was neglected, so the measured value added in trade of particular sectors in different functional activities also included the export value of other sectors in the country, resulting in deviation in the measurement of the sectors' functional specialization in export. Obviously, it was necessary to take the sectors' factor ownership as the basis of returns (Wang *et al.*, 2015; Zheng and Wang, 2017) or in another word, start with forward-linkage decomposition to accurately estimate the value added of different functional activities of sectors of a country in export. Second, extensive cross-country comparison was made on a country's functional specialization in export in different types of activities, but functional specialization at the industrial level was not included into analysis and the specialization level of Chinese industries and its dynamic changes were not revealed. Given the universal difference among industries and the increasingly important role of "lubricant" played by the service industry in China's economic operation (Dietzenbacher *et al.*, 2013), it was apparently necessary to further dig to the domestic industrial level and include manufacturing and the service industry into analysis to improve effectiveness and pertinence of related industrial policies.

This paper contributes to the literature mainly in the following areas. First, theoretically speaking, with industrial factor returns as basis, the paper uses forward-linkage decomposition to improve the measurement of domestic value added in export of a country's sectors in different functional activities and on such basis, constructs modified functional specialization indicators at the national and industrial level. Compared with backward linkage, the modified forward linkage removes the domestic value added in export from other sectors of the country in export of gross value, and at the same time, includes the domestic value added in export of the sector concealed in the export of other sectors. In doing so, the method better identifies a sector's authentic domestic value added in export in different functional activities and more accurately evaluates the functional specialization level and its dynamic changes. Second, empirically speaking, with heterogeneity among countries and sectors in functional activities taken into consideration, the paper comprehensively measures and analyzes China's overall and industrial (manufacturing and the service industry) functional specialization in export in different activities and its dynamic changes, and reveals the specialization differences among Chinese industries in activities such as R&D, management, marketing and fabrication. On such basis, it compares China and main developed economies to help understand China's authentic specialization level in trade

in goods and in services and identify the differences between a large power of trade as China is and a strong power of trade. In doing so, the paper provides some insightful implications for promoting Chinese industries to move up to the medium-high end of the GVCs and helping China realize functional upgrading in export.

2. Theoretical Model and Data

2.1. Measurement of Functional Specialization

The study starts from a single-country input-output table that distinguishes the value added of industrial functional activities, and identifies four types of activities, i.e. management, R&D, marketing and fabrication. Suppose that a country consists of N sectors and each sector only produces a single product or service (i.e. pure sector). The sectors' output can both be used to meet end demand and be input for intermediate production. At the time of market clearing, sector i satisfies the equation (1):

$$x_i \equiv \sum_j z_{ij} + \sum_j y_{ij} \quad (1)$$

In equation (1), x_i is the total output of sector i ; z_{ij} is the intermediate consumption of products of sector i by sector j ; y_{ij} is the end demand of sector j for products of sector i . Then, when all of the N products in a country reach the status of market clearing, we get N identities similar to equation (1) and they can be expressed in matrix as:

$$X = Z\iota + Y = AX + Y \quad \text{or} \quad X = (I - A)^{-1}Y = BY \quad (2)$$

X is the column vector of total output; Z is the flow matrix of domestic intermediate input; ι is the sum column vector with elements being 1; $A = Z\hat{X}^{-1}$ is the domestic direct consumption coefficient matrix,¹ Element $a_{ij} = z_{ij}/x_j$ represents the direct consumption of products of sector i by unit output of sector j ; $B = (I - A)^{-1}$ is the Leontief inverse matrix, which is also called matrix of total demand coefficient, referring to the total output of all sectors' products required to produce unit end products; Y is the column vector of end demand and consists of domestic end demand F and export E . Then, all the output needed for satisfying the export is $E + AE + A^2E + \dots = \sum_{p=0}^{\infty} A^p E = (I - A)^{-1}E = BE$.

Make the element $v_{i,k}$ in the row vector v_k indicate the value added created by sector i in the functional activity k and the functional activity k can be categorized into four types, including management, R&D, marketing and fabrication. Then the row vector of direct

¹ The vector with a hat is diagonalized. Make the vector elements distribute along the main diagonal and set all the elements off the main diagonal as 0.

value-added coefficient in the functional activity k can be calculated with $V_k = v_k \hat{X}^{-1}$, and the element $V_{i,k} = v_{i,k} / x_i$ means the value added created by labor in the functional activity k in unit output of sector i . In this case, when there are N sectors in a country, the domestic value added in exports (DVA) obtained by the functional activity k at the sectoral level contained in the export of the sectors in the country can be calculated with $\hat{V}_k B \hat{E}$:

$$\begin{aligned} \hat{V}_k B \hat{E} &= \begin{bmatrix} V_{1,k} & 0 & \cdots & 0 \\ 0 & V_{2,k} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & V_{N,k} \end{bmatrix} \begin{bmatrix} B_{11} & B_{12} & \cdots & B_{1N} \\ B_{21} & B_{22} & \cdots & B_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ B_{N1} & B_{N2} & \cdots & B_{NN} \end{bmatrix} \begin{bmatrix} E_1 & 0 & \cdots & 0 \\ 0 & E_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & E_N \end{bmatrix} \\ &= \begin{bmatrix} V_{1,k} B_{11} E_1 & V_{1,k} B_{12} E_2 & \cdots & V_{1,k} B_{1N} E_N \\ V_{2,k} B_{21} E_1 & V_{2,k} B_{22} E_2 & \cdots & V_{2,k} B_{2N} E_N \\ \vdots & \vdots & \ddots & \vdots \\ V_{N,k} B_{N1} E_1 & V_{N,k} B_{N2} E_2 & \cdots & V_{N,k} B_{NN} E_N \end{bmatrix} \end{aligned} \quad (3)$$

In equation (3), $\hat{V}_k B \hat{E}$ is a $N \times N$ matrix. Its element $V_{i,k} B_{ij} E_j$ ($i, j = 1, 2, \dots, N$) means the domestic value added in export realized by industry i in functional activity k through export of industry j , or the value added of industry i in functional activity k contained in the export of industry j . The sectors' "authentic export" in a country includes not only the value added $V_{i,k} B_{ij} E_j$ ($i = j$) realized through export of the industry itself, but also the value added $V_{i,k} B_{ij} E_j$ ($i \neq j$) indirectly realized by providing other industries with intermediate input. Given so, in order to get the authentic domestic value added in export of all sectors in functional activity k , we only need to get the horizontal sum of all the row elements in equation (3):

$$\begin{aligned} DVA_k &= \hat{V}_k B \hat{E} \mathbf{1} = \hat{V}_k B \mathbf{E} \\ &= \begin{bmatrix} V_{1,k} B_{11} E_1 + V_{1,k} B_{12} E_2 + \cdots + V_{1,k} B_{1N} E_N \\ V_{2,k} B_{21} E_1 + V_{2,k} B_{22} E_2 + \cdots + V_{2,k} B_{2N} E_N \\ \vdots \\ V_{N,k} B_{N1} E_1 + V_{N,k} B_{N2} E_2 + \cdots + V_{N,k} B_{NN} E_N \end{bmatrix} = \begin{bmatrix} DVA_{1,k} \\ DVA_{2,k} \\ \vdots \\ DVA_{N,k} \end{bmatrix} \end{aligned} \quad (4)$$

Based on equation (4), we embed a country's domestic value added in export in different functional activities into functional specialization (FS) proposed by Timmer *et al.* (2019) and come to the modified functional specialization:

$$FS_k^s = \frac{DVA_k^s / \sum_k DVA_k^s}{\sum_s DVA_k^s / \sum_{k,s} DVA_k^s} \quad (5)$$

DVA_k^s refers to the domestic value added in export of country s in functional activity k ; $\sum_k DVA_k^s$ means the sum of domestic value added in export of country s in all the functional activities; $\sum_s DAV_k^s$ is the sum of domestic value added in export of all the countries in the world in functional activity k ; $\sum_{k,s} DVA_k^s$ is the sum of domestic value added in export of all the countries in the world in all the functional activities. If FS_k^s index is greater than 1, it means that country s has a high specialization level in functional activity k and enjoys relative comparative advantage; if FS_k^s index is lower than 1, it means that country s is lower than global average in specialization in functional activity k and shows comparative disadvantage.

Furthermore, the paper also offers the calculation formula for a country's functional specialization at the industrial level. We can calculate with equation (6) and get:

$$FS_{i,k}^s = \frac{DVA_{i,k}^s / \sum_k DVA_k^s}{\sum_s DVA_{i,k}^s / \sum_{k,s} DVA_k^s} \quad (6)$$

$DVA_{i,k}^s$ is the domestic value added in export of industry i in country s in functional activity k ; $\sum_s DVA_{i,k}^s$ is the sum of domestic value added in export of industry i in all the countries in the world in functional activity k . As its explanation is similar to that at the national overall level, it will not be elaborated here.

2.2. Data Source and Explanations

The paper mainly uses the World Input-Output Table (Dietzenbacher *et al.*, 2013; Timmer *et al.*, 2015) released by World Input-Output Database (WIOD) in 2013. The 2013 WIOD data covers 40 countries in the world and 1 rest of world (ROW). To be specific, each country consists of 35 sectors and the input-output table covers a time span from 1995 to 2011. During the period, the sum of GDP of the 40 economies accounted for around 85% of global GDP, which is sufficient to reflect the global production and trade pattern (Timmer *et al.*, 2015). The paper also adopts the Labor Occupations Database (LOD) data. LOD lists the proportion of remuneration of different labor occupation types in total labor remuneration at the national-sectoral level in 1999–2011, and its classification of sectors is entirely consistent with the 2013 WIOD input-output table. As the labor occupation data goes back to 1999, the paper focuses on 1999–2011 as the research period. The basic input-output table used in the paper is a current price table denominated at current prices. Generally speaking, for intertemporal comparison and analysis, input-output tables of different years should be deflated to remove the price factor and get a constant price table. However, as the indicators on a country's functional specialization in export in the paper are based on ratio and the price factor and dimensional influence have already been removed,

whether the tables are deflated or not will not affect the analysis conclusions (Wang *et al.*, 2019).

3. Measurement and Analysis of Functional Specialization

3.1. Overall Analysis

The paper first measures the functional specialization of China in GVCs by function and the changing trend, and the result is shown in Figure 1, from which we can draw the following basic conclusions.

China's specialization in export showed significant heterogeneity in function, which remained relatively stable during the analysis period. In 1999–2011, China's specialization in export in fabrication was high; it was closely followed by marketing specialization, which, however, turned out to be relative comparative disadvantage in global export market; specialization in management and R&D was obviously low, showing significant comparative disadvantage. As shown in Figure 1, for China, its specialization in fabrication was the highest during the analysis period, with its vertical axis value apparently surpassing 1 and ranging between 1.6957 and 1.8729. Contrary to that of fabrication, specialization in management and R&D was the lowest, with the value not exceeding 0.40 throughout the period. Between the two situations was marketing specialization, which fluctuated around 0.80 and still was manifested as relative comparative disadvantage. This was consistent with the research conclusions of Timmer *et al.* (2019), which held that China was embedded into global production network more in the capacity of “fabricator”, but clearly stayed in a “peripheral” position in headquarter economic activities (e.g. R&D and management).

When China embedded in the GVCs, its functional specialization showed different changing trends in different functional activities. The specialization level in fabrication and R&D generally displayed an upward trend; the level in marketing and management showed a downward trend, while marketing specialization slightly turned upwards at the end of the analysis period. The measurement result in Figure 1 shows:

First, China's general specialization in fabrication increased from 1.6957 in 1999 to 1.8394 in 2011 and the rising trend was obviously enhanced after China's accession to WTO in 2001. It indicated that as China successfully integrated into GVCs, China's comparative advantage in export in fabrication was further improved. Second, similar to the changing trend in fabrication specialization, the specialization in R&D slightly rose from 0.2897 to 0.3852 across the analysis period, showing that China realized the improvement of comparative advantage in R&D to some extent. Apparently, the change was consistent with the practice that China's expenditure in R&D steadily grew year by year. However, the growth of R&D specialization was not significant during the period and the level remained an obvious comparative disadvantage at the end of

the period, meaning that China still had a long way to go to improve and catch up in export in R&D. Third, in 1999–2011, China's specialization in export in marketing and management (especially management) displayed a trend of declining in general, which was more visible after the accession to WTO in 2001. It indicated that during the analysis period, China's comparative disadvantage in export in marketing and management was worsened. At first glance, this seemed deviated from existing studies on China's trade upgrading. Of course, the reason behind the decline may not be the increasingly weaker comparative advantage in marketing and management, but more likely the lagging-behind development in marketing and management.¹

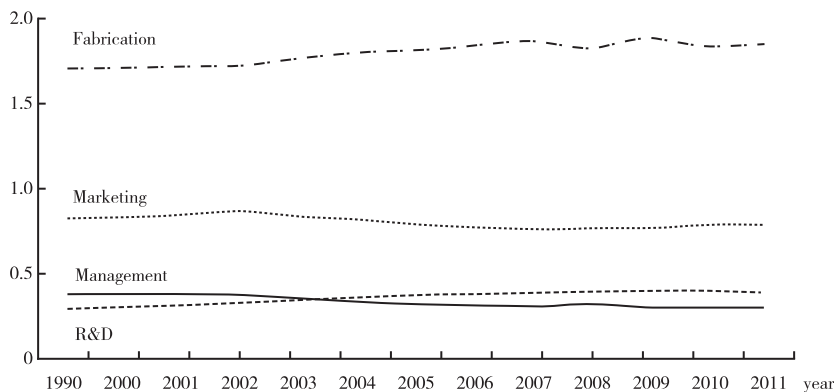


Figure 1. Changing Trends of China's Functional Specialization in GVCs in Different Functional Activities

Furthermore, the paper also measures the functional specialization of other main developed economies in the world (G7, including the United States, Japan, Germany, England, France, Canada and Italy) and Taiwan, China in GVCs in different functional activities, and compares them with Mainland China. Figure 2 introduces the measurement results in details.

In cross-country comparison, Mainland China's fabrication specialization in export throughout the analysis period was leading the world. According to Figure 2, among all the sample economies, Mainland China's fabrication specialization level was the highest, approaching 2.0 and exceeding that of G7 developed economies and Taiwan, China. In fact, even among all the 40 WIOD economies (excluding ROW), Mainland China

¹ Though China's specialization in export in marketing and management declined, the value-added returns of the two in participating in export still increased. Compared with the beginning of the analysis period, China's domestic value added in export in marketing and management in GVCs grew by 5.55 times and 4.66 times respectively at the end of the period, which, however, was lower than the growth in fabrication (5.76 times) and R&D (9.19 times). According to equation (5), though China's value-added returns in export in marketing and management increased, if its value-added returns in export in other functional activities increased as well by a larger margin, in comparison, the development in marketing and management turned out to be lagging behind.

remained the top of the world in fabrication specialization in the analysis period, except for 2001–2003 when it was surpassed by Turkey. As for the reasons, China relied on its sufficient labor force to rapidly integrate into the global production network and actively undertake the outsourcing from developed economies (e.g. the United States). It was dedicated to medium- and low-end fabrication and production activities such as processing and assembling (Dedrick *et al.*, 2010; Xing and Neal, 2010; Ni, 2017). This explained why China rapidly developed into the “World Factory” or “Asian Factory” during the period.

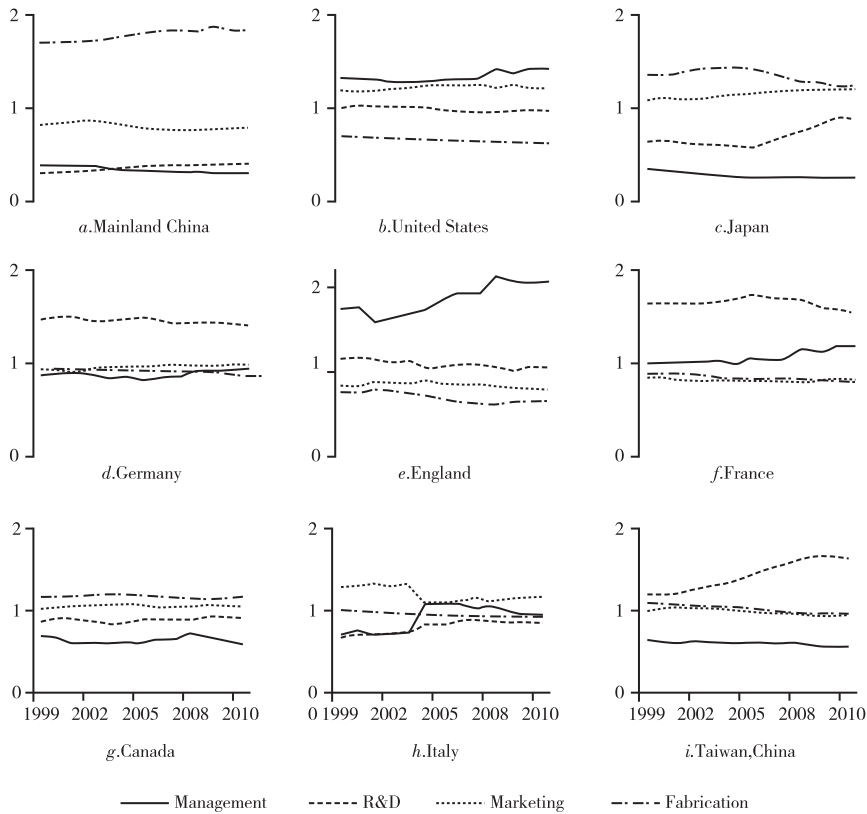


Figure 2. Changing Trends of Functional Specialization in Export of China and Main Developed Economies

Contrary to fabrication, Mainland China showed significant comparative disadvantage in export in headquarter economic activities (e.g. management and R&D), and its functional specialization was comprehensively lagging behind other developed economies. Take 2011 as an example. As revealed in Figure 2, Mainland China’s specialization in export in management and R&D was 0.2985 and 0.3852 respectively, much lower than that of main developed economies at the same year. To be specific, England and the United States exhibited significant management specialization level in export, being 2.0645

and 1.4145 respectively, while Taiwan, China and France had an R&D specialization level much higher than other economies, being 1.6209 and 1.5417 respectively. In fact, even compared with other BRIC countries that were also developing countries, Mainland China still showed comparative disadvantage in export in R&D and management.

Furthermore, the paper ranks the 40 economies (excluding the ROW) in the descending order by their functional specialization in headquarter economic activities in 1999–2011 and finds that China's specialization level in management and R&D across the analysis period was almost locked at the world's lowest level. Specifically, China's specialization level in export in management ranked 39th among the 40 economies (second to last) and its level in R&D ranked 40th (last). China, with its position in the ranking basically unchanged, was unable to pose any export threat to developed economies such as the United States and those in Europe, and this further confirmed the research conclusion of Ni (2017) on China's technology content in export. The analysis forcefully refuted the great clamor of "China threat theory with technology export" on the one hand, and on the other hand, indicated that China still had a long way to go in improving its specialization in export in headquarter economic activities such as management and R&D. It was encouraging that China's R&D specialization in export did realize improvement to some extent during the analysis period, which slightly increased from 0.2897 in 1999 to 0.3852 in 2011.

3.2. Analysis by Industry

Table 1 introduces the functional specialization of China's segmented manufacturing sectors in GVCs in different functional activities during 1999–2011, especially the changes and the latest international ranking. The conclusions are as follows.

The measurement results on the specialization of manufacturing sectors in export based on gross value added and based on value added in different functional activities differ significantly. For one thing, this highlights that the trade accounting based on gross value added lacks full understanding on specialization of a country's sectors in export; for another, it displays the necessity of better understanding the sectors' specialization in export in management, R&D, marketing and fabrication from the perspective of functional specialization. Take two representative manufacturing sectors, textiles and electrical and optical equipment, as examples. Under the trade accounting framework based on gross value added, China's specialization level was significant in the two industries, especially in textiles, with a specialization index in export reaching up to 3.1207 in 2011, while the index at the same term in electrical and optical equipment was 1.8139. If we hope to further look at the industries' specialization in export under functional division and find the answer to such questions as "is Chinese textiles industry more dedicated to fabrication or R&D and how specialized is it in fabrication", the gross value

added-based trade accounting will seem incompetent at this point. In such a case, measurement of functional specialization based on value added in different functional activities exactly offers a quantitative analysis method. As shown in Table 1, in 2011, China's specialization in export in electrical and optical equipment was 1.8139 and the country enjoyed strong international comparative advantage. Furthermore, the relative comparative advantage was reflected more in fabrication and marketing, especially in fabrication, with its specialization level reaching up to 3.0123. On the contrary, the industry in China displayed obvious relative comparative disadvantage in management and R&D, with the specialization in the two activities being 0.4009 and 0.5153 respectively. Between this result and the specialization index 1.8139 in export measured on the basis of gross domestic value added in export, there existed a marked difference.

Table 1. Changes and International Ranking of Functional Specialization of China's Segmented Manufacturing Sectors

		1999	2011		1999	2011		1999	2011		
S03	MGT	0.3134	0.2549 [36]	S08	MGT	0.5050	0.3037 [26]	S13	MGT	0.3334	0.3976 [32]
	R&D	0.3354	0.4115 [37]		R&D	0.4201	0.4276 [26]		R&D	0.2132	0.3544 [29]
	MAR	0.8314	0.9611 [24]		MAR	1.1329	1.1803 [9]		MAR	0.7100	0.8830 [12]
	FAB	1.0255	1.1238 [18]		FAB	1.6810	1.4043 [8]		FAB	0.7875	1.4175 [8]
	TVA	1.2015	1.0042		TVA	0.9445	0.6317		TVA	0.7443	1.0876
S04	MGT	0.9988	0.8175 [16]	S09	MGT	0.3838	0.3856 [35]	S14	MGT	0.3356	0.4009 [24]
	R&D	1.0469	1.2027 [14]		R&D	0.2390	0.3556 [32]		R&D	0.2661	0.5153 [24]
	MAR	1.9498	1.7986 [5]		MAR	0.9784	1.0523 [12]		MAR	1.0174	1.3292 [4]
	FAB	4.7111	4.7447 [2]		FAB	1.6318	1.9801 [2]		FAB	1.6423	3.0123 [2]
	TVA	3.7044	3.1207		TVA	1.0004	1.1297		TVA	1.1400	1.8139
S05	MGT	0.8561	0.9306 [11]	S10	MGT	0.7135	0.6396 [32]	S15	MGT	0.1429	0.2126 [33]
	R&D	0.9357	0.5555 [19]		R&D	0.2828	0.2211 [31]		R&D	0.0803	0.2225 [30]
	MAR	1.7357	1.5974 [7]		MAR	1.2364	1.1871 [12]		MAR	0.2851	0.5732 [22]
	FAB	5.1416	4.3351 [3]		FAB	1.6609	1.7250 [2]		FAB	0.2806	0.7723 [22]
	TVA	3.8067	3.1207		TVA	1.6123	1.5941		TVA	0.2860	0.6035

		1999	2011			1999	2011			1999	2011
S06	MGT	0.5850	0.5211 [30]	S11	MGT	1.3864	0.7132 [28]	S16	MGT	0.1979	0.1969 [34]
	R&D	0.2222	0.3143 [32]		R&D	0.8528	0.5217 [26]		R&D	0.1323	0.1242 [38]
	MAR	0.7488	0.9854 [19]		MAR	2.0603	1.3483 [14]		MAR	0.4639	0.8715 [18]
	FAB	1.4403	1.9590 [14]		FAB	2.9295	1.9569 [6]		FAB	1.1991	1.2810 [19]
	TVA	1.2877	1.6836		TVA	2.2503	1.6522		TVA	1.3120	1.4504
S07	MGT	0.3721	0.3022 [37]	S12	MGT	0.5062	0.4216 [35]				
	R&D	0.1773	0.1120 [39]		R&D	0.3441	0.3884 [33]				
	MAR	0.4283	0.4548 [36]		MAR	1.1002	1.0521 [10]				
	FAB	1.2709	1.3906 [9]		FAB	1.0747	1.2082 [11]				
	TVA	0.7172	0.8486		TVA	1.0190	1.3055				

Notes: Figures in square brackets refer to ranking of the functional specialization level of China's segmented manufacturing sectors among the corresponding industries of all the 40 WIOD economies (excluding the ROW) in 2011. Larger (smaller) figure means lower (higher) position in the ranking. MGT = management; MAR = marketing; FAB = fabrication; TVA = total value added. S03: food, beverages and tobacco; S04: textiles and textile products; S05: leather, leather and footwear; S06: wood and products of wood and cork; S07: pulp, paper, paper, printing and publishing; S08: coke, refined petroleum and nuclear fuel; S09: chemicals and chemical products; S10: rubber and plastics; S11: other non-metallic mineral; S12: basic metals and fabricated metal; S13: machinery, n.e.c.; S14: electrical and optical equipment; S15: transport equipment; S16: manufacturing, n.e.c., recycling.

When embedded into GVCs, China's manufacturing basically followed the functional development path of "relying on fabrication, entering market, targeting management and R&D". For the 14 China's segmented manufacturing sectors, in the entire analysis period, three categories of functional activities were identified. The first was fabrication, with its functional specialization staying at a high level. The majority of the segmented manufacturing sectors had a specialization index in fabrication of higher than 1, and for textiles, a labor-intensive manufacturing sector, its specialization especially surpassed 4 and displayed significant comparative advantage¹. The second was management and R&D, whose functional specialization was the lowest. For the most segmented manufacturing sectors (excluding textiles and leather and footwear), not only their specialization in management and R&D stayed below 1, but the maximum

¹ Machinery and transport equipment are exceptions. Their specialization index in fabrication was lower than 1 at the beginning of the analysis period, but as time went by, the level kept rising. Especially in machinery equipment, relative comparative disadvantage (0.7875) was turned into relative comparative advantage (1.4175).

value was still lower than the critical value 0.80 of “weak comparative disadvantage” (Dai, 2015), with their specialization even lagging behind the critical value 0.80 by a quite large margin. These sectors were at a position of noticeable comparative disadvantage in management and R&D. The third was marketing, whose specialization level was between the two categories above. By 2011, China’s segmented manufacturing sectors hadn’t gained comprehensive comparative advantage yet, but their average specialization index was gradually approaching 1. Besides, some manufacturing sectors had already enjoyed relative comparative advantage in marketing. For instance, the typical technology-intensive manufacturing sector of electric and optical equipment had a specialization index in marketing of up to 1.3292 in 2011. In other words, while relying on its specialization advantage in fabrication, China’s manufacturing is marching ahead towards specialization advantage in marketing.

Consistent with the functional development path of China’s manufacturing in “relying on fabrication, entering market, targeting management and R&D”, China’s segmented manufacturing sectors’ specialization in fabrication was at a high level in the world overall and even leading the world; in management and R&D, it ranked behind in the world and was at a subordinate position; in marketing, the specialization level ranged between the two situations above. According to the international ranking in Table 1, for the majority of China’s manufacturing sectors, their ranking in fabrication specialization was the highest and followed by that in marketing. Especially, as a traditional advantageous sector in export, China’s textiles in its fabrication specialization ranked second among all of the 40 economies, reaching the world’s leading level and enjoying significant comparative advantage in export. Meanwhile, as China’s largest export sector and a typical technology-intensive manufacturing sector, electric and optical equipment similarly reached the world’s leading level in fabrication specialization and ranked the second globally in 2011. However, as glad as we are for China’s achievements in export, we should not forget that China’s manufacturing still lags obviously behind Europe, the United States and other developed economies in specialization in management and R&D. Electric and optical equipment is taken as an example again. Though its specialization in fabrication and marketing was not weaker than developed economies and even had the upper hand, it was apparently at a disadvantage in specialization in R&D and management, ranking behind the middle (24th) among the sample economies, while the two functional activities had stronger influence and control upon value chains. There was a serious mismatch with its leading position in the world in fabrication and marketing. This further highlighted that the task would be lasting and arduous for China to develop from a “large power of manufacturing” to a “strong power of manufacturing”.

Table 2 further reports the dynamic changes of the functional specialization of China’s segmented service industry in GVCs in different functional activities and

the latest international ranking. Based on the measurement results in the table, the following conclusions are drawn.

Table 2. Changes and International Ranking of Functional Specialization of China's Segmented Service Industry

		1999	2011			1999	2011			1999	2011
S17	MGT	1.0667	0.9087 [25]	S24	MGT	0.6875	0.9769 [16]	S30	MGT	0.1708	0.1887 [34]
	R&D	0.6607	1.1835 [18]		R&D	0.4149	0.6171 [21]		R&D	0.2598	0.2531 [36]
	MAR	1.8467	2.1052 [3]		MAR	1.0108	1.6499 [6]		MAR	0.2220	0.4191 [33]
	FAB	2.4250	2.6074 [3]		FAB	1.9963	2.2230 [6]		FAB	0.7300	0.7512 [22]
	TVA	1.5638	1.4875		TVA	1.1800	1.8576		TVA	0.2628	0.4327
S18	MGT	0.1252	0.0545 [39]	S25	MGT	0.3334	0.2129 [31]	S31	MGT	0.1493	0.2422 [34]
	R&D	0.2302	0.1784 [39]		R&D	0.1819	0.2110 [34]		R&D	0.0133	0.0415 [38]
	MAR	0.3317	0.1951 [39]		MAR	0.5174	0.6848 [28]		MAR	0.0535	0.1841 [36]
	FAB	0.4384	0.3843 [37]		FAB	0.4107	0.5730 [24]		FAB	0.0716	0.2131 [35]
	TVA	0.3339	0.2864		TVA	0.8167	0.8524		TVA	0.0479	0.1149
S20	MGT	0.7104	0.3826 [37]	S26	MGT	0.1467	0.0513 [40]	S32	MGT	0.5211	0.2678 [30]
	R&D	0.2721	0.1921 [38]		R&D	0.1929	0.0241 [40]		R&D	0.9720	1.1054 [13]
	MAR	1.5566	0.9953 [19]		MAR	0.3859	0.1525 [39]		MAR	0.3307	0.3567 [30]
	FAB	0.7270	0.4394 [37]		FAB	0.6319	0.2600 [38]		FAB	0.6022	0.7957 [18]
	TVA	1.1919	1.1321		TVA	0.5509	0.3423		TVA	0.6826	0.7137
S21	MGT	0.1155	0.0686 [39]	S27	MGT	0.2278	0.3719 [37]	S33	MGT	0.4862	0.7517 [23]
	R&D	0.0433	0.0357 [40]		R&D	0.2391	0.7989 [31]		R&D	0.9295	2.2629 [6]
	MAR	0.7606	0.4516 [39]		MAR	0.6290	1.1333 [13]		MAR	0.2776	0.8180 [26]
	FAB	0.1323	0.1151 [40]		FAB	0.2046	0.5301 [16]		FAB	0.6754	1.6512 [14]
	TVA	0.5979	0.5697		TVA	0.7518	1.1309		TVA	0.5374	1.4278

		1999	2011			1999	2011			1999	2011
	MGT	0.4153	0.2525 [36]		MGT	0.1737	0.2175 [34]		MGT	0.5429	0.2109 [38]
	R&D	0.1888	0.1493 [35]		R&D	0.0783	0.0979 [40]		R&D	0.4046	0.2293 [35]
S22	MAR	1.4905	1.1687 [15]	S28	MAR	0.6491	1.0151 [18]	S34	MAR	1.0852	0.6378 [28]
	FAB	0.7055	0.3932 [27]		FAB	1.3307	1.9039 [4]		FAB	2.3601	1.0890 [4]
	TVA	1.6644	1.4322		TVA	0.6854	0.8570		TVA	0.9994	0.8573
	MGT	0.2701	0.1118 [39]		MGT	0.8419	0.3498 [23]				
	R&D	0.3917	0.2004 [35]		R&D	1.0350	0.6202 [16]				
S23	MAR	1.0808	0.8759 [27]	S29	MAR	1.0351	0.8391 [14]				
	FAB	1.4594	0.7312 [31]		FAB	2.7424	1.5583 [8]				
	TVA	1.2779	0.9357		TVA	0.4226	0.7202				

Notes: Figures in square brackets refer to ranking of the functional specialization level of China's segmented service industry among the corresponding industries of all the 40 WIOD economies (excluding the ROW) in 2011. Larger (smaller) figure means lower (higher) position in the ranking. MGT = management; MAR = marketing; FAB = fabrication; TVA = total value added. S17: electricity, gas and water supply; S18: construction; S20: wholesale trade and commission trade, except of motor vehicles and motorcycles; S21: retail trade, except of motor vehicles and motorcycles; repair of household goods; S22: hotels and restaurants; S23: inland transport; S24: water transport; S25: air transport; S26: other supporting and auxiliary transport activities; activities of travel agencies; S27: post and telecommunications; S28: financial intermediation; S29: real estate activities; S30: renting of M&Eq and other business activities; S31: public admin and defense; compulsory social security; S32: education; S33: health and social work; S34: other community, social and personal services.

The trade accounting based on gross value added lacks thorough understanding on the specialization of China's service industry in export and conceals the differences among various service sectors in specialization in R&D, management, marketing and fabrication. Measurement of functional specialization, however, exactly overcomes the limitation and provides a method of quantitatively analyzing the specialization of China's service industry in export in different functional activities. For the segmented service industry, there exists significant difference between the industrial specialization level and the level in functional activities measured based on gross value added. For electricity, gas and water supply, based on the gross domestic value added in export, the conclusion that the service industry showed comparative advantage in export (1.4875) in 2011 will be drawn. However, when we dig deeper into different functional activities, we find that the industry displayed significant comparative advantage in fabrication and marketing (2.6074 and 2.1052 respectively) and weak comparative advantage in export in R&D (1.1835), but showed comparative disadvantage in management (0.9087). Given that a country (sector)'s specialization in such functional

activities as fabrication, R&D, management and marketing in GVCs has a bearing on its influence and control on value chains (Gereffi *et al.*, 2005; Sturgeon and Gereffi, 2009), the measurement result above implies that to re-evaluate the specialization of China's segmented service industry in export from the perspective of functional specialization is of great importance. On such basis, we can more accurately identify their authentic position in international division of labor and thus avoid being misled when devising the industrial strategies of globalization.

China's service industry, when embedded into GVCs labor division, didn't show any clear pattern of functional division and its functional specialization level was generally lower than that of manufacturing, but there existed differences among service sectors. According to Table 2, electricity, gas and water supply as well as water transport showed a high level of specialization in marketing and fabrication. In comparison, the functional specialization index of other service sectors was mostly lower than 1 and even lagged far behind the critical value 0.80 of "weak comparative disadvantage". It was imperative to improve their specialization level and position in labor division. If we compare Table 2 with Table 1, we can also find that the functional specialization level of China's service industry was in general weaker than manufacturing, especially in construction, retail trade, other supporting and auxiliary transport activities, and service sectors such as public admin administration, national defense, and compulsory social security, whose functional specialization index was no greater than 0.50 at most. This further indicated that China's service trade was rather weak in its specialization in functional activities. As for the reason, it was related with the degree of China's service industry being opened up and differences among sectors during the analysis period. For one thing, during the last round of opening up, China offered greater favor to manufacturing, which "advanced alone" (Dai, 2015) and thus the service trade relatively lagged behind. For another, compared with manufacturing, the service industry is non-tradable industries in some sense and is difficult or impossible to trade. The two factors combined and caused China's service trade to lag behind manufacturing noticeably with an apparently lower domestic value added in export, thus resulting in a lower functional specialization level of service sectors than that of manufacturing in general.

China's segmented service industry generally lagged behind in the world in their functional specialization, but some highlights shall not be neglected. As shown in Table 2, among the 40 sample economies in 2011, the majority of China's service sectors ranked behind the middle position globally (after the 20th position) in their functional specialization and were even among the last. The specialization of typical industries such as construction, retail trade and other supporting and auxiliary transport activities ranked 37th at best performance (fourth from the bottom), signaling that specialization of China's service industry in functional activities was lagging behind in the world. Besides, it is noted that not all the service sectors in China were lagging behind in the specialization in export. There were still some highlights, but this was

insufficient to reverse the conclusion that China's service sectors were lagging behind in functional specialization in general. For instance, the specialization in fabrication of finance and other community, social and personal services ranked among the top in the world, taking the 4th position among the 40 economies. The analysis above indicated that though China has developed into the world's second largest power in service trade in recent years, the gap with a strong power in service trade is still wide. By the end of the analysis period, China has not been a true strong power in service trade yet. Expectedly, the path from a "large power in service trade" to a "strong power in service trade" for China will be long and hard.

4. Conclusions and Implications

Based on the WIOD world input-output table and supporting labor occupation data, the paper measures and analyzes the functional specialization of China in export and its dynamic changes, and compares it with other main developed economies in the world. After empirical analysis, it comes to the following conclusions.

In 1999–2011, China's specialization in export showed significant differences among functional activities, with its specialization level in fabrication being high and the level in headquarter economic activities (e.g. marketing, R&D, and management) staying obviously low. In dynamic, the specialization in different functional activities displayed different trends. The specialization in fabrication and R&D was generally improved, but that in marketing and management was decreased. According to the cross-country comparison, China's specialization in export in fabrication took the lead and was among the best in the world. On the contrary, the specialization in management and R&D was weak, with China being almost locked at the world's lowest level across the analysis period and unable to pose any export threat to developed economies. Based on industrial analysis, the trade accounting based on gross value added concealed the differences among China's segmented manufacturing sectors and service sectors in export specialization in R&D, management, marketing and fabrication, but the perspective of functional specialization offered a concrete method for quantitative analysis. When embedded into GVCs, China's segmented manufacturing sectors basically followed the development path of "relying on fabrication, entering market, targeting management and R&D". Its specialization in fabrication ranked among the first in the world and even led the world, but the level in management and R&D ranked among the last, staying at a subordinate position. The functional specialization of China's service industry was in general weaker than that of manufacturing and the specialization of China's segmented service sectors was lagging behind in the world in general. China still has a long way to go from a large power in service trade to a strong power in service trade.

Based on the empirical conclusions, the paper proposes the following suggestions.

At present, China faces the urgent need of marching towards the medium-high end of the GVCs, while shoring up the “weak spots” in headquarter economic activities is critical to this end. It is necessary to step up the support to key links under the precondition of further consolidating the specialization in export in fabrication, expand from processing and fabrication to R&D management and market services, and actively foster China’s new edges in participating in global production division. In the future, it is advisable to rely on the comparative advantage of manufacturing to further integrate into GVCs production division system in depth. By improving auxiliary support for industries and extending industrial chains for refined production, we can further enhance the fabrication advantage and on such basis, pool resources to expand to R&D design, brand marketing and after-sale services. In order to realize the target of developing from a large power of trade to a strong power of trade, it is imperative to shore up the “weak spots” in service trade. We need to keep expanding import of high-quality services and put into full play the effects of high-end imported services such as competition effect, spillover effect and the effect of forcing domestic service market to reform, so as to facilitate the development of domestic service industry. Meanwhile, it is important to promote Chinese quality services to “go global”, and seize the important opportunity of the Belt and Road Initiative to dig into the cooperation potential with the economies along the Belt and Road in service trade.

In the future, studies can be conducted in the following areas. Theoretically speaking, first, since capital returns are difficult to decompose and there exists a gap between the actual place of belonging of capital returns and their place of creation, the paper focuses on the domestic value added in export in different types of functional activities and on such basis, measures the functional specialization of industries across countries. However, as the proportion of capital returns gradually increases (Timmer *et al.*, 2014), how to more scientifically and effectively classify capital income in function seems increasingly urgent. This is an important direction of research in the future. Second, this paper, in its study on the dynamic changes and international comparison on China’s functional specialization in export, neglects the differences between Chinese and foreign enterprises and between processing trade and non-processing trade. Further study can distinguish the enterprise ownership and modes of trade in China in the world input-output tables and analyze China’s functional specialization in export and the dynamic changes in GVCs through enterprises of different ownership and in different modes of trade. Empirically speaking, first, the paper analyzes the authentic functional specialization and the dynamic changes of China in GVCs in different types of activities, but does not explore the reasons behind the changes and the economic influences. Further researches can dig into the determining mechanisms for a country’s comparative advantage in GVCs functional division or explore influences of the comparative advantage in functional division on a country’s income distribution and welfare. Second, the paper studies China’s specialization in export

and the dynamic changes from the perspective of relative value. For countries with economy size as large as China, the perspective of absolute value can be taken to study the absolute returns in export in marketing, management, R&D and fabrication, thereby judging if China realizes the functional upgrading in export.

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