Original Research Article

A Study on the Trade Competitiveness and Complementarity of Industrial Robots Between China and RCEP Member States

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ABSTRACT

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| China's trade in industrial robots with other RCEP member countries occupies an important position in China's trade in goods. The article combines trade data from 2014-2023, analyzes trade scale and trade structure, and uses TC index, RCA index and TCI index to detect trade potential. The results show that the trade scale of industrial robots between China and other RCEP member countries grows year by year, the trade market structure is relatively concentrated, and there are differences in the competitive advantages and complementarities of different member countries in different product areas, which provides new perspectives and possibilities for trade cooperation. Accordingly, the article proposes to optimize the export structure, meet the diversified market demand, strengthen bilateral and multilateral cooperation and achieve complementary advantages and other development proposals to further promote the development of industrial robotics trade between China and other RCEP member countries to achieve mutual benefit and win-win situation. |

*Keywords: RCEP; trade in industrial robots; trade competitiveness; trade complementarity;*

1. INTRODUCTION

Industrial robots are a strategic technology to lead the future, an important element in the development of artificial intelligence, and a necessary means for the intelligent transformation of the manufacturing industry. According to the latest study of the International Federation of Robots (IFR), the average global sales of industrial robots increased by 19% from 2014 to 2023, with a growth rate of up to 30% in 2023, and the trend of growth in global demand for industrial robots is obvious. China has become the world's largest industrial robot market for five consecutive years since 2014, and exports have gradually increased. Industrial robots have become an important driving force to pull the world's economic growth and intelligent transformation of the manufacturing industry**(Zhao, Y., Said, R., Ismail, N. W., & Hamzah, H. Z.,2022).**

From 2014-2023, China's industrial robot exports to other RCEP member countries grew at an average annual rate of 9.9%, and its share of total industrial robot exports during the same period increased from 20.1% to 25.1%.Other RCEP member countries are also the top source of China's industrial robot imports, with 40% of China's industrial robots imported from other RCEP member countries. With the formal entry into force and implementation of the Regional Comprehensive Economic Partnership Agreement (RCEP) on January 1, 2022, China's trade with other RCEP member countries will be more convenient **(Tan, F., & Wang, J.,2025)**. An in-depth analysis of the competitiveness and complementarity of industrial robots trade between China and other RCEP member countries is not only conducive to better exerting the comparative advantages of each country, improving the efficiency and potential of bilateral trade, and promoting the comprehensive development of China's industrial robots trade with other RCEP member countries, but also conducive to the stabilization of China's overall pattern of foreign trade and the realization of the high-quality development of foreign trade**(Wang, D., & Li, G.,2022；Hong, L., Liu, X., Zhan, H., & Han, F.,2022).**

2. Overview of China's trade in industrial robots with other RCEP member countries

According to the study, industrial robots can be categorized into high technological complexity and low technological complexity industrial robots; in addition, according to the application purpose, industrial robots can be categorized into production-oriented industrial robots (HS code 842489, HS code 851521, HS code 851531, HS code 848640, HS code 851580) service production-oriented industrial robots (HS code 842890), and other multifunctional industrial robots (HS code 847950).

This paper focuses on three major categories: production-oriented industrial robots, service production industrial robots and other multifunctional industrial robots. The specific corresponding HS codes (International Code Harmonization System) are shown in Table 1.

**Table 1. Types and numbers of industrial robots**

|  |  |  |
| --- | --- | --- |
| **No.** | **Product Category** | **HS Code** |
| 1 | Production-oriented Industrial Robots | 842489、851521、851531、848640、851580 |
| 2 | Service Production-oriented Industrial Robots | 842890 |
| 3 | Other Multifunctional Industrial Robots | 847950 |

**2.1 Trade Scale**

Since 2014, China's trade in industrial robots with other RCEP member countries has developed rapidly, with total trade showing an overall growth trend (see Table 2).From 2014-2023, total trade has grown from US$364.59 million to US$646.84 million, with a cumulative growth of 77.41%. In particular, exports grew at a faster rate, with an average annual growth of 9.9%, which is 2 percentage points higher than the average annual growth rate of imports. In terms of individual years, most years show positive growth, and only three years, 2019, 2022 and 2023, show negative growth. Among them, the import trade of industrial robots declined in 2019, with an overall trade growth rate of -12.93%, while the trade growth rate in 2021 was as high as 34.89%, and the growth rate in 2020 was over 5%, specifically 5.76%. From the point of view of trade balance, China's industrial robot trade with other RCEP member countries has always had a trade deficit. 2022 and 2023 two years, China and other RCEP member countries industrial robot trade deficit significantly alleviated, the value of the deficit fell sharply to 300.28 million U.S. dollars and 191.11 million U.S. dollars, to a certain extent, that January 1, 2022 RCEP rules After the formal entry into force of the RCEP rules, the RCEP rules improved China's industrial robot trade with other RCEP member countries.

**Table 2. China's trade in industrial robots with other RCEP members (in USD)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Year** | **Export Amount** | **Import Amount** | **Total Trade** | **Trade Growth Rate** | **Trade Balance** |
| 2014 | 949228400 | 2696711990 | 3645940390 | 0.154647837 | -1747483590 |
| 2015 | 922398492 | 2870750988 | 3793149480 | 0.040376165 | -1948352496 |
| 2016 | 960717913 | 3129498448 | 4090216361 | 0.078316682 | -2168780535 |
| 2017 | 1102852756 | 4164841152 | 5267693908 | 0.287876592 | -3061988396 |
| 2018 | 1165173281 | 5264041325 | 6429214606 | 0.220498897 | -4098868044 |
| 2019 | 1439183017 | 4158499141 | 5597682158 | -0.129336552 | -2719316124 |
| 2020 | 1566647459 | 4353690151 | 5920337610 | 0.057640903 | -2787042692 |
| 2021 | 1928869839 | 6056991737 | 7985861576 | 0.348886179 | -4128121898 |
| 2022 | 2055614547 | 5058384974 | 7113999521 | -0.109175703 | -3002770427 |
| 2023 | 2278633092 | 4189762616 | 6468395708 | -0.090751175 | -1911129524 |

*Source: Processed from UN Comtrade data, same below.*

**2.2 Trade Structure**

**2.1.1 Country Structure**

At the level of import sources, China's imports of industrial robots from other RCEP member countries are characterized by two distinct features. First, it is concentrated in a few countries. As shown in Table 3, the top three Japan, South Korea and Singapore accounted for 46.38%, 28.41% and 18.91% respectively, totaling as high as 93.7%, meaning that more than 90% of China's imports of industrial robots from other RCEP member countries come from these three countries. Second, imports from member countries remain relatively stable. In terms of the trend from 2014-2023, only Singapore and South Korea show more obvious fluctuations. Among them, Singapore shows significant growth, with a net increase of about 7 percentage points in share over the decade, while South Korea declines from 28.16% in 2014 to 17.30% in 2023.

At the export level, it can be seen from Table 4 that China's industrial robot exports to other RCEP member countries are similarly characterized by both concentration and stability. First, the export object is concentrated in Japan, Vietnam, Singapore and South Korea. The average proportion of these four countries is 17.29%, 17.07%, 15.73% and 11.83% respectively, totaling up to 61.92%. Second, judging from the trend of changes in the share of each member, the share of most countries is relatively stable, with little change. The countries with faster growth and larger declines in share are Thailand and Singapore. Thailand's share increased by a net of about 8 percentage points over the decade, while Singapore's share declined from 20.59 per cent in 2014 to 11.03 per cent in 2023, a cumulative increase of about 9 percentage points.

**Table 3. China's imports of industrial robots from other RCEP member countries by member country (%)**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year Source** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022** | **2023** | **Average Share** |
|
| Australia | 0.0439 | 0.1029 | 0.1563 | 0.0785 | 0.1221 | 0.0869 | 0.0831 | 0.0910 | 0.0869 | 0.1592 | 0.1011 |
| Philippines | 0.1232 | 0.0409 | 0.0213 | 0.0264 | 0.0932 | 0.0656 | 0.1385 | 0.0207 | 0.0212 | 0.0649 | 0.0616 |
| South Korea | 28.1630 | 35.5685 | 32.1545 | 27.9012 | 38.5388 | 34.3789 | 29.3746 | 20.3957 | 20.2938 | 17.2955 | 28.4064 |
| Malaysia | 3.9363 | 2.4600 | 3.1100 | 2.9204 | 2.5342 | 2.6527 | 4.0386 | 5.6128 | 5.1010 | 3.8428 | 3.6209 |
| Japan | 49.3718 | 44.5679 | 44.7225 | 51.0318 | 41.3710 | 48.0452 | 45.4350 | 43.2775 | 45.9734 | 50.0368 | 46.3833 |
| Thailand | 0.5559 | 0.9662 | 0.9858 | 1.1264 | 0.4140 | 0.2299 | 0.5338 | 1.2539 | 0.7358 | 0.6121 | 0.7414 |
| Singapore | 17.0422 | 15.4590 | 17.5130 | 15.6529 | 15.4418 | 13.2749 | 18.7421 | 27.0105 | 24.2907 | 24.6638 | 18.9091 |
| New Zealand | 0.1007 | 0.0497 | 0.0184 | 0.0403 | 0.1458 | 0.0675 | 0.0000 | 0.0322 | 0.0782 | 0.0110 | 0.0544 |
| Indonesia | 0.0011 | 0.0001 | 0.0009 | 0.0003 | 0.0002 | 0.0176 | 0.0171 | 0.0231 | 0.0363 | 0.0299 | 0.0127 |
| Vietnam | 0.6620 | 0.7848 | 1.3171 | 1.2218 | 1.3388 | 1.1809 | 1.6372 | 2.2827 | 3.3826 | 3.2840 | 1.7092 |
| Myanmar | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Brunei | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Cambodia | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Laos | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

**Table 4. China's exports of industrial robots from other RCEP member countries by member country (%)**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year Country** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022** | **2023** | **Average Share** |
|
| Australia | 11.7083 | 8.5586 | 5.7412 | 8.2582 | 5.5273 | 4.5537 | 6.6088 | 6.9450 | 5.5687 | 5.5040 | 6.8974 |
| Philippines | 2.8209 | 3.9769 | 3.0716 | 2.5071 | 3.3328 | 3.7353 | 2.6571 | 4.6157 | 2.8460 | 2.4649 | 3.2028 |
| South Korea | 13.8539 | 12.8769 | 9.9922 | 12.3574 | 9.4825 | 10.0236 | 15.3558 | 10.4951 | 13.0610 | 10.8169 | 11.8315 |
| Cambodia | 0.5159 | 0.7005 | 0.5741 | 0.5344 | 1.0176 | 0.9833 | 1.1644 | 1.2640 | 2.5752 | 1.5725 | 1.0902 |
| Laos | 0.4626 | 0.3450 | 0.1066 | 0.5497 | 0.1446 | 0.2423 | 0.2166 | 0.0896 | 0.1305 | 1.0289 | 0.3316 |
| Malaysia | 5.7708 | 8.1472 | 7.2410 | 7.1606 | 8.4558 | 8.0102 | 7.0113 | 9.0541 | 8.0584 | 8.0589 | 7.6968 |
| Myanmar | 1.1026 | 1.5548 | 0.9477 | 1.1251 | 0.9721 | 0.7338 | 0.5625 | 0.3658 | 1.0285 | 0.3343 | 0.8727 |
| Japan | 14.5539 | 17.4564 | 16.8786 | 15.8622 | 21.6936 | 20.8268 | 20.3874 | 17.6453 | 14.8578 | 12.7625 | 17.2924 |
| Thailand | 7.2763 | 7.6914 | 8.1226 | 8.1130 | 7.6927 | 10.1188 | 7.4196 | 10.0206 | 10.0783 | 15.8116 | 9.2345 |
| Brunei | 0.0580 | 0.0816 | 0.0121 | 0.2155 | 0.6327 | 0.0765 | 0.0266 | 0.0326 | 0.0442 | 0.0280 | 0.1208 |
| Singapore | 20.5882 | 17.5804 | 22.7479 | 18.2552 | 15.7127 | 9.8726 | 12.4770 | 13.8666 | 15.1686 | 11.0333 | 15.7302 |
| New Zealand | 0.5838 | 0.8219 | 0.8848 | 0.9190 | 0.8567 | 0.6399 | 0.7137 | 0.8465 | 0.8080 | 0.6880 | 0.7762 |
| Indonesia | 9.5552 | 7.5225 | 7.4694 | 5.8213 | 7.6464 | 8.5789 | 5.1674 | 6.7509 | 9.7335 | 10.2415 | 7.8487 |
| Vietnam | 11.1497 | 12.6859 | 16.2101 | 18.3213 | 16.8327 | 21.6043 | 20.2317 | 18.0080 | 16.0413 | 19.6549 | 17.0740 |

*Note: According to the data screening, China does not have Brunei, Cambodia and Laos in terms of import trade of industrial robots from other RCEP member countries; it means that China does not have trade with Brunei, Cambodia and Laos in terms of import trade of industrial robots; in terms of export trade, China has trade with other RCEP member countries.*

At the level of total trade, as can be seen from Figure 1, the distribution of the share of China's trade in industrial robots with other RCEP member countries is relatively concentrated. Japan ranked first, accounting for 38.63%; South Korea ranked second, accounting for 23.93%; Singapore ranked third, accounting for 18.24%. The total share of the three countries is as high as 80.8%. The data shows that the three countries have a high share of industrial robot trade in the RCEP market, showing a strong competitive advantage. The Philippines, Cambodia, Laos, Myanmar, Brunei and New Zealand all have a share of less than 1%.

**Fig. 1. Distribution of China's trade in industrial robots with other RCEP member countries in terms of share of each member country**

*Note: The share of individual member countries in the figure is the average share from 2014-2023.*

**2.1.2 Country Structure**

As can be seen from Figure 2 and Table 5, at the level of total trade, production-oriented industrial robots ranked first, service-production industrial robots ranked second, and other multifunctional industrial robots ranked third, with an average share of 65.65%, 17.19%, and 17.16%, respectively. In terms of trade balance, service production-oriented industrial robots maintain a trade surplus, with an average trade surplus of $18.61 million from 2014 to 2023; production-oriented and other multifunctional industrial robots continue to have trade deficits, and the deficits are all on the rise, and production-oriented industrial robots have larger trade deficits, with an average trade deficit of $135.06 from 2014 to 2023. million dollars.

From the three types of industrial robots trade country-by-country distribution (Table 6), in 2023, China and the other RCEP member countries for the production of industrial robots exports ranked the top three countries are Vietnam, Thailand and Singapore, imports ranked the top three countries are Singapore, Japan and South Korea; specific analysis, South Korea, Japan, Malaysia and Singapore are in deficit, of which Japan has the largest trade gap, amounting to 87.00 million U.S. dollars, in addition to the remaining 10 countries are in surplus; service production of industrial robots exports ranked the top three countries Japan, Indonesia and Vietnam, imports ranked the top three countries are Japan, South Korea and Malaysia; service production of industrial robots trade as a whole is in surplus; other multi-functional industrial robots exports ranked the top three countries South Korea, Thailand and Vietnam, imports of The top three countries are Japan, South Korea and Malaysia; specific analysis, in addition to Japan the remaining 13 countries are in surplus, Japan's trade deficit reached 94.58 million U.S. dollars.

**Fig. 2. Structure of China's trade in industrial robots with other RCEP member countries(million dollar)**

**Table 5. Overall trade in industrial robots between China and other RCEP member countries (million dollar)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Category** | **Production-oriented Industrial Robots** | | | **Service Production-oriented Industrial Robots** | | | **Other Multifunctional Industrial Robots** | | |
| 2014 | 2023 | Average | 2014 | 2023 | Average | 2014 | 2023 | Average |
| Total Trade | 231.1829 | 439.1188 | 335.1509 | 72.4256 | 93.9129 | 83.1692 | 60.9855 | 113.8079 | 87.3967 |
| Trade Balance | -110.1648 | -159.9497 | -135.0573 | -12.4551 | 49.6751 | 18.6100 | -52.1284 | -80.8383 | -66.4834 |
| Trade Share | 63.4083% | 67.8868% | 65.6476% | 19.8647% | 14.5187% | 17.1917% | 16.7270% | 17.5945% | 17.1607% |

**Table 6. Commodity structure of China's trade in industrial robots with other RCEP member countries, 2023**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Country** | **Production-oriented Industrial**  **Robots** | | | **Service Production-oriented Industrial Robots** | | | **Other Multifunctional Industrial Robots** | | |
| Import | Export | trade balance | Import | Export | trade balance | Import | Export | trade balance |
| Australia | 0.0099 | 5.8572 | 5.8473 | 0.6339 | 5.8122 | 5.1783 | 0.0232 | 0.8722 | 0.849 |
| Philippines | 0.2709 | 3.1085 | 2.8376 | 0.001 | 2.2826 | 2.2815 | 0 | 0.2254 | 0.2254 |
| South Korea | 64.4112 | 13.3436 | -51.0675 | 6.9393 | 7.2313 | 0.2919 | 1.1134 | 4.0728 | 2.9594 |
| Cambodia | 0 | 2.566 | 2.566 | 0 | 0.9922 | 0.9922 | 0 | 0.025 | 0.025 |
| Laos | 0 | 2.011 | 2.011 | 0 | 0.3279 | 0.3279 | 0 | 0.0056 | 0.0056 |
| Malaysia | 14.9196 | 11.2848 | -3.6348 | 1.1169 | 5.8728 | 4.7559 | 0.064 | 1.2058 | 1.1418 |
| Myanmar | 0 | 0.4445 | 0.4445 | 0 | 0.3135 | 0.3135 | 0 | 0.0038 | 0.0038 |
| Japan | 101.0292 | 14.0294 | -86.9998 | 12.4931 | 13.5102 | 1.0171 | 96.1202 | 1.5415 | -94.5787 |
| Thailand | 2.5613 | 24.5567 | 21.9954 | 0.0028 | 7.6251 | 7.6223 | 0.0004 | 3.8471 | 3.8468 |
| Brunei | 0 | 0.0315 | 0.0314 | 0 | 0.0237 | 0.0237 | 0 | 0.0086 | 0.0086 |
| Singapore | 102.7557 | 20.7611 | -81.9946 | 0.5797 | 3.0112 | 2.4315 | 0 | 1.3684 | 1.3684 |
| New Zealand | 0.0067 | 0.8211 | 0.8144 | 0.0392 | 0.5517 | 0.5124 | 0 | 0.1949 | 0.1949 |
| Indonesia | 0.1249 | 10.5154 | 10.3905 | 0.0004 | 12.3999 | 12.3995 | 0 | 0.4212 | 0.4212 |
| Vietnam | 13.4449 | 30.2539 | 16.8089 | 0.3123 | 11.8397 | 11.5274 | 0.002 | 2.6927 | 2.6907 |
| Total | 299.5343 | 139.5845 | -159.9497 | 22.1189 | 71.7940 | 49.6751 | 97.3231 | 16.4848 | -80.8383 |

*Note: In addition to the above description, in the trade of other multifunctional industrial robots, China does not have import trade transactions of such industrial robots with Singapore, New Zealand, and Indonesia, which are among the other RCEP members.*

1. Assessment of Trade Competitiveness in Industrial Robots Between China and RCEP Member States

**3.1 Trade competitiveness at the aggregate level**

In this paper, the TC index (Trade Competitiveness Index) is used to measure the overall level trade competitiveness. Referring to the existing literature **(Chen, J., Chen, D., & Yao, A.2020)**, the TC index is specifically calculated as:

TC=(X-M)/(X+M) （1）

In this formula,where X is the export value of all kinds of industrial robotic products of each RCEP member country, and M is the import value.The TC index takes the value range of [-1,1]. When the TC index is close to 1, it means that the country's trade competitiveness is very strong, when the index is close to -1, indicating that trade competitiveness is relatively weak. When the TC index is equal to 1, it means that the country only exports and does not import; when the index is equal to -1, it means that the country only imports and does not export. When the index is 0, it means that the country's trade competitiveness is at a medium level.

Table 7 shows the fluctuation of the TC index for industrial robots in China and other RCEP member countries from 2014-2023. The average fluctuation is 0.28 [(0.24+0.31+0.27)/3≈0.28], indicating that the RCEP member countries have become more competitive in industrial robot trade, but the increase is not very large. Further from the fluctuation of each type of product, in terms of production-oriented industrial robots. the member countries with upward trend in TC index are China and Malaysia, indicating that the competitiveness of these two countries in production-oriented industrial robots is strengthening, of which the fluctuation value of Malaysia is the largest, and the TC index has increased by 0.32 from 2014 to 2023; and the other fluctuation of Myanmar from 2014 to 2023 value of 0, indicating that the trade competitiveness of Myanmar as a country is at a medium level; and five countries, Australia, the Philippines, Japan, Brunei and New Zealand, have a declining trend in the TC index, indicating weakening competitiveness, with Japan having the largest fluctuation value, with the TC index declining by 0.18 from 2014 to 2023.For industrial robots that serve production, the TC indices of China, Australia and the Philippines rises, with the largest increase in China, where the TC index rises by 0.61 in 2023 compared to 2014; in addition, Myanmar's TC index remains unchanged in 2023 compared to 2014; whereas four countries, Malaysia, Japan, Brunei, and New Zealand, see a decline in their TC indexes, with the largest decrease in Japan, where the TC index declines by 0.44 in 2023 compared to 2014.For industrial robots for other multifunctional applications. China, the Philippines, Malaysia, Brunei and New Zealand saw their TC indexes rise, with Malaysia seeing the largest increase, with its 2023 TC index rising by 0.66 from 2014; in addition, Myanmar saw its 2023 TC index fall by 1 from 2014, suggesting that the country only imports but does not export; while Australia and Japan saw their TC indexes fall, with Australia seeing the largest decrease, with its 2023 TC index decreases by 0.3 from 2014.

**Table 7. Fluctuation of TC index for industrial robots to RCEP member countries, 2014-2023**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Country** | **Production-oriented Industrial**  **Robots** | | | **Service Production-oriented Industrial Robots** | | | **Other Multifunctional Industrial Robots** | | |
| 2014 | 2023 | Period  fluctuation | 2014 | 2023 | Period  fluctuation | 2014 | 2023 | Period  fluctuation |
| Australia | -0.33 | -0.11 | 0.22 | -0.27 | 0.34 | 0.61 | -0.73 | -0.47 | 0.27 |
| Philippines | -0.73 | -0.83 | -0.10 | -0.89 | -0.88 | 0.01 | -0.26 | -0.56 | -0.30 |
| South Korea | -0.61 | -0.67 | -0.06 | -0.95 | -0.76 | 0.19 | -0.98 | -0.86 | 0.12 |
| Cambodia | 0.09 | 0.00 | -0.09 | -0.11 | 0.00 | 0.11 | 0.11 | 0.00 | -0.11 |
| Laos | -1.00 | 0.00 | 1.00 | -1.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 |
| Malaysia | -1.00 | 0.00 | 1.00 | -1.00 | 0.00 | 1.00 | -1.00 | 0.00 | 1.00 |
| Myanmar | -0.26 | 0.06 | 0.32 | -0.43 | -0.45 | -0.01 | -0.78 | -0.12 | 0.66 |
| Japan | -1.00 | -1.00 | 0.00 | -1.00 | -1.00 | 0.00 | 0.00 | -1.00 | -1.00 |
| Thailand | 0.72 | 0.53 | -0.18 | 0.65 | 0.20 | -0.44 | 0.95 | 0.95 | -0.01 |
| Brunei | -0.73 | 0.00 | 0.73 | -0.83 | 0.00 | 0.83 | -0.93 | 0.00 | 0.93 |
| Singapore | -0.81 | -0.87 | -0.06 | -0.38 | -0.48 | -0.11 | -1.00 | -0.46 | 0.54 |
| New Zealand | 0.73 | 0.00 | -0.73 | 0.12 | 0.00 | -0.12 | -0.24 | 0.00 | 0.24 |
| Indonesia | -0.59 | -0.72 | -0.14 | -0.45 | -0.58 | -0.13 | -0.71 | -0.57 | 0.14 |
| Vietnam | -0.93 | 0.00 | 0.93 | -0.96 | 0.00 | 0.96 | -0.99 | 0.00 | 0.99 |
| Total | -0.80 | 0.00 | 0.80 | -0.77 | 0.00 | 0.77 | -0.63 | 0.00 | 0.63 |

*Note: After data screening, we know that the 2023 data on industrial robots of 7 countries, namely, South Korea, Cambodia, Laos, Thailand, Singapore, Indonesia and Vietnam, are missing, and the reasons are analyzed as follows: firstly, it may be due to the promulgation of the policies on industrial robots in China, and therefore industrial robots of the above countries do not participate in the international trade, and the data are 0; secondly, it may be due to the untimely updating of the data, which is not discussed in depth here*

**3.2 Trade competitiveness at the regional level**

In this paper, the RCA index (Revealed Comparative Advantage Index) is used to measure trade competitiveness at the regional level. Referring to the existing literature **(French, S.,2017)**, in order to measure China's competitiveness in industrial robotics to each RCEP member country in a more specific way, the calculation of the RCA index is adjusted to:

RCAabj = (Xabj/Xab)÷(XaWj/XaW) （2）

where Xabj denotes the value of China's exports of industrial robots to other RCEP member countriesb and Xab denotes the total value of China's exports to other RCEP member countriesb; XaWj denotes the total value of China's exports of industrial robots to the world, and XaW denotes the total value of China's exports to the world of all commodities.

Table 8 shows the fluctuation of the RCA index of industrial robots between China and other RCEP member countries from 2014 to 2023. The average fluctuation is nearly -1.66 [(-0.38-4.59-0.02)/3 ≈ -1.66], indicating that China's regional demonstrated comparative advantage over the other RCEP member countries is declining as a whole, and the decline is more obvious. Further from the point of view of the fluctuation of various types of products, in terms of production-oriented industrial robots, the RCA index shows an upward trend of member countries Cambodia, Laos, Malaysia, Thailand and Vietnam, indicating that the comparative advantage has been enhanced, among which the index fluctuation values of Laos and Thailand are larger, and the RCA index rises by 4.30 and 1.18 from 2014 to 2023, respectively; and in addition, New Zealand's index fluctuation is 0, which indicates that the the country's trade competitiveness in production-oriented industrial robots is at a medium level; while seven countries, including Singapore, Myanmar, and South Korea, have declining RCA indexes, indicating weakening comparative advantages, with Singapore's index having the largest change, with the RCA index declining by 2.15 in 2023 compared to 2014. for service-producing industrial robots, South Korea, Japan, Malaysia, Brunei, Indonesia, and Vietnam Six countries saw their RCA indexes rise, and eight countries, including Australia, Laos, and Cambodia, saw their RCA indexes fall, with Vietnam seeing the largest increase, with its 2023 RCA index rising 0.58,from 2014, and Australia seeing the largest decline, with its 2023 RCA index falling 4.59 from 2014.For other multifunctional industrial robots, Australia, South Korea, Malaysia, Myanmar, Japan, and Indonesia, the RCA Index declined in six countries, while the rest of the countries increased slightly. Myanmar had the largest decrease, with the 2023 RCA Index down 1.04 from 2014, and Vietnam had the largest increase, with the 2023 RCA Index up 1.11 from 2014.

**Table 8. RCA index for industrial robots in China and other RCEP member countries**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Country** | **Production-oriented Industrial**  **Robots** | | | **Service Production-oriented Industrial Robots** | | | **Other Multifunctional Industrial Robots** | | |
| 2014 | 2023 | Period  fluctuation | 2014 | 2023 | Period  fluctuation | 2014 | 2023 | Period  fluctuation |
| Australia | 1.04 | 0.66 | -0.38 | 5.98 | 1.39 | -4.59 | 0.90 | 0.89 | -0.02 |
| Philippines | 0.61 | 0.50 | -0.12 | 2.00 | 0.77 | -1.23 | 0.12 | 0.32 | 0.20 |
| South Korea | 1.31 | 0.75 | -0.56 | 0.46 | 0.86 | 0.40 | 2.88 | 2.05 | -0.84 |
| Cambodia | 0.73 | 1.68 | 0.95 | 2.83 | 1.38 | -1.45 | 0.00 | 0.15 | 0.15 |
| Laos | 0.72 | 5.02 | 4.30 | 5.52 | 1.73 | -3.78 | 0.00 | 0.13 | 0.13 |
| Malaysia | 0.93 | 1.08 | 0.15 | 1.11 | 1.19 | 0.08 | 1.86 | 1.03 | -0.83 |
| Myanmar | 1.01 | 0.33 | -0.68 | 0.89 | 0.49 | -0.40 | 1.06 | 0.02 | -1.04 |
| Japan | 0.71 | 0.74 | 0.04 | 1.03 | 1.52 | 0.49 | 0.80 | 0.73 | -0.07 |
| Thailand | 1.53 | 2.71 | 1.18 | 2.02 | 1.78 | -0.23 | 3.13 | 3.81 | 0.68 |
| Brunei | 0.36 | 0.31 | -0.05 | 0.13 | 0.49 | 0.36 | 0.00 | 0.75 | 0.75 |
| Singapore | 4.40 | 2.26 | -2.15 | 1.86 | 0.69 | -1.16 | 0.86 | 1.33 | 0.48 |
| New Zealand | 0.87 | 0.87 | 0.00 | 1.26 | 1.24 | -0.02 | 1.51 | 1.86 | 0.35 |
| Indonesia | 1.77 | 1.35 | -0.42 | 2.80 | 3.37 | 0.57 | 0.82 | 0.48 | -0.33 |
| Vietnam | 1.75 | 1.84 | 0.09 | 0.95 | 1.52 | 0.58 | 0.35 | 1.47 | 1.11 |
| Total | 1.27 | 1.44 | 0.17 | 2.06 | 1.32 | -0.74 | 1.02 | 1.07 | 0.05 |

4. Complementarity Measurement of Industrial Robot Trade between China and Other RCEP Member Countries

In this paper, the TCI index (Trade Complementarities Index) is used to measure trade complementarities**(Tang, C., Rosland, A., Li, J., & Yasmeen, R.,2023).** The formula is as follows:

（3）

In the formula, for country a and country b in j product traders complementarity coefficient, represents country a in product j on the comparative advantage, represents country b in product j on the comparative disadvantage, and respectively, and a country j product exports and the world's exports of j products; and respectively, and respectively, for the total exports of all commodities of country a and the world's total exports of all commodities; and respectively, and represents country b in product j imports and the world's imports of j products, and respectively are country b's total imports of all goods and the world's total imports of all goods. When country a's comparative advantage in product j is more obvious, and country b's comparative disadvantage in product j is more obvious, then country a and country b's trade complementarity in product j is stronger; conversely, the two countries' trade complementarity in product j is weaker. The larger the index, the stronger the trade complementarity between the two countries; conversely, the smaller the index, the weaker the trade complementarity between the two countries.

Table 9 shows the fluctuation of the TCI index of industrial robots between China and other RCEP member countries from 2014 to 2023. In terms of the direction of fluctuation (excluding countries with 0 data in 2023), countries with positive fluctuations in the TCI index are significantly more than those with negative fluctuations, indicating that China's trade complementarity with other RCEP member countries in industrial robots has shown an overall trend of enhancement. Further from the point of view of the fluctuation of various types of products, production-oriented industrial robots, the overall fluctuation is relatively small, Australia, the Philippines, Malaysia, Japan and New Zealand five countries TCI index rose, indicating that the trade complementarity is enhanced, of which the Philippines TCI index rose more significantly, the TCI index of 2023 rose by 0.0134 compared with 2014; Myanmar and Brunei two countries TCI indexes tend to be close to 0, with weaker trade complementarity. As for industrial robots for service production, the overall fluctuation is small, and trade complementarity is relatively stable. The TCI indexes of six countries, Australia, the Philippines, Malaysia, Myanmar, Japan and New Zealand, have risen, indicating that trade complementarity has increased; the TCI index of Brunei has declined, but the rate of decline has not been very obvious, but it is also a certain degree of reflecting that China's trade complementarity with that country has weakened. In terms of other multifunctional industrial robots, the TCI indexes of the remaining countries except Myanmar and Cambodia are all positive, indicating that trade complementarity has increased; Myanmar and Cambodia were found to have no trade with China in terms of other multifunctional industrial robots at the data screening stage.

**Table 9. TCI index of industrial robots between China and other RCEP member countries**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Country** | **Production-oriented Industrial**  **Robots** | | | **Service Production-oriented Industrial Robots** | | | **Other Multifunctional Industrial Robots** | | |
| 2014 | 2023 | Period  fluctuation | 2014 | 2023 | Period  fluctuation | 2014 | 2023 | Period  fluctuation |
| Australia | 0.0026 | 0.0057 | 0.0031 | 0.0092 | 0.0203 | 0.0111 | 0.0002 | 0.0005 | 0.0003 |
| Philippines | 0.0005 | 0.0139 | 0.0134 | 0.0017 | 0.0031 | 0.0015 | 0.0001 | 0.0003 | 0.0002 |
| South Korea | 0.0064 | 0.0000 | -0.0064 | 0.0023 | 0.0000 | -0.0023 | 0.0009 | 0.0023 | 0.0013 |
| Cambodia | 0.0005 | 0.0000 | -0.0005 | 0.0025 | 0.0000 | -0.0025 | 0.0000 | 0.0000 | 0.0000 |
| Laos | 0.0040 | 0.0000 | -0.0040 | 0.0094 | 0.0000 | -0.0094 | 0.0002 | 0.0006 | 0.0003 |
| Malaysia | 0.0064 | 0.0171 | 0.0108 | 0.0012 | 0.0041 | 0.0029 | 0.0009 | 0.0023 | 0.0013 |
| Myanmar | 0.0008 | 0.0007 | 0.0000 | 0.0007 | 0.0016 | 0.0010 | 0.0000 | 0.0000 | 0.0000 |
| Japan | 0.0014 | 0.0060 | 0.0046 | 0.0006 | 0.0022 | 0.0016 | 0.0002 | 0.0004 | 0.0002 |
| Thailand | 0.0053 | 0.0000 | -0.0053 | 0.0019 | 0.0000 | -0.0019 | 0.0008 | 0.0019 | 0.0011 |
| Brunei | 0.0012 | 0.0013 | 0.0001 | 0.0026 | 0.0023 | -0.0003 | 0.0001 | 0.0002 | 0.0001 |
| Singapore | 0.0024 | 0.0000 | -0.0024 | 0.0010 | 0.0000 | -0.0010 | 0.0005 | 0.0012 | 0.0007 |
| New Zealand | 0.0035 | 0.0070 | 0.0035 | 0.0055 | 0.0133 | 0.0077 | 0.0003 | 0.0008 | 0.0005 |
| Indonesia | 0.0032 | 0.0000 | -0.0032 | 0.0015 | 0.0000 | -0.0015 | 0.0012 | 0.0029 | 0.0017 |
| Vietnam | 0.0047 | 0.0000 | -0.0047 | 0.0013 | 0.0000 | -0.0013 | 0.0007 | 0.0016 | 0.0010 |
| Total | 0.0031 | 0.0037 | 0.0006 | 0.0029 | 0.0034 | 0.0004 | 0.0004 | 0.0011 | 0.0006 |

5.Main conclusions and recommendations for countermeasures

**5.1 Main conclusions**

The study found that the scale of trade between China and other RCEP member countries in the field of industrial robots has been growing year by year, with a high degree of market concentration. The top three countries account for as much as 90% of the total. China's trade relationship with other RCEP member countries in industrial robots is competitive and complementary.

Competitively, China has a competitive advantage in industrial robots for service production, but has competitors in production-oriented and other multifunctional industrial robots. There are differences in the products of each country, Japan, South Korea and Singapore have a certain competitive advantage in three types of industrial robots and other technology- and capital-intensive products; on the contrary, Myanmar, Cambodia and Laos do not have a competitive advantage in these three types of products compared with other countries, according to the theory of the life cycle of the product that countries in the third world in the maturity of the product can be entered into the market for standardized production, and at the same time transfer the factory to their own country. The advantages and positioning of the products produced by different RCEP member countries provide an important reference and inspiration for further trade cooperation. There is a clear homogeneity between China and Vietnam, South Korea, Japan, Malaysia and Thailand in terms of industrial robots, not to say that there is a competitive relationship between them.

In terms of complementarity, the trade complementarity between China and other RCEP member countries is increasing, and there is a certain potential for trade development. In terms of trade complementarities of various types of industrial robots, China has strong complementarities with Australia, the Philippines and Malaysia in the field of production-oriented industrial robots; China has complementarities with Australia and New Zealand in the field of service-producing industrial robots; and in the field of other multifunctional industrial robots, China has certain complementarities with the rest of the countries, except for Myanmar and Cambodia.

**5.2 Recommendations for countermeasures**

**5.2.1 Optimize export structure to meet diversified market demand**

Promote the development of industrial robots in the direction of high-end and intelligentization, and improve the added value and technical content of products **(Bi, S.,2021)**. For Vietnam, Japan and other countries, in-depth study of their market demand, optimize product design, function and pricing, and improve the adaptability of products to the local market. At the same time, through technological innovation and market research, develop industrial robot products with special features to increase product differentiation and reduce direct competition.RCEP member countries cover different levels of development and market environments, and the demand for industrial robots presents diversified characteristics.Through diversified market strategies, we can further expand the market share of China's industrial robotic products in RCEP member countries.

**5.2.2 Strengthening bilateral and multilateral cooperation to achieve complementarity of advantages**

Make full use of the cooperation mechanism under the RCEP framework, and give full play to their respective advantages in technology, labor, and market through technical exchanges and industrial cooperation to achieve complementarity **(Chirathivat, S.,2002)**. Technical cooperation with countries such as South Korea and Malaysia to jointly develop new products and technologies; and cooperation with labor-intensive countries (e.g., Vietnam and Myanmar) to produce low- and medium-end industrial robot products. In short, both sides utilize their respective comparative advantages to develop higher levels of trade cooperation through technological innovation and enhanced product value-added.

**5.2.3 Promoting mutual recognition of standards and certification and reducing trade barriers**

Through a unified standard and certification system, trade barriers can be reduced and product quality and competitiveness can be improved, thus reducing import restrictions on industrial robot products in each member country, reducing non-tariff barriers and further promoting trade liberalization . At the same time, the enterprise side of the production of industrial robots should actively understand and adapt to the standard requirements of member countries to improve product compliance. Encourage enterprises to participate in the development of international standards to improve the recognition of China's industrial robot products in the international market.

**5.2.4 Establishing an information-sharing platform to enhance information exchange**

Big data, cloud computing and other technologies are utilized to establish an industrial robotics product trade information sharing platform between China and RCEP member countries to promote the exchange of information and the discovery of cooperation opportunities among all parties **(Li, Y., Peng, Y., Luo, J., Cheng, Y., & Veglianti, E., 2019)**. The platform can include market dynamics, policies and regulations, and technology dynamics to help enterprises understand the trade environment and business opportunities in each country in a timely manner. The platform strengthens information exchange and cooperation between industrial robotics enterprises of both sides, and promotes resource sharing and business docking.

**5.2.5 Cultivate and introduce specialized talents to enhance competitiveness**

First, the Government and enterprises can jointly organize trade and technology exchange activities for industrial robot products, invite international experts and entrepreneurs to China for exchanges and cooperation, and enhance the level of research and development and innovation of China's industrial robot products through the introduction of international advanced technology and talents. Secondly, we will strengthen the cultivation of talents in the field of industrial robotic products, and cooperate with universities and research institutes to carry out professional courses and training programs. Third, encourage enterprises to cooperate with universities to provide internships and employment opportunities for students and cultivate talents with practical experience in the trade of industrial robot products.

**5.2.6 Strengthening intergovernmental cooperation and policy coordination**

First, strengthen the research on trade policies and laws and regulations of RCEP member countries to understand potential trade risks in advance. Second, establish a sound risk early warning mechanism to detect and respond to potential trade risks and disputes in a timely manner. Third, both sides can provide a better policy environment and facilitation for trade by deepening the FTA and establishing trade facilitation measures.

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