Reanalysis of comparative advantage of China's manufacturing exports based on factor income

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Abstract: Under the background of global division of production, the international transfer of production factors makes China appear "inverse comparative advantage" in the global trade pattern. Taking factor income as the entry point, this paper aims to explore the endowment advantages of China's manufacturing exports, clarify the real international competitiveness of China's manufacturing industry, and provide economic explanations for the phenomenon of "deformation" of revealed comparative advantage (RCA). Based on the production accounting framework of the global value chain that distinguishes firm heterogeneity, this paper advances the production decomposition accounting framework from the perspective of value added to factor income, and proposes the RCA index of factor income accordingly. It is further deconstructed into RCA index of labor income, RCA index of capital income of domestic enterprises and RCA index of capital income of domestic-funded enterprises in host country. It shows that the RCA index of China's manufacturing exports based on factor income roughly experienced an N-shaped trend from 2000 to 2019, and always presented a significant comparative advantage during this period. Labor-intensive sectors, resource-based sectors and several technology-intensive sectors have obvious competitive advantages, but high-tech manufacturing sectors such as the transportation equipment and pharmaceutical products still have shortcomings. Among different production factors, The RCA index of labor income has always occupied the first place, but in recent years, the contribution rate of China's outward investment income has increased, gradually becoming an important part of the comparative advantage of manufacturing industry. The labor income of domestic firms is the most important factor to promote the increase of RCA index of most manufacturing sectors, but it is also a key factor to limit the improvement of comparative advantage of some high-tech manufacturing sectors including chemical products, pharmaceutical products and transportation equipment. The competitiveness of capital income of home country to a certain extent inhibited the improvement of comparative advantage of resource-based sectors and emerging technology sectors. With the development of digitalization in the manufacturing industry chain and the promotion of a new round of technological revolution, China should further consolidate the competitiveness of advantageous industries, especially the position of products with real production factor endowment advantages, in order to achieve a higher position in global value chain.

Keywords: Factor income; RCA index; Labor income; Capital income; Influencing factors

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1 Introduction

After the reform and opening up, especially since China's accession to the WTO, it has actively integrated into the international production system of products by leveraging its labor cost and resource endowment advantages. The scale of trade and the amount of foreign direct investment attracted have been continuously increasing year by year, creating a growth miracle in the global economic competition and cooperation. According to customs statistics, in 2024, China's international trade development withstood the impact of multiple unexpected factors. The total scale of imports and exports reached 43.85 trillion yuan, ranking first in the world for eight consecutive years, demonstrating strong economic resilience and development potential. With the in-depth development of the global value chain characterized by intra-product division of labor, the intermediate links of final product production are no longer limited to within one country, and the direct or indirect consumption of intermediate products from multiple countries or regions has formed a potential "black box" (Zhou et al., 2022). High export scale is not only insufficient to demonstrate international competitiveness, but may even be constrained by the decline of benefits and the lack of core technologies, being held back by powerful developed countries in the "low-end lock-in" situation (Gereffi et al., 2005; Lu et al., 2018). The "shopping spree" type of low value-added and low-profit operation competition model coexists with the development path of processing and manufacturing that China has pioneered (Dai, 2015).

In recent years, China has used imported intermediate goods as a carrier for technological spillovers and learning, resulting in a significant increase in the technological content hidden in its export products. At the same time, a series of discussions have emerged regarding the phenomenon of "reverse comparative advantage" (Wen, 2017; He and Ma, 2022). The international flow of production factors has transformed the world's industrial landscape, and trade and investment have deeply integrated in the context of economic globalization. Can the explosive growth in export scale truly reflect the improvement in China's own technological capabilities and the resulting enhancement of comparative advantage? The "surplus threat theory" advocated by developed countries led by the United States does it truly reflect the real situation of trade? To answer these questions, it is necessary to conduct in-depth research on the current and evolving trends of China's manufacturing export comparative advantage from the perspective of global value chain division, based on the economic essence of the international flow of production factors.

Comparative advantage is one of the core indicators for measuring the international competitiveness of manufacturing and the density of export products. The concept of revealed comparative advantage (RCA index) proposed by Balassa (1965) has been widely applied in existing research (Li and Liu, 2012; Jin et al., 2013; Fu and Li, 2010). The importance of accurately measuring industrial competitiveness is self-evident. However, the existing accounting methods based on traditional trade total value divide the boundaries of economies, emphasizing independent horizontal specialization by each country. In the context of the globalization of production, there is a serious misleading effect. On one hand, the theory of the two loosening of international trade laid the theoretical foundation for the deepening of intermediate product trade and product internal division of labor (Baldwin, 2013). The production of an export product often requires crossing multiple countries or regions. Different countries focus on a certain advantageous section of the product value chain and obtain corresponding value distribution. Especially for economies embedded at the bottom position of the smile curve through processing and assembly (Meng and Ye, 2020; Ye et al., 2015), the "distortion" measurement of trade total value is particularly significant. More and more scholars have put forward the issue of adding value trade accounting to the research agenda (Johnson and Noguera, 2012; Li and Xu, 2013; Koopman et al., 2014; Kee and Tang, 2016). Value-added trade breaks through the limitation of "what is sold is what is earned" in the traditional Heckscher-Ohlin comparative advantage theory and incorporates the industrial division of labor in the cross-border flow of production factors into consideration. On the other hand, international direct investment fundamentally changes the operation mechanism of resource allocation (Zhang, 2020). Multinational companies or foreign enterprises establish cross-border flow networks of production factors with capital as the carrier, enabling countries that did not originally have comparative advantages to have capital factors and cooperate with domestic labor and other low-cost production factors in vertical specialized division of labor, gradually evolving into internal and front-end connections in the production process (Zhu et al., 2022). Thus, the comparative advantage demonstrated by China's capital-intensive industries is actually the comparative advantage of foreign enterprises. The previous economic judgment based on the territorial measurement of comparative advantage is no longer an intuitive reflection of the country's factor endowment structure. The international specialization of factor cooperation has led to a territorial structure effect on the factor income of a country's participation in international trade. This has given rise to many attempts to consider the correction of trade accounting frameworks by taking into account the cross-border distribution and attribution of factor income (Li et al., 2021; Duan et al., 2012; Zhou and Zhu, 2020; Li et al., 2018). However, unfortunately, comparative advantage-related research has not expanded and extended the perspective to the factor income level, ignoring the actual attribution of export factor income of multinational enterprises. Therefore, it is necessary to correct the trade comparative advantage under the principle of factor income to improve the accuracy and authenticity of trade accounting.

As the organizer and key carrier of international production division, multinational companies have enhanced the interactive and interrelated effect of production factors among different national economies through cross-border capital, technology and talent investment. They play an important role in constructing production division networks and optimizing global resource allocation. According to data from the National Bureau of Statistics, from 2005 to 2021, the total import and export volume of foreign-invested enterprises in China accounted for an average proportion of 48.56% of the national import and export volume, always remaining at around 50%; among which, the average proportion of export volume and import volume was 48.05% and 49.23% respectively. The "World Investment Report 2022" and "China Foreign Investment Statistical Bulletin 2022" released by the United Nations Conference on Trade and Development (UNCTAD) indicate that in 2021, global cross-border investment (FDI) reached 1.58 trillion US dollars, increasing by 64.3% compared with the previous year. China, as one of the major destinations for foreign investment globally, accounted for 11.4% of the global FDI total flow. Multinational companies make investment decisions based on factors such as land, resources, and labor, and gather and channel global high-quality advanced production factors into the host country. The added value trade formed by vertical specialized division and cooperation not only reflects the added value generated by domestic factors but also includes the added value generated by foreign production factors. It is worth noting that there is a deep-level association of income distribution transfer between the parent company of multinational companies and its branches in China. The factor income created by foreign-funded enterprises' exports should be largely attributed to the cross-border investment income accounting framework of the parent country. However, the current value-added accounting based on the territorial principle treats foreign-funded enterprises and domestic-funded enterprises equally, and together they constitute the economic income of the country, ignoring the ownership issue between the actual benefits and ownership characteristics of the former's participation in production division. To better judge China's real benefits and competitive advantages in the global value chain, it is necessary to advance the value-added accounting framework to the ownership perspective based on national income.

In view of this, some studies have addressed the issue of the ownership of export value-added based on the characteristics of national ownership of factors of income. One category mainly focuses on the trade accounting of the economies themselves. Duan et al. (2012) calculated the direct and indirect export value-added of foreign-funded enterprises by compiling a Chinese input-output table reflecting the national attributes of factors. Zhou and Zhu (2020) proposed a calculation framework based on the ownership structure of factors of rights and used microdata and input-output tables to measure the average deviation of ownership value-added and local value-added of foreign-funded processing trade enterprises. Considering that processing trade and foreign-invested enterprises account for a high proportion of China's total exports, Ma et al. (2014) extended the method of Koopman et al. (2012), in addition to distinguishing between general trade and processing trade methods, also divided exports into trade activities led by foreign-funded enterprises and domestic enterprises within China. For a long time, the huge trade surplus of China's exports has been criticized by developed countries, and trade protectionism and trade frictions have intensified. As a result, a series of studies have emerged that focus on examining the balance of bilateral trade income distribution. Li et al. (2018) used an input-output model with internal and external distinctions to compare the numerical differences in trade value, trade value-added, and national income for the US trade balance. They will later extend the framework to a global income chain model for multiple annual periods (Li et al., 2021), and empirically analyzed the bilateral trade balance between China, the United States, and the European Union, finding that the trade value and value-added perspectives, due to not involving the national attributes of the factor countries, will lead to inaccurate calculation results. Bohn et al. (2021) pointed out that the current value-added trade accounting framework ignores the international income transfer needs of multinational companies, and from the perspective of income, the US current account deficit almost disappears. Similar studies analyzed the main driving factors of the US-China trade surplus from the perspectives of local and ownership integration (Guo and Zhu, 2022; Chen and Zhang, 2017; Lin et al., 2014; Zhu et al., 2022) in the context of the global value chain. Coordinated division of labor and win-win cooperation are objective trade facts.

The above research reveals the actual gains of China's trade participation from the "quantitative" perspective, correcting the measurement errors of income results based on the existing territorial principle framework. It has practical reference value for clarifying the current international interest distribution pattern and promoting trade rule negotiations. However, it still lacks studies that rise to the "qualitative" level, that is, conducting in-depth analysis of the "reverse comparative advantage" phenomenon that China has emerged in the global trade landscape. Introducing the revised territorial added value into the calculation framework of explicit comparative advantage not only helps clarify the real international competitiveness of China's manufacturing industry and provides an economic explanation for the "deformation" of comparative advantage; but also can identify the differences in the strength of enterprise entities that promote the transformation and upgrading of manufacturing industries, providing scientific basis for the formulation of the next stage of industrial policies. This paper uses the inter-country input-output tables of different types of enterprises (including domestic and multinational enterprises) released by the Organization for Economic Cooperation and Development in 2024. Based on the global distribution transfer matrix of corporate investment income, it redistributes the capital gains of foreign-funded enterprises in the host country and related domestic capital enterprises from the home country. On the basis of the territorial added value measured from the perspective of factor income, it measures the comparative advantage index of China's manufacturing exports from 2000 to 2019 and conducts a comparative analysis with the territorial added value accounting results based on trade value and added value perspectives. Considering that in the international division of labor dominated by foreign-funded enterprises, the real trade income of a country can be divided into three parts: the added value created by labor factors, the implicit capital compensation in the added value of domestic-funded enterprises, and the implicit capital compensation in the added value of foreign-funded enterprises. The latter is closely related to the adjustment of the global layout strategy of foreign-funded enterprises, and the evolution of international economic and trade situations and foreign legal systems will profoundly affect the security and stability of the economic operation of the host country (Huang et al., 2019; Jsvorcik and Poelhekke, 2017). Therefore, this paper combines the economic background of global value chain reconfiguration, decomposes the territorial added value from the perspective of factor income into labor factor income, the implicit capital compensation of domestic enterprises within the country, and the implicit capital compensation of domestic-funded enterprises in the host country, and then explores the comparative advantage characteristics of China's manufacturing industries reflected by different types of factor income.

The major contributions are as follows: (1) A measurement method of RCA index based on factor income is proposed, providing theoretical support for accurately judging national competitive advantage and factor endowment. (2) This paper measures RCA index of different enterprises, laying a micro foundation for the research on RCA to penetrate into the enterprise dimension. (3) This paper attempts to deconstruct the RCA index based on factor income into the RCA index of labor income, RCA index of capital income of domestic enterprises and RCA index of capital income of domestic-funded enterprises in host country, which is helpful to identify the hidden comparative advantage potential of different factor incomes.

The remainder of the paper is organized as follows: section 2 introduces the global value chain production decomposition framework under the principle of ownership and constructs a comparative advantage index from the perspective of factor income. Sections 3 and 4 calculate and analyze the comparative advantage of China's manufacturing exports from the perspective of heterogeneous production factors, and compares the RCA index from the factor income perspective with the measurement results from the value-added perspective. Section 5 concludes.

2 Methodology and data

2.1 The input-output accounting framework reflecting the activities of multinational companies

This study is based on the production accounting framework of the global value chain of multinational companies (Zhu et al., 2022). By introducing factor income trade, it expands the production decomposition and accounting framework of heterogeneous enterprises from the perspective of value added (GDP) to that of factor income (GNI), and accordingly proposes the factor income explicit comparative advantage index based on the total value explicit comparative advantage index and the value-added explicit comparative advantage index, in order to reflect the comparative advantages of a country's production factors in participating in the global production network division of labor.

To simplify the model, we consider G countries (or regions), N industries, and within each industry, there are two types of enterprises: domestic enterprises (D) and multinational enterprises (F). Based on this, an extended Inter-Country Input-Output model reflecting different enterprise types and cross-border production links between different industries is obtained. The specific structure is shown in Table 1.

Table 1. Inter-Country Input-Output table distinguishing firm ownership

Output / Input			Intermediate Use							Final Use				Total Output
			Country 1		Country 2		⋯	Country G		Country 1	Country 2	⋯	Country G	
Input			D	F	D	F	⋯	D	F					
Intermediate Input	Country 1	D	z_{DD}^{11}	z_{DF}^{11}	z_{DD}^{12}	z_{DF}^{12}	⋯	z_{DD}^{1G}	z_{DF}^{1G}	y_D^{11}	y_D^{12}	⋯	y_D^{1G}	x_D^1
		F	z_{FD}^{11}	z_{FF}^{11}	z_{FD}^{12}	z_{FF}^{12}	⋯	z_{FD}^{1G}	z_{FF}^{1G}	y_F^{11}	y_F^{12}	⋯	y_F^{1G}	x_F^1
	Country 2	D	z_{DD}^{21}	z_{DF}^{21}	z_{DD}^{22}	z_{DF}^{22}	⋯	z_{DD}^{2G}	z_{DF}^{2G}	y_D^{21}	y_D^{22}	⋯	y_D^{2G}	x_D^2
		F	z_{FD}^{21}	z_{FF}^{21}	z_{FD}^{22}	z_{FF}^{22}	⋯	z_{FD}^{2G}	z_{FF}^{2G}	y_F^{21}	y_F^{22}	⋯	y_F^{2G}	x_F^2
	⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋱	⋮	⋮
	Country G	D	z_{DD}^{G1}	z_{DF}^{G1}	z_{DD}^{G2}	z_{DF}^{G2}	⋯	z_{DD}^{GG}	z_{DF}^{GG}	y_D^{G1}	y_D^{G2}	⋯	y_D^{GG}	x_D^G
		F	z_{FD}^{G1}	z_{FF}^{G1}	z_{FD}^{G2}	z_{FF}^{G2}	⋯	z_{FD}^{GG}	z_{FF}^{GG}	y_F^{G1}	y_F^{G2}	⋯	y_F^{GG}	x_F^G
Value-added			va_D^1	va_F^1	va_D^2	va_F^2	⋯	va_D^G	va_F^G					
Total Input			$(x_D^1)'$	$(x_F^1)'$	$(x_D^2)'$	$(x_F^2)'$	⋯	$(x_D^G)'$	$(x_F^G)'$					

In the table, *z*, *y*, *x* and *va* represent the intermediate use matrices (N×N), final output vectors (N×1), total output vectors (N×1) and value-added vectors (1×N) for different countries and types of enterprises, with the superscript indicating the country and the subscript indicating the enterprise type. Taking the intermediate use matrix as an example, each *z* represents the intermediate use flow matrix within or between different countries and types of enterprises, with the superscript indicating the supplying country and the using country, and the subscript indicating the supplying enterprise type and the using enterprise type. Here, D and F represent domestic and multinational enterprises respectively. For instance, z_{FD}^{rs} represents the intermediate use matrix where products produced by multinational enterprises (F) in r country are used as input for reproduction by domestic enterprises (D) in s country. The same applies to the rest.

According to the definition in Table 1, the total export values of each country and industry can be obtained. Among them, the export vector (e^{rs}) from country r to country s is as follows:

$$e^{rs} = z^{rs}\mu' + y^{rs} \tag{1}$$

Among them, μ represents the row vector where each element is 1, ' indicates transposition processing, and μ' is used for row summation processing of the intermediate matrix z^{rs}. The first term on the right side of the equal sign in formula (1) ($z^{rs}\mu'$) is the intermediate export vector from country r to country s, and the second term (y^{rs}) is the final export vector from country r to country s. The total export matrix E (GN×G), which is composed of bilateral exports, is also the total value trade matrix, and is further divided into the intermediate export matrix and the final export matrix.

According to formula (3) in Wang et al. (2017), and formula (4) in Zhu et al. (2013), the value-added decomposition matrix can be obtained as follows:

$$\hat{V}BY = \hat{V}LY^L + \hat{V}LE = \hat{V}LY^L + \hat{V}LY^E + \hat{V}L\mathrm{A}^E BY \tag{2}$$

Among them, Y represents the final output matrix composed of the final products of various countries and industries (GN×G), where the rows represent the producing countries and industries of the final products, and the columns represent the demanders of the final products, namely the countries where the final products are ultimately used (such as final consumption or the part that forms capital goods); $V \equiv Va\hat{X}^{-1}$ is the value-added coefficient vector; $B = (I - A)^{-1}$ is the global Leontief inverse matrix, reflecting the industrial correlations among countries, $A \equiv Z\hat{X}^{-1}$ is the direct input coefficient matrix, indicating the intermediate inputs required by each sector for unit output; $L = (I - A^L)^{-1}$ is the local Leontief inverse matrix, reflecting the correlations among different industries within each country. Among them, A^L is the local direct input coefficient matrix of each country, that is, the coefficient matrix composed of the diagonal submatrices of the direct input coefficient matrix A, $A^E = A - A^L$ is the direct intermediate import input coefficient. Y^L is the local final use matrix of each country, that is, the coefficient matrix of the diagonal submatrices of the final output matrix Y, $Y^E = Y - Y^L$ is the part of final output that is exported, that is, the final product export matrix. ^ represents diagonalization processing.

As defined by Wang et al. (2017), in formula (2), through forward production decomposition, the value-added of each country and industry can be divided into three parts: the first part ($\hat{V}LY^L$) is the pure domestic value chain, the second part ($\hat{V}LY^E$) is the traditional trade value chain, and the third part ($\hat{V}L\mathrm{A}^E BY$) is the global value chain. During the entire process from the production creation of value-added to its final use, the first part of the pure domestic value chain does not involve the cross-border flow of value-added and does not belong to the value-added trade part. However, the latter two parts both involve the cross-border flow of value-added, forming the value-added trade matrix (*VAT*). Among them, the second part of the traditional trade value chain is where the value-added is implicitly contained in the domestic final product exports, and the third part of the global value chain is where the value-added is implicitly contained in the domestic intermediate product exports, both participating in international competition. Therefore, when calculating the size of the comparative advantages of each country and industry, these two parts need to be included, respectively representing the comparative advantages of value-added in the production of final product exports and intermediate product exports.

$$VAT = \hat{V}LE = \hat{V}LY^E + \hat{V}LA^E BY \tag{3}$$

Substituting the added value creation of enterprises into formula (2), a framework for decomposing the forward production activities of different value chains for domestic enterprises and multinational enterprises can be obtained:

$$\hat{V}BY = \hat{V}_D LY^L + \hat{V}_D LE + \hat{V}_F LY^L + \hat{V}_F LE \tag{4}$$

Furthermore, distinguish between the labor factors and the capital factors. Assuming that the labor factors can freely flow within the same industry but face barriers between industries, and that the capital factors of domestic and foreign enterprises cannot flow between each other, the production factors are classified as labor factors, domestic capital factors, and foreign capital factors. Thus, a forward production decomposition framework for distinguishing production factors and a value-added trade matrix can be obtained:

$$\begin{aligned}\hat{V}BY = &\left(\mathrm{I} - \widehat{K}\right)\hat{V}_D LY^L + \left(\mathrm{I} - \widehat{K}\right)\hat{V}_D LE + \left(\mathrm{I} - \widehat{K}\right)\hat{V}_F LY^L + \left(\mathrm{I} - \widehat{K}\right)\hat{V}_F LE \\ &+ \widehat{K}\hat{V}_D LY^L + \widehat{K}\hat{V}_D LE + \widehat{K}\hat{V}_F LY^L + \widehat{K}\hat{V}_F LE\end{aligned} \tag{5}$$

$$VAT = \left(\mathrm{I} - \widehat{K}\right)(\hat{V}_D LE + \hat{V}_F LE) + \widehat{K}\hat{V}_D LE + \widehat{K}\hat{V}_F LE \tag{6}$$

Among them, K represents the vector of the proportion of capital returns of each department in the host country's capital output (1×GN). The last two items (the 7th and 8th items) on the right side of the equal sign in Formula (5) belong to the value added created by the capital factors of foreign-funded enterprises. There is a deviation in the territorial and ownership of production factors, so they need to be returned to each source country (the home country) according to the source of production factors.

According to Zhu et al. (2022), the source country weight matrix W_M of the production output of multinational enterprises can be used to allocate the capital returns of the multinational enterprise's value added to each home country. The calculation formula is as follows:

$$W_M \widehat{K}\widehat{Va}_F = W_M \widehat{K}\hat{V}_F LY^L + W_M \widehat{K}\hat{V}_F LE \tag{7}$$

Among them, W_M represents the proportion matrix (GN×GN) of each source country in the total output of multinational enterprises within and outside the host country.

By combining Formula (3) and Formula (7), the factor income trade (*FIT*) of a country can be calculated.

$$FIT = \left(\mathrm{I} - \widehat{K}\right)\left(\hat{V}_D LE + \hat{V}_F LE\right) + \widehat{K}\hat{V}_D LE + W_M \widehat{K}\hat{V}_F LY^L + W_M \widehat{K}\hat{V}_F LE \tag{8}$$

In formula (8), the first row shows the input of a country's production factors into the export production of domestic enterprises, which represents the part of the country's production factors that directly participate in international competition as the host country. Among them, the first two items represent the portion of a country's labor factors input into the export production of all domestic enterprises, and the third item represents the portion of a country's capital factors input into the export production of domestic-funded enterprises. The fourth and fifth items represent the portion of a country's capital factors input into the production of foreign enterprises, that is, as the home country, the production factors of this country indirectly participate in international competition through cross-border investment.

2.2 Construction of the Global Value Chain Comparative Advantage Index

Sum the rows of the total export matrix *E*, the value-added trade matrix *VAT*, and the factor income trade matrix *FIT*, respectively, to obtain the total exports (e_i^s), total value-added exports (vat_i^s), and total factor income exports (fit_i^s) for each country and each industry. Based on the calculation method of the explicit comparative advantage (RCA) index, the RCA index based on total export value (RCA_Gross, *RCA_G*), the RCA index based on total value-added exports (RCA_Value Added, *RCA_VA*), and the RCA index based on total factor income exports (RCA_Factor Income, *RCA_FI*) can be constructed. The calculation formulas are as follows:

$$RCA\_G_i^s = \frac{e_i^s / \sum_i^N e_i^s}{\sum_r^G e_i^s / \sum_r^G \sum_i^N e_i^s}$$

$$RCA\_VA_i^s = \frac{vat_i^s / \sum_i^N vat_i^s}{\sum_r^G vat_i^s / \sum_r^G \sum_i^N vat_i^s} \tag{9}$$

$$RCA\_FI_i^s = \frac{fit_i^s / \sum_i^N fit_i^s}{\sum_r^G fit_i^s / \sum_r^G \sum_i^N fit_i^s}$$

Furthermore, based on Formulas (1), (3) and (9), the *RCA_G*index, *RCA_VA* index and *RCA_FI* index can be decomposed respectively. Among them, the *RCA_G* index can be decomposed into the final export total value RCA index and the intermediate export total value RCA index; the *RCA_VA* index can be decomposed into the final export value-added RCA index and the intermediate export value-added RCA index; it can also be decomposed using Formula (6) into the labor income export RCA index, the capital income export RCA index of domestic enterprises and the capital income export RCA index of multinational enterprises; the *RCA_FI* index can be decomposed into the labor income export RCA index (*RCA_FIL*), the capital factor income export RCA index of domestic enterprises (*RCA_FIKD*) and the capital income RCA index of the domestic-funded enterprises located overseas (the RCA index of the overseas Chinese-funded enterprises, *RCA_FIKDO*).

2.3 Data sources and processing

The data used in this article is the Analytical Database on International Inputs and Outputs of Multinational Enterprises (AMNE-ICIO) released by the OECD in 2024. According to the definition of the AMNE database, foreign enterprises are the branches of multinational companies in the host country, while others include domestic multinational companies (domestic companies with foreign subsidiaries) and domestic companies not involved in international investment. In the OECD-AMNE database, domestic enterprises are combined from these sources in the OECD-ICIO database. The database contains official statistics on multinational companies collected and published by national statistical offices of various countries (since 1985, including 32 OECD countries plus Costa Rica and Lithuania, covering over 50 industries). To estimate the missing information between countries and industries, data from other countries was used, and various statistical methods were adopted. The specific compilation method can be found in Cadestin et al. (2018).

The OECD's AMNE-ICIO data covers 76 countries across 45 industries from 2000 to 2020, as well as the rest of the world. To convert the territorial value added calculated based on the AMNE-ICIO database into the ownership value added of the investing country, this paper uses the value added data and the data on the proportion of labor remuneration in value added for each country's each sector published by the OECD database, calculates the proportion of capital remuneration in value added in each country's each sector, and combines it with the bilateral output flow matrix of multinational companies in the OECD AMNE-ICIO database. According to the method of formula (7), the income distribution flow matrix of foreign-funded enterprises' value added in each country's each sector is obtained.

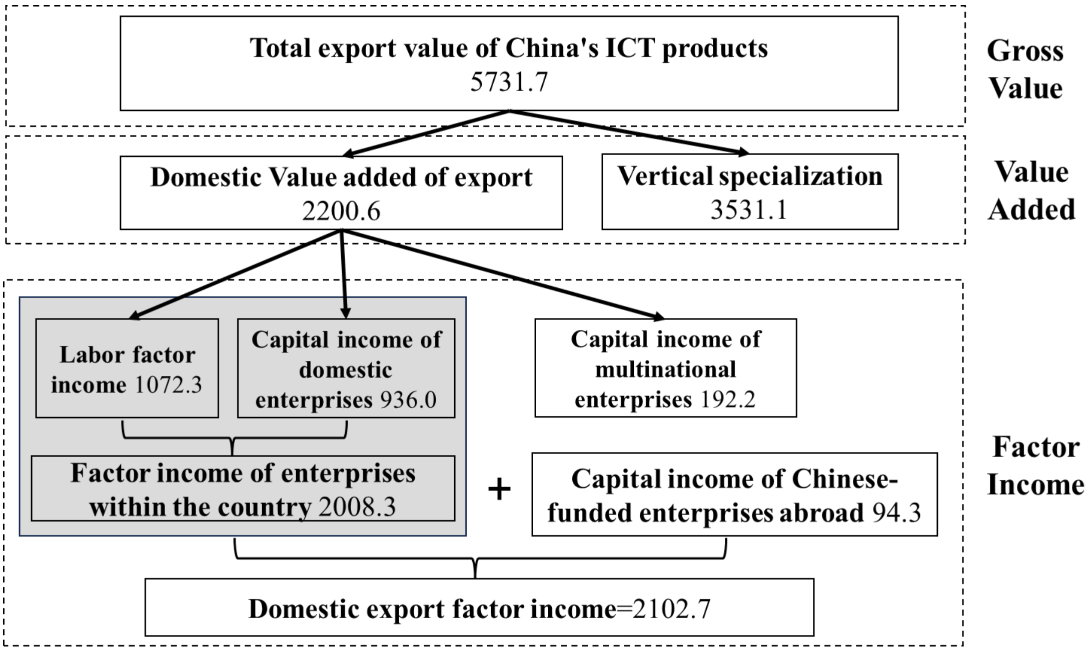
3 Typical Facts of China's digitalization development

This section first depicts the differentiated characteristics between export value-added and export factor income from the perspective of scale, thereby making a conceptual distinction between the two. Based on this, it measures and compares the comparative advantage indices of China's manufacturing industry and its sub-sectors under the two measurement methods, identifies the misjudgment of the comparative advantage of manufacturing sectors under the value-added measurement method, and proposes the rationality of using the factor income RCA index to measure the factor endowment advantage of a country's certain sector. To analyze the differences in the comparative advantages of different production factors in China, the RCA index under the factor income measurement method is further decomposed into the labor income RCA index, the capital income RCA index of domestic enterprises, and the capital income RCA index of domestic-funded enterprises located overseas, and the endowment advantages of different production factors of China's manufacturing industry are interpreted respectively.

3.1 The conceptual distinction between export value-added and export factor income

Measuring the export volume of various sectors in China is an important part of analyzing their comparative advantages. According to the export decomposition model, the export value-added of a certain sector in a country measures the value-added of that sector in the domestic economy driven by exports, and is a part of the total exports of that sector. Therefore, its scale is often smaller than the total export value of that sector. Due to the investment activities of multinational companies and the cross-border flow of capital factors, there is a transfer of income, resulting in the export value-added of a country including part of the income of other countries. Therefore, there is a difference between the export volume from the perspective of factor income and value-added, and the degree of this difference depends on the scale of net outflow of capital returns.

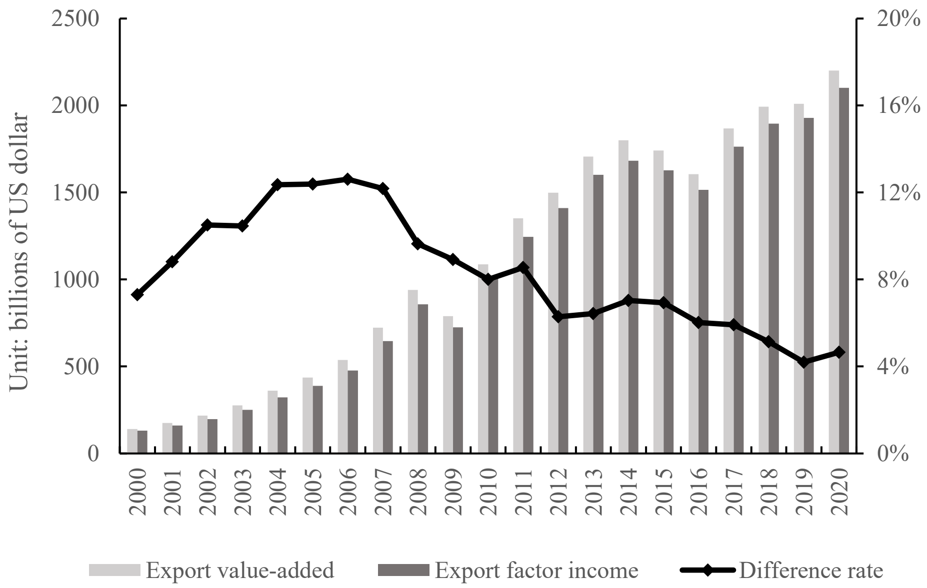
To more clearly illustrate the distinction between export value-added and export factor income, Figure 1 presents the export decomposition of China’s ICT manufacturing sector in 2020. In that year, total exports of China’s ICT manufacturing sector stood at USD 573.17 billion, comprising USD 220.06 billion in domestic value-added exports and USD 353.11 billion in vertical specialization. Domestic value-added accounted for merely 38.4% of total exports, indicating that China relies heavily on imported intermediate inputs in the production of computer products, whereby the majority of value-added generated in exports is captured by other economies. Within the global value chain (GVC) for ICT product manufacturing, technological constraints have locked China in low-end processing and assembly activities. It participates in GVC production mainly by leveraging low-cost labor advantages and secures a relatively low share of profits. Based on factor attributes, value-added exports of the ICT manufacturing sector are broken down into USD 107.23 billion in labor factor income, USD 93.60 billion in capital factor income from domestic-funded enterprises, and USD 19.22 billion in capital factor income from foreign-funded enterprises. The first two items, totaling USD 200.83 billion, represent Chinese factor income, accounting for approximately 91.2%, whereas capital factor income of foreign-funded enterprises belongs to the home countries of multinational corporations and should not be classified as Chinese factor income. The 9.43 billion US dollars in investment profits generated by the Chinese outbound enterprises belong to the capital factor income from China's exports. This enables the conversion of gains from the value-added perspective to the factor income perspective. Such findings are closely associated with the patterns of foreign investment attraction and production models of foreign-funded enterprises in China’s ICT sector. As a high-end manufacturing segment, the manufacture of computer, electronic and optical products is dominated by core intellectual property held by economies such as the United States, Japan, South Korea and Europe. Foreign-funded enterprises are largely drawn to China by its low-cost labor and well-established supporting infrastructure. Most of these firms are export-oriented, with their exports heavily reliant on capital and low-skilled labor, resulting in the repatriation of part of production profits.



Note: The numerical units in the figure are in billions of US dollars.

Figure 1 Decomposition of China's ICT manufacturing sector exports

Figure 2 further depicts the changes in the export scale of the ICT manufacturing sector from 2000 to 2020, revealing the differences in exports under different measurement methods from the perspective of "quantity". According to Figure 1, the scale of the Chinese ICT sector shows a decreasing trend from value-added to factor income. However, from the perspective of the trend of change, the domestic gains obtained by China's exports have become increasingly significant, and the difference rate between the two has gradually decreased. This indicates that the dependence of domestic enterprises on foreign technologies and production factors is gradually weakening. From 2000 to 2020, the export volume under the factor income measurement method increased by a total of 197.1 billion US dollars, approximately 15 times. Compared with the value-added export, the growth of export factor income was more significant, indicating that with the rapid development of China's computer technology, Chinese local enterprises such as Huawei and Xiaomi began to transition from the processing and assembly stage to independent innovation, and their dependence on foreign technologies and production factors has weakened, and the domestic gains obtained by exports have become increasingly significant. By comparison, there are significant differences in the export volume of the Chinese ICT sector under different measurement methods. Using the traditional total trade statistics method may "overestimate" the real trade situation, while the trade statistics method from the perspective of value-added will magnify the export earnings of the Chinese ICT sector, which may lead to a misjudgment of its competitive advantages. In order to more accurately trace the industrial association between the input of factors from upstream industries and indirect exports with the downstream industries, and to identify the factor endowment advantages reflected in the real earnings of each department in China, the following focuses on the comparative advantages characteristics of China's manufacturing industry under the factor income measurement method and its comparison with the results from the value-added measurement method.



Note: The difference rate = (export value-added - export factor income) / export value-added.

Figure 2 Changes in scale of export and their differences in the ICT manufacturing sector in China under the value-added and factor income accounting framework from 2000 to 2020

3.2 The RCA index of China's manufacturing sectors based on the factor income

Figure 3 presents the RCA index of factor income for China's manufacturing exports from 2000 to 2020 and its comparison with the RCA index of value added. The study shows: ① The RCA index of manufacturing exports in the factor income has always been greater than 1 from 2000 to 2020, indicating that China's manufacturing industry has an advantage in factors in international trade. ② From the trend perspective, the RCA index of factor income for China's manufacturing industry has roughly experienced an "up-down-up" N-shaped pattern. From 2000 to 2012, the RCA index of factor income for China's manufacturing industry showed a strong upward trend, reaching a peak of

1.73 in 2012, and then entering a downward stage. From 2012 to 2016, the RCA index of national income declined significantly, indicating that with economic development and technological progress, the advantages of traditional production factors such as labor and land in China's traditional production are gradually shrinking. After 2016, the RCA index of factor income returned to an upward stage, and the transformation towards servitization and digitalization provided channels and impetus for the development of our country's advantageous productive forces. ③ The RCA index of factor income is always lower than the RCA index of value added. The difference between the two shows an expanding trend. With the development of the global manufacturing production network and the large-scale inflow of foreign capital, the gap between the manufacturing competitive advantage from the perspective of factor income and that from the perspective of value added in China gradually increased, demonstrating a very significant differentiated feature. In recent years, driven by the independent innovation of Chinese manufacturing enterprises, the gap between the RCA index of factor income and that of value added has narrowed somewhat, but it still cannot be ignored. When measuring the explicit comparative advantage of China's manufacturing exports, the significant difference between the two indices fully demonstrates the potential misleading nature of the previous RCA indicators, that is, they cannot reflect the true factor endowment and competitive advantage in a country's production.

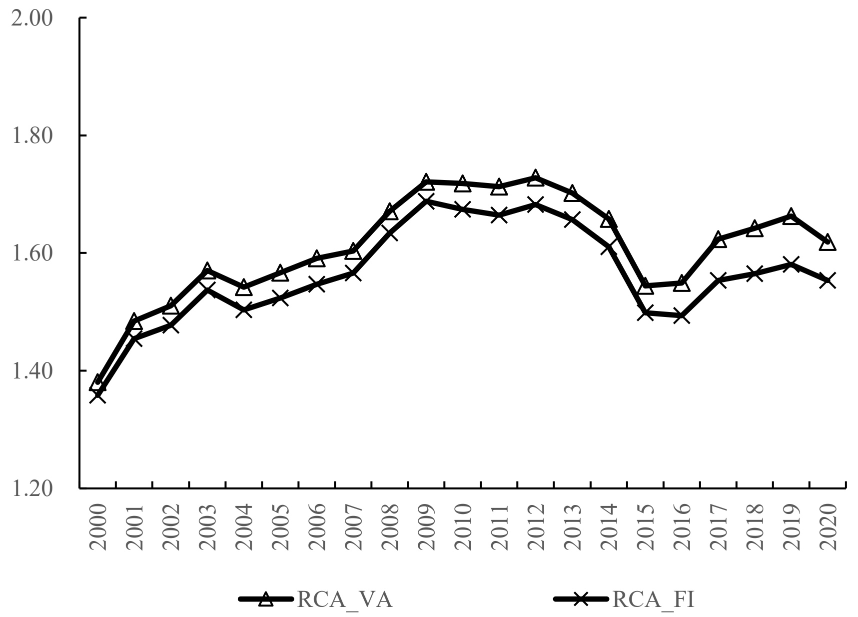
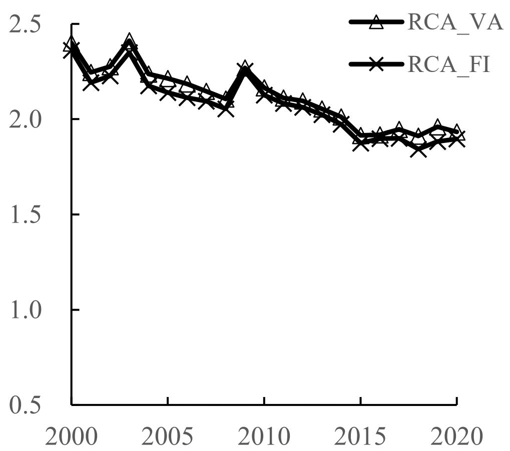


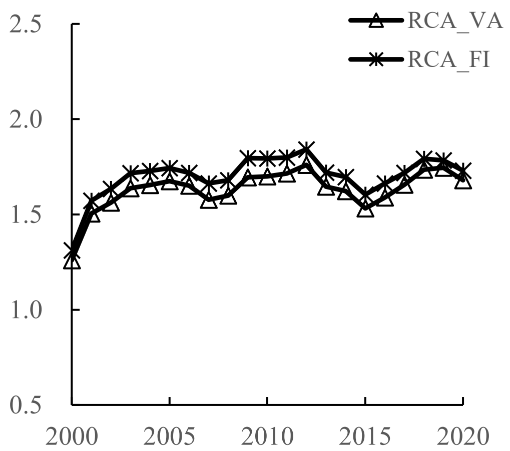
Figure 3 Changes in the RCA index of China's manufacturing sectors from 2000 to 2020, based on factor income and value added\

Further, this paper analyzes the changes in comparative advantage levels of manufacturing industries with different R&D intensities from the factor-income perspective, and finds significant differences in the revealed comparative advantage (RCA) indices under the two measurement approaches across China’s manufacturing sectors by R&D intensity. As shown in Figure 4, for low-technology manufacturing, the value-added-based RCA index and the factor-income-based RCA index are relatively close, ranging from 1.84 to 2.41, with the former slightly higher than the latter. This indicates that most gains from exports of China’s low-technology manufacturing sectors, especially labor-intensive manufacturing, are captured by domestic labor and other factors, granting them strong competitiveness in the international market. In contrast, the RCA indices of medium-technology manufacturing are lower than those of low-technology manufacturing in most periods, with an insignificant gap between the two RCA measures and a fluctuation range of 1.26~1.84. For high-technology manufacturing, however, there is a marked divergence between the two RCA indices. In 2020, the value-added-based RCA index stood at 1.47 while the factor-income-based RCA index was 1.35, meaning the former was notably larger than the latter. Although China's high-technology manufacturing sector exhibits certain competitiveness, this gap suggests that its comparative advantage from an income perspective is less prominent than that measured by value-added. When gauging truly factor-endowed production factors or products in China's high-tech sectors from the factor-income perspective, it is evident that substantial room remains for improvement if China aims to establish absolute international competitive advantages and occupy high-end or even dominant positions in global value chains.

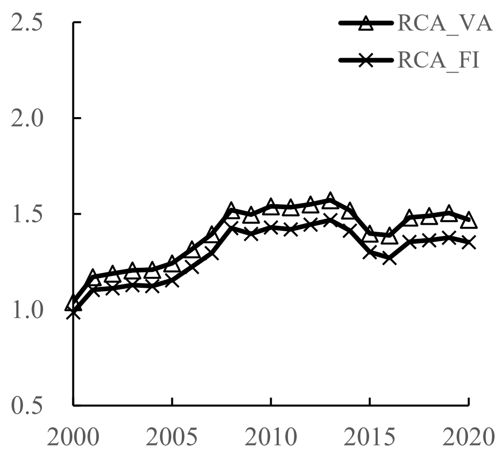
The divergent evolutionary trends among manufacturing industries with varying R&D intensities reflect that China's advantageous manufacturing sectors are shifting from labor-intensive to technology-intensive types, and its competitive edge is transitioning from cost advantages based on primary factors such as labor to technological advantages driven by advanced factors including digital technologies. Specifically, from 2000 to 2020, the comparative advantage indices of China's low-technology manufacturing continuously declined. Its value-added-based and factor-income-based RCA trend lines largely overlapped, both showing a fluctuating downward trajectory, which mirrors the diminishing competitiveness of China's low-tech manufacturing. Both medium- and high-tech manufacturing sectors witnessed fluctuating rises in their RCA indices. Medium-technology manufacturing maintained comparative advantages throughout the period, whereas high-technology manufacturing underwent a transition from comparative disadvantage to advantage. In 2000, the factor-income-based RCA index of China's high-technology manufacturing was below 1, indicating a comparative disadvantage. The index exceeded 1 in 2001, turning high-technology manufacturing into a comparative-advantage sector whose strengths have kept growing ever since. Leveraging its vast domestic market and intense industrial competition, China has accumulated certain technological advantages in medium and high-end manufacturing, fostering competitiveness in overseas markets.



(a) low-tech manufacturing sectors



(b) medium-tech manufacturing sectors



(c) high-tech manufacturing sectors

Figure 4 Changes in RCA index of different manufacturing sectors with different R&D intensities in China from 2000 to 2020

To identify key sectors driving comparative-advantage disparities across manufacturing industries with different R&D intensities, this paper further analyzes the comparative advantages of China's disaggregated manufacturing sectors under the two measurement approaches. Table 2 summarizes the value-added-based and factor-income-based revealed comparative advantage (RCA) indices for 17 Chinese manufacturing sectors in 2000 and 2020, including 5 low-technology, 4 medium-technology and 7 high-technology manufacturing sectors.

A comparison of RCA index across disaggregated manufacturing sectors (Table 2) reveals that, from the factor-income perspective, China exhibits prominent global competitiveness in labor-intensive sectors represented by textiles, upstream resource-based sectors such as non-metallic minerals and basic metals, and certain technology-intensive sectors including electrical equipment. Nevertheless, core technology and high-end manufacturing sectors such as transport equipment and pharmaceuticals remain weak points. In 2000, the factor-income-based RCA index of the textile, apparel and leather manufacturing sector (hereinafter referred to as the textile sector) reached 6.13, making it China's most comparatively advantaged manufacturing sector. Endowed with low-cost labor, a large domestic market and massive production capacity, China holds factor-endowment advantages in labor-intensive and upstream resource-based sectors, securing a vital position in the global market. Although the index declined to 3.95 in 2020 over the period 2000-2020, it still ranked first among all Chinese manufacturing sectors. The strong competitiveness of the textile sector largely explains why the comparative advantage indices of China's low-technology manufacturing sectors are notably higher than those of medium- and high-technology counterparts. Among upstream resource-based sectors, the factor-income-based RCA indices of basic metals and non-metallic minerals stood at 2.10 and 1.96 respectively. A large volume of their products are used as intermediate inputs in machinery, electrical equipment, and computer and electronic product manufacturing. Value-added is indirectly exported through downstream industrial goods, with most associated gains retained in the domestic market, thereby generating pronounced revealed comparative advantages under the factor-income measure. China's capital-intensive and technology-intensive manufacturing sectors also possess certain global competitiveness. In particular, high-technology manufacturing sectors including electrical equipment, computers, electronic and optical products, chemicals, and machinery exhibit strong export comparative advantages. In 2020, the factor-income-based RCA indices of electrical equipment manufacturing and computer, electronic and optical product manufacturing reached 2.29 and 2.20 respectively, indicating robust competitiveness. Additionally, traditional high-value-added manufacturing fields such as chemicals and machinery both recorded RCA indices above 1, signifying moderate comparative advantages. In the era of rapid internet development, digitalization and informatization have grown increasingly critical to manufacturing and its industrial chains. The competitive edge of the computer industry has strengthened, and its integration and application in high-technology sectors such as electrical machinery have boosted their technological sophistication and overall competitiveness.

Despite China's progress in building advantages within capital- and technology-intensive sectors, weaknesses persist in certain core-technology and high-end manufacturing segments. Under current conditions, China lacks international competitiveness in high-tech and R&D-intensive industries such as transport equipment manufacturing and pharmaceuticals, reflecting deficiencies in core competitiveness, lagging key technologies and inadequate innovation capacity. In 2020, the pharmaceutical sector posted value-added-based and factor-income-based RCA indices of 0.28 and 0.27 respectively, making it the most comparatively disadvantaged sector across China's manufacturing industries. China's pharmaceutical exports are predominantly concentrated in labor-intensive products such as gauze and alcohol, whereas critical core technologies remain monopolized by developed economies. Multiple technical barriers imposed by these economies have severely hindered China's pharmaceutical exports. Furthermore, the RCA indices for motor vehicles, trailers, semi-trailers and other transport equipment are well below 1, representing two other distinctly disadvantaged high-technology manufacturing sectors. The domestic upstream industrial-chain value-added embodied in their actual exports remains low, and the competitiveness of intermediate-goods exports along China's related industrial chains still lags behind traditional automotive manufacturing powerhouses such as Japan, Europe and the United States.

Compared the RCA index under the two measurement approaches, it shows that the value-added measurement overestimates the comparative-advantage indices of most of China's high-technology manufacturing sectors relative to the factor-income-based measure, while markedly underestimating those of the basic metals and textile sectors. In 2000, the factor-income-based RCA index of China's textile sector (6.13) was significantly higher than its value-added-based counterpart (5.48). This indicates that production factors embodied in textile exports are mostly domestically endowed factors, with most generated value-added retained within China, thereby boosting export income ratios and comparative-advantage indices. Nevertheless, alongside the withdrawal of foreign-funded enterprises and the erosion of China's labor-cost advantages, the factor-income-based RCA index declined sharply and the gap between the two indices gradually narrowed. The comparative-advantage index of the basic metals sector is also substantially underestimated. In 2020, its factor-income-based and value-added-based RCA indices stood at 2.10 and 1.93 respectively, making it the medium-technology manufacturing sector with the most severely underestimated comparative advantage.

For high-technology manufacturing sectors, the factor-income-based RCA index remained consistently lower than the value-added-based RCA index from 2000 to 2020. This pattern is particularly evident in motor vehicle, trailer and semi-trailer manufacturing, computer, electronic and optical product manufacturing, and chemical product manufacturing, where the gap between the two indices ranges from approximately 0.06 to 0.08 and widened gradually over the sample period. China’s technological progress and improved factor advantages are creating pathways and potential for the transformation and upgrading of the ICT sector.

Table 2. Different RCA index of China's manufacturing sectors

Sector	2000		2020	
	RCA_VA	RCA_FI	RCA_VA	RCA_FI
Manufacturing Sectors	**1.3804**	**1.3582**	**1.6187**	**1.5536**
Low-tech	**2.3998**	**2.3609**	**1.9326**	**1.8963**
-Textiles	5.4771	6.1257	3.5639	3.9460
-Wood and wood products	0.9557	1.0692	1.4510	1.5495
-Paper products and printing	0.7763	0.8213	1.3819	1.4236
-Coke and refined petroleum products	1.4214	1.3452	1.2584	1.2478
-Food products, beverages and tobacco	1.5307	1.2677	1.0283	0.9473
Medium-tech	**1.2596**	**1.3114**	**1.6804**	**1.7306**
-Basic metals	1.3143	1.4591	1.9301	2.0968
-Other non-metallic mineral products	1.4190	1.2265	2.2927	1.9656
-Rubber and plastic products	1.5038	1.5334	1.7498	1.8017
-Fabricated metal products	0.7491	0.8152	1.3921	1.4876
-Other manufacturing	1.4955	1.5201	1.2672	1.2657
High-tech	**1.0403**	**0.9873**	**1.4705**	**1.3524**
-Electrical equipment	1.5581	1.5565	2.3114	2.2936
-Computer, electronic and optical products	1.2777	1.2762	2.2692	2.2002
-Chemicals and chemical products	1.5345	1.4571	1.5143	1.4508
-Machinery and equipment	0.7599	0.7879	1.3435	1.3163
-Other transport equipment	0.6471	0.6812	0.6743	0.6894
-Motor vehicles	0.5100	0.4283	0.5560	0.4784
-Pharmaceuticals	0.4178	0.2881	0.2820	0.2724

Note: In the table, the high, medium and low technology manufacturing sectors are ranked within each group from the largest to the smallest according to the RCA index of factor income in 2020.

These analyses indicate that RCA indicators calculated based on traditional trade statistics and value-added trade methods may lead to misjudgments regarding a country’s industrial export competitiveness, whereas the factor-income-based RCA index is more rational in identifying truly advantageous industries or production factors. Driven by digitalization and informatization of manufacturing industrial chains as well as a new round of technological revolution, China should further consolidate the competitiveness of its advantageous industries, especially the position of products based on genuinely endowed production factors, so as to climb toward higher-value-added segments of global value chains.

3.3 The Disintegration of RCA index of China's Manufacturing Sectors

The above analysis identifies prominent heterogeneous characteristics in the comparative-advantage levels of China's manufacturing industry across different measurement perspectives, with the gap in comparative advantages between the factor-income and value-added views gradually widening in certain manufacturing sectors. To unpack the drivers behind such disparities and explore the actual factor-endowment advantages in China's manufacturing production, this paper further decomposes the factor-income-based RCA indices of China's manufacturing sectors into the labor-income-based RCA index, the domestic-firm capital-income-based RCA index, and the overseas Chinese-funded firm capital-income-based RCA index on the basis of distinguishing firm heterogeneity. It compares the changing trends of RCA indices across different production factors and their contributions to variations in the overall factor-income-based RCA index.

Figure 5 illustrates the contribution rates of income from three production factors-labor, capital of domestic-funded enterprises, and capital of overseas Chinese-funded enterprises-as well as the dynamic evolution of their respective RCA indices from 2000 to 2020. In terms of contribution rates, labor income made the largest contribution, reaching 42.6% in 2000, though its share has declined year by year. By contrast, the contribution rates of capital income from domestic-funded enterprises and overseas Chinese-funded capital have generally trended upward. In recent years, as the demographic dividend fades, China's cost advantage in labor has become unsustainable. During the sample period, China, as an FDI host country, witnessed a 6.2-percentage-point drop in the contribution rate of labor compensation, while its contribution rate of investment income as a home country of outward investment rose by 5.4 percentage points. This indicates that China's outward investment income has gradually become an important component in measuring the comparative advantages of its manufacturing industry. Against the backdrop of global value chain restructuring, rising labor costs have driven Chinese enterprises to “go global”. By establishing overseas affiliates through outward investment to conduct production activities, Chinese firms fully leverage advantageous foreign resources to enhance the competitiveness of domestic products, placing Chinese goods in a more favorable position in international competition.

Judging from the RCA indices of different production factors, all three have remained above 1 since 2012, demonstrating comparative advantages in China's manufacturing export income. The RCA index of capital income from domestic-funded enterprises has consistently ranked first, further verifying that the upgrading of capital factors among indigenous Chinese enterprises is the key driver of improved manufacturing competitiveness. Meanwhile, the RCA index of labor income has closely tracked the overall factor-income-based RCA index in recent years, showing that labor income remains the dominant factor shaping the overall index. The RCA index of overseas Chinese-funded capital income is notably lower than those of the other two factors, standing at 1.15 in 2020, compared with 1.48 for labor income and 1.81 for domestic-firm capital income. This suggests that although China's outward investment income has generated certain competitive advantages, such advantages remain weaker than those of labor factors. China therefore needs to formulate rational strategic plans for outward investment, further optimize the industrial structure of its overseas investment, and improve the technological level and international competitiveness of Chinese-funded enterprises abroad.

In terms of evolutionary trends, the RCA indices of capital income from domestic-funded enterprises and labor income in China's manufacturing sector both follow an up-down-up trajectory, whereas the RCA index of overseas Chinese-funded capital income exhibits a down-then-up trend. Specifically, the RCA index of domestic-firm capital income fluctuated upward overall from 2000 to 2012, peaking at 1.95 in 2012 before declining and rebounding after 2015. The RCA index of labor income followed a similar pattern, with turning points in 2010 and 2015. By contrast, the RCA index of overseas Chinese-funded capital income fell continuously before 2005, reversed its downward trend in 2005, and dipped slightly in 2017–2018. Synthesizing the fluctuation patterns of the three indices, the comparative advantage of China's outward investment has weakened under the impacts of Sino-US trade frictions and geopolitical crises, while the comparative advantages of domestic production factors have been further consolidated.

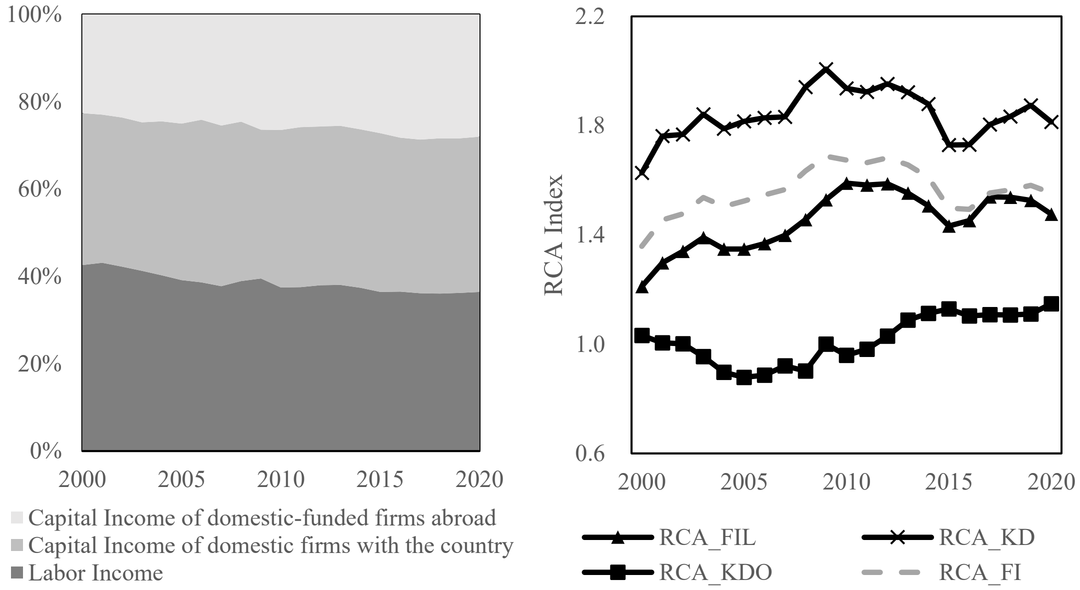


Figure 5 The contribution of different factors to income and RCA index in China's manufacturing sectors from 2000 to 2020

Table 3 presents the factor-specific RCA indices for disaggregated manufacturing sectors in 2020. As shown in the table, low-technology manufacturing sectors derive their main competitive advantages from labor-factor income, while medium- and high-technology manufacturing sectors exhibit prominent competitive advantages in capital-factor income of domestic-funded enterprises.

Specifically, the labor-income-based RCA index for the textile, apparel and leather sector reached 3.74 in 2020, far exceeding those of other production factors, reflecting the sector's reliance on endowment-advantaged labor as a labor-intensive industry. As a resource-intensive sector, basic metal manufacturing features distinctive mineral resource characteristics. With preferential policy support, neither foreign-funded enterprises in China nor overseas Chinese-funded enterprises can match the competitiveness of indigenous firms, giving domestic-enterprise capital a marked competitive advantage with an RCA index of 2.10. Meanwhile, capital-factor income of Chinese-funded enterprises in overseas metal-product sectors shows comparative disadvantage, indicating that the competitiveness of Chinese firms investing in foreign metal-related industries needs further improvement. Within high-technology manufacturing, the factor-income-based RCA index of computer, electronic and optical product manufacturing is mainly driven by labor-factor advantages, with insignificant strengths in capital from overseas Chinese-funded enterprises. Motor vehicle, trailer and semi-trailer manufacturing currently boasts robust overseas exports, where capital from overseas Chinese-funded enterprises delivers considerable competitive advantages. By contrast, the RCA indices of capital-factor income from overseas Chinese-funded enterprises in machinery, other transport equipment and pharmaceuticals are below 1, indicating comparative disadvantage. This suggests that China's global-expanding high-tech industries still face intense competition. On the one hand, institutional and resource constraints hinder operational implementation in developing host economies. On the other hand, technological weaknesses restrict market penetration in developed economies, resulting in a lack of core competitiveness.

Table 3 RCA index of different factors for various manufacturing sectors in China in 2020

Sector	RCA_FI	RCA_FIL	RCA_FIKD	RCA_FIKDO
Low-tech	**1.8963**	**2.0218**	**1.8572**	**1.3073**
-Textiles	3.9460	3.7436	3.0767	3.0211
-Wood and wood products	1.5495	1.1948	1.6037	0.7744
-Paper products and printing	1.4236	1.1105	1.6469	1.0671
-Coke and refined petroleum products	1.2478	0.8685	1.3054	1.4715
-Food products, beverages and tobacco	0.9473	0.7841	1.2549	1.1455
Medium-tech	**1.7306**	**1.2902**	**1.9798**	**1.3732**
-Basic metals	2.0968	1.3911	2.1019	1.9848
-Other non-metallic mineral products	1.9656	1.7191	2.7103	1.5714
-Rubber and plastic products	1.8017	1.3869	2.2175	1.5289
-Fabricated metal products	1.4876	1.0497	1.7604	0.9270
-Other manufacturing	1.2657	1.2246	1.2924	0.6719
High-tech	**1.3524**	**1.3692**	**1.7047**	**1.0574**
-Electrical equipment	2.2936	1.8089	2.7553	2.3232
-Computer, electronic and optical products	2.2002	2.7485	2.0019	1.1625
-Chemicals and chemical products	1.4508	1.0965	1.8959	1.2948
-Machinery and equipment	1.3163	1.0184	1.7818	0.8518
-Other transport equipment	0.6894	0.5759	0.7467	0.9638
-Motor vehicles	0.4784	0.2866	0.7598	1.0543
-Pharmaceuticals	0.2724	0.3484	0.4180	0.4857

Note: The high, medium and low technology manufacturing sectors are ranked within each group from the largest to the smallest according to the RCA index of factor income in 2020.

4 Trends and driving factors of different production factors China's in manufacturing sectors

This paper further reports the changes in factor-specific RCA indices and their driving factors for the aggregate manufacturing sector and disaggregated manufacturing sub-sectors from 2000 to 2020 (Table 4).

For the manufacturing sector as a whole, the RCA index rose by 0.20 over the study period. RCA indices increased for both medium-technology and high-technology manufacturing (by 0.42 and 0.37 respectively), whereas the factor-based comparative advantage of low-technology manufacturing declined markedly (-0.46). The overall rise in the manufacturing RCA index stems from the combined effects of the three production factors. Capital from overseas Chinese-funded enterprises played an indispensable positive role, contributing 54.64%, followed by capital from domestic-funded enterprises. Labor made a limited contribution of only 18.48%. This pattern is broadly consistent across medium- and high-technology manufacturing sectors, where capital, as a key production factor, actively boosts competitive advantages. By contrast, the comparative advantage of low-technology manufacturing is mainly shaped by the labor-factor RCA index, which fell by 0.39 from 2000 to 2020 with a contribution rate of 51.73%. The declining labor-factor advantage in low-technology manufacturing, together with the rising labor-factor advantage in medium- and high-technology manufacturing, jointly reflect the improvement in the quality of China's labor force.

Results from disaggregated manufacturing sectors reveal pronounced industry heterogeneity in RCA index changes. From 2000 to 2020, most sub-sectors within China's high-technology manufacturing saw rising RCA indices. For relatively advantaged sectors including computer, electronic and optical products, electrical equipment, and machinery manufacturing, the contribution gaps among the three production factors were small. In contrast, for the comparatively disadvantaged transport equipment manufacturing sector, capital-factor income from overseas Chinese-funded enterprises acted as the primary driving force. Specifically, the rising RCA index of the motor vehicle manufacturing sector was mainly driven by higher capital returns of overseas Chinese-funded firms (61.62%), with positive contributions also from capital-factor income of domestic-funded enterprises and labor-factor income. The other transport equipment manufacturing sector was similarly lifted by improved competitiveness of Chinese overseas capital returns, which generated a contribution rate as high as 390.13% through outward investment income, while other production factors actually restrained the overall competitiveness of this sector. Pharmaceuticals and chemicals were the only two high-technology manufacturing sub-sectors with declining RCA indices. Insufficient competitiveness of overseas Chinese-funded firms significantly dragged down the comparative advantage of the pharmaceutical sector. Within medium-technology manufacturing, all sub-sectors except other manufacturing and the repair and installation of machinery experienced rising comparative advantage indices, driven jointly by labor-factor income, capital-factor income of domestic-funded enterprises, and capital-factor income of overseas Chinese-funded enterprises. However, numerous low-technology manufacturing sub-sectors recorded falling RCA indices over the sample period. Deteriorating comparative advantages in labor-factor income and domestic-firm capital-factor income largely pulled down the RCA indices of labor-intensive and resource-based sectors. Taking the textile, apparel and leather sector as an example, its RCA index decreased by 2.18 from 2000 to 2020, with the change in labor-factor-based RCA index of −1.64 contributing 45.45% to this decline.

The above analysis indicates that domestic income factors constitute key constraints on the improvement of comparative advantages in medium- and low-technology manufacturing as well as certain high-technology manufacturing sub-sectors, whereas the competitiveness of capital factors from overseas Chinese-funded enterprises is the main factor hindering RCA growth in sectors such as chemicals and pharmaceuticals.

Table 4 Changes in RCA index of different factors in China's manufacturing sectors from 2000 to 2020 and their influencing factors

Sector	Total change of *RCA_FI*	Change of *RCA_FIL*	Change of *RCA_FIKD*	Change of *RCA_FIKDO*
Manufacturing Sectors	**0.1954**	**0.2644(18.48)**	**0.1861(26.88)**	**0.1158(54.64)**
Low-tech	**-0.4646**	**-0.3937(51.73)**	**-0.5172(46.39)**	**-0.0390(1.89)**
-Textiles	-2.1797[01]	-1.6404(45.45)	-2.1620(42.70)	0.6308(11.85)
-Wood and wood products	0.4803[09]	0.4226(31.53)	0.4631(34.54)	-0.3678(33.93)
-Paper products and printing	0.6023[07]	0.4800(33.92)	0.7016(35.94)	0.2393(30.15)
-Coke and refined petroleum products	-0.0974[13]	-1.6605(75.83)	0.1664(60.53)	-0.0757(-36.36)
-Food products, beverages and tobacco	-0.3204[10]	-0.2716(48.62)	-0.7121(44.56)	-0.0038(6.82)
Medium-tech	**0.4193**	**0.1902(29.04)**	**0.5172(33.08)**	**0.1741(37.88)**
-Basic metals	0.6378[06]	0.0461(31.36)	0.8252(34.44)	-0.0561(34.20)
-Other non-metallic mineral products	0.7391[03]	0.2465(33.10)	1.2254(35.46)	0.2299(31.44)
-Rubber and plastic products	0.2683[11]	0.3086(21.90)	0.0827(28.88)	0.3948(49.22)
-Fabricated metal products	0.6724[05]	0.4712(34.33)	0.7372(36.18)	0.1102(29.48)
-Other manufacturing	-0.2544[12]	-0.1266(54.2)	-0.4057(47.84)	0.1226(-2.03)
High-tech	**0.3651**	**0.5184(30.21)**	**0.3819(33.76)**	**0.1403(36.02)**
-Electrical equipment	0.737[04]	0.5728(31.85)	0.8167(34.72)	1.1944(33.43)
-Computer, electronic and optical products	0.9239[02]	1.6256(33.87)	0.6223(35.91)	-0.1142(30.22)
-Chemicals and chemical products	-0.0064[17]	-0.3037(667.98)	0.0485(407.99)	0.2727(-975.97)
-Machinery and equipment	0.5284[08]	0.4203(33.56)	0.7299(35.73)	0.0385(30.71)
-Other transport equipment	0.0082[16]	-0.021(-192.95)	0.0164(-97.18)	0.2213(390.13)
-Motor vehicles	0.0501[14]	-0.0627(14.08)	0.0069(24.30)	0.3818(61.62)
-Pharmaceuticals	-0.0157[15]	-0.0547(88.35)	-0.309(67.88)	-0.2633(-56.23)

Note: The values in the table represent the changes in different RCA indices. The numbers in square brackets [] in the first column denote the ranking of the absolute changes in sector-level RCA indices. The figures in parentheses () in the subsequent three columns indicate the percentage contribution (%) of changes in RCA indices driven by each production factor to the total change in the corresponding period.

In summary, the comparative advantages of different production factors in China’s manufacturing sectors differ both in magnitude and evolutionary trends. The analysis yields the following findings: the RCA index of capital returns of domestic-funded enterprises consistently ranks the highest. Although China’s outward investment income has developed certain competitive advantages, such strengths remain inferior to those of domestic production factors. At present, medium- and low-technology manufacturing sectors still mainly rely on labor-factor income for competitiveness, while capital-factor income of domestic-funded enterprises exhibits prominent advantages in medium- and high-technology manufacturing sectors. As China's labor-cost advantage has become unsustainable in recent years, the contribution rate of outward investment income has risen, gradually becoming a vital component of manufacturing comparative advantages.

In addition, changes in RCA indices show significant industry heterogeneity: domestic income factors act as key constraints on RCA growth for most manufacturing sectors, whereas the competitiveness of capital factors from overseas Chinese-funded enterprises partially hinders the improvement of comparative advantages in resource-based sectors (coke and refined petroleum) and emerging technology sectors (chemicals and pharmaceuticals).

5 Conclusions

Based on the production accounting framework of the global value chain that distinguishes firm heterogeneity, this paper advances the production decomposition accounting framework from the perspective of value added to factor income, and proposes the RCA index of factor income accordingly. It is further deconstructed into RCA index of labor income, RCA index of capital income of domestic enterprises and RCA index of capital income of domestic-funded enterprises in host country. It shows that: (1) Under the traditional value-added measurement framework, the RCA index of China's manufacturing sector, especially that of high-tech manufacturing, is significantly overestimated. (2) In the terms of factor income, China's labor-intensive sectors such as the textile industry, upstream resource-based sectors such as non-metallic minerals and basic metals, and some technology-intensive sectors such as electrical equipment possess obvious global competitive advantages. However, core technology and high-end manufacturing sectors such as transportation equipment manufacturing and pharmaceutical products still have shortcomings. (3) Among different production factors, The RCA index of labor income has always occupied the first place, but in recent years, the contribution rate of China's outward investment income has increased, gradually becoming an important part of the comparative advantage of manufacturing industry. (4) The labor income of domestic firms is the most important factor to promote the increase of RCA index of most manufacturing sectors, but it is also a key factor to limit the improvement of comparative advantage of some high-tech manufacturing sectors including chemical products, pharmaceutical products and transportation equipment. The competitiveness of capital income of home country to a certain extent inhibited the improvement of comparative advantage of resource-based sectors and emerging technology sectors.

As one of the three major drivers of economic growth, exports are highly vulnerable to fluctuations in the international economic environment. Globalized production relies on cross-border division of labor and well-established global value chain (GVC) systems. External shocks such as weakening external demand and trade frictions may trigger volatility or even disruptions in global value chains, leading to sluggish or even counter-cyclical declines in China's manufacturing export growth measured in gross value, value-added and national income terms. Against the backdrop of large-scale GVC restructuring, to upgrade toward high-end GVC segments and escape low-end lock-in, China needs to adopt appropriate restructuring pathways. It should gradually shift from cost advantages built on primary production factors such as low-cost labor to technological advantages driven by advanced factors including digital technologies, so as to foster core industrial competitiveness and gain leading positions in manufacturing value chains. Meanwhile, emerging risks including outward relocation of foreign capital and diminishing labor-factor advantages have limited the improvement of domestic production-factor strengths. Therefore, the global expansion of indigenous Chinese enterprises may become a crucial direction for enhancing manufacturing comparative advantages in the future.

Credit authorship contribution statement

Xuefan Guo: Methodology, Data curation, Formal analysis, Writing original draft, Review and editing. **Kunfu Zhu:** Conceptualization, Methodology, Review and editing. **Jiarong Wang:** Data curation, Review & editing.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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