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Comprehensive assessment model and method of international trade market competitiveness based on principal component analysis

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ABSTRACT

This paper takes ten economies as examples to analyze and assess the current situation of their international trade development through RCA, MS and TC indexes. On the basis of Porter's "diamond model" theory, a comprehensive evaluation index system of international trade competitiveness is set up in combination with the actual situation. The entropy value method is used to measure the comprehensive index of international trade competitiveness, and the influence of various influencing factors on international trade competitiveness is empirically studied based on the principal component multiple regression analysis. The results show that the U.S. international trade competitiveness is far ahead, with an average score of 3.67 in 2020-2024, and the lowest score is Singapore, with a score of only -2.17. The degree of explanation of international trade competitiveness of the four factors reaches 98.9%, and all of them have a promotional effect on the international trade competitiveness, in the following order: factors of production>enterprise strategy and competition>related industries>demand factors.

Keywords: international trade competitiveness; index analysis; diamond model; principal component analysis; multiple regression analysis

1. Introduction

International trade, also known as import and export trade, generally refers to the trading activities of goods and services across national borders [1]. International trade plays a vital role in the development of the country, which can not only improve the economic efficiency of enterprises, but also increase the financial income of the country, thus promoting economic development [2-4]. With the deepening of the globalization process, international trade is an irreplaceable trade situation,

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which is highly valued by countries around the world [5-6]. Trade barriers between countries are gradually broken in the international trade system, enterprises from different countries enter a huge international market, and the competition between enterprises becomes increasingly fierce [7]. In this context, enterprises can no longer follow the traditional development model, but begin to optimize and upgrade, strategic transformation and the adoption of advanced management models, so as to enhance the international competitiveness of enterprises and be well prepared to meet the challenges of international trade [8-11].

Although the new crown pneumonia epidemic that began in early 2020 has had a certain impact on international trade, the development of international trade will not be stagnant. Countries around the world still need to follow the trend of the times, take positive countermeasures, and strive to seize the opportunities in the new situation to continuously improve the market competitiveness of their enterprises, and then realize sustainable development [12-15]. Therefore, the research on the evaluation of enterprise market competitiveness in the international trade environment and the construction of professional market competitiveness evaluation indexes and evaluation models have important theoretical and practical significance [16-17].

This paper firstly describes the indicators for measuring the competitiveness of international trade, and takes the trade data of ten countries as the research sample. From the perspective of comparative advantage and competitive advantage, it analyzes the development status of international trade in each country. Based on the “diamond model”, it explores the influence of four dimensional factors on international trade competitiveness. Quantitative measurement of international trade competitiveness is carried out by principal component analysis, and the dynamic evolution trend of international trade competitiveness is explored by kernel density estimation. The international trade competitiveness index is taken as the explanatory variable, and the four dimensional factors are taken as the explanatory variables to carry out multiple regression analysis. The multiple regression results are tested for robustness to verify the effects of the four factors on international trade competitiveness.

2. Study on the development of competitiveness in international trade markets

2.1. Selection of Measurement Indicators

1) International market share (MS index). International market share refers to the proportion of a country's product exports that accounts for the total global product exports, and the product can be either one product or a large product category. The MS index can give a general indication of a country's overall competitiveness, $MS = X_i / W_i$. A larger MS index indicates a higher proportion of a country's product exports and a stronger competitiveness of its trade in services. The MS index can also be used as an indicator of a country's competitiveness. The larger the MS index, the higher the export share of a country's products and the stronger the competitiveness of trade in services. X_i indicates the export value of -country's product i, W_i indicates the export value of the world's product i. The value of MS ranges from 0 to 1, and the larger the value, the stronger the competitiveness.

2) Indicative Comparative Advantage Index (RCA Index). The index of demonstrated comparative advantage, abbreviated as RCA index, $RCA = (X_{ij} / X_i) / (W_j / W)$ indicates a higher level of competitiveness with a larger RCA index. X_{ij} denotes the value of exports of i countries j goods, X_i denotes the total exports of i countries, W_j denotes the total global exports of products j and W denotes the total global exports of all goods. The RCA index reflects the global position of a country's services sector. If the value of RCA is $[1.25, 2.5)$, it indicates that the country's exports j have a relatively high level of competition in the international arena; A range of $[2.5, \infty)$ values for RCA indicates that the country's exports j have a very high level of international competitiveness; If RCA takes a value in the range of $[0.8, 1.25)$, it indicates that the country's exports of j products

have a low level of international competition; A range of RCA values of $[0,0.8]$ indicates that the country's exports of product j have a very low level of international competitiveness. The closer the RCA is to zero, the less competitive it is.

3) Trade Competition Index (TCI). Concept of Trade Competitiveness Index. The Trade Competitiveness Index (TC Index) refers to the ratio of the difference between a country's import and export trade to the total import and export trade volume. It can reflect the strength of a country's product or service competitiveness in the international arena at the level of absolute dominance, having the advantage of eliminating macro-factor constraints such as inflation. $TC=\left(X_{ij}-M_{ij}\right)/\left(X_{ij}+M_{ij}\right)$, the larger the TC index indicates the more obvious its advantage. X_{ij} represents exports of commodity j in country i and M_{ij} represents imports of commodity j in country i. A country's commodity advantage can be visualized by the TC index, which has a range of $[-1,1]$, within which competitiveness increases monotonically. The closer the TC value is to 1, the greater the comparative advantage, indicating that a country's industry or product is more internationally competitive, and vice versa. This index eliminates all macroeconomic disturbances such as inflation. Therefore, the TC index is comparable at different stages.

2.2. Analysis of the current status of international trade development

The statistics in this paper are mainly from the United Nations Conference on Trade and Development database and the World Trade Organization database. RCA was selected for comparative advantage and TC and MS for competitive advantage.

2.2.1. RCA. This study utilizes the trade data of 10 countries to calculate the Relative Overall Demonstrated Comparative Advantage (RODCA) index to assess the competitive position of each country in the global market.The RODCA index and rankings of the 10 countries' trade in 2024 are shown in Figure 1.Ireland has the highest RODCA index of 1.75, which indicates that the country has a significant competitive advantage in the global market. The United Kingdom ranks 2nd with an RCA index of 1.47, indicating its strong competitiveness in the global market. In addition, the U.S. and Japan ranked 4th and 5th with RCA indexes of 1.33 and 1.32 respectively, indicating that these two countries also have a certain degree of competitiveness. China ranks 9th with an RCA index of only 0.93, implying that China's demonstrated competitiveness is relatively weak overall, and France ranks the lowest with an RCA index of 0.91, suggesting that the country is at a disadvantage in terms of trade competitiveness among the 10 countries.

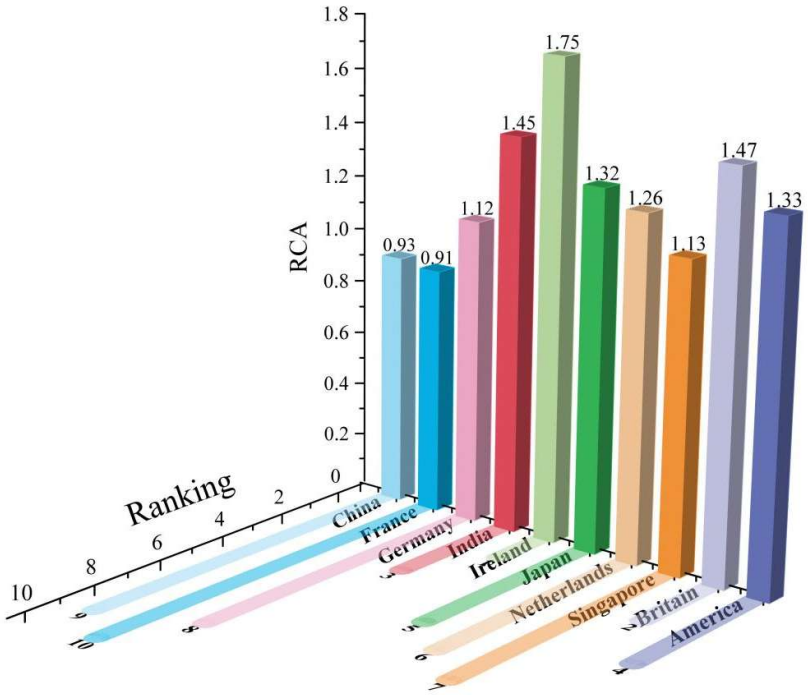

Fig. 1. RCA and ranking of ten countries'trade in 2024

2.2.2. MS. Using the trade data of 10 countries, this study calculates the relative overall international market share index to more intuitively measure the share and competitiveness of each country in the global market. The overall international market share and ranking of the trade of the 10 countries in 2024 are shown in Figure 2. The data show that the competitive pattern of the global trade market presents diversified characteristics, and the competitiveness gap and development potential of countries perform differently. The United States, with a market share of 16.62%, is substantially higher than several other countries, indicating that the United States has a strong competitive advantage in the trade market. The United Kingdom and Ireland, with market shares of 9.66 per cent and 8.24 per cent respectively, show strong competitiveness and have maintained a relatively stable market position in globalized competition.

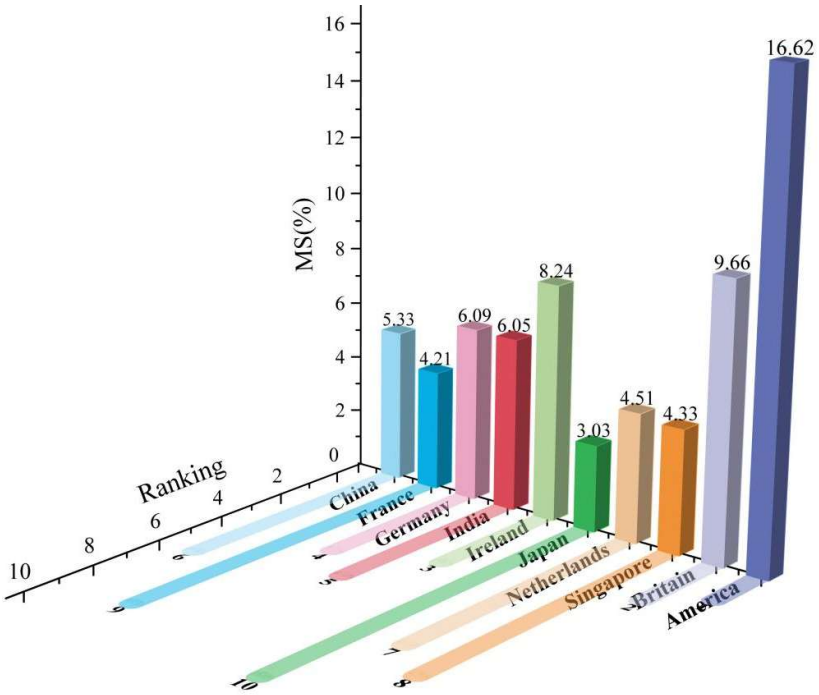

Fig. 2. MS and ranking of ten countries' trade in 2024

2.2.3. TC. This study utilizes the trade data of 10 countries to calculate the relative overall competitive advantage index in order to comprehensively assess the strength of the competitive advantage of each country's trade.The overall competitive advantage index of the trade of the 10 countries in 2020-2024 is shown in Figure 3.The TC indexes of the United States, the United Kingdom, and India ranked high among the 10 countries, with smaller fluctuations in the TC indexes of the United States and the United Kingdom and an overall upward trend in the TC index of India, indicating that the three countries have significant competitive advantages and more stable competitive positions. The TC index of the United States and the United Kingdom is less volatile, and India's TC index shows an overall upward trend, indicating that the three countries have a significant competitive advantage in trade and a stable competitive position. The TC indexes of Germany, France and Singapore are generally in the middle, with weak competitive advantages, while the TC indexes of Japan and Ireland are mostly negative, indicating certain competitive disadvantages.

China's overall trade competitive advantage index, although ranked in the middle of the ten countries, shows a positive trend, growing from 0.04 in 2020 to 0.15 in 2024, and ranking from 7 to 4, indicating that China's trade competitiveness has a large upside and a better growth trend.

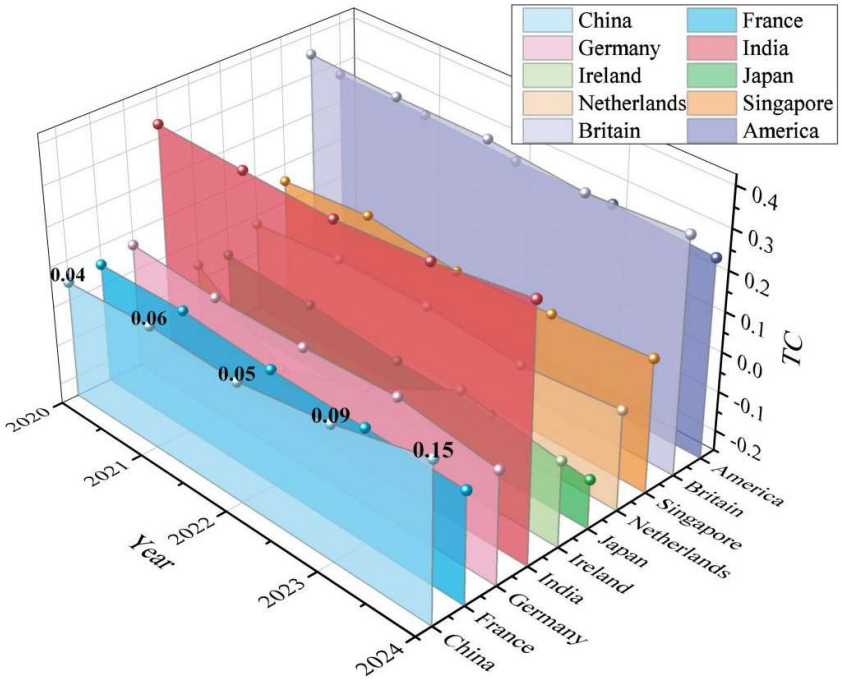

Fig. 3. TC of ten countries' trade,2020-2024

3. Measurement of international trade competitiveness based on principal component analysis

3.1. Construction of a comprehensive evaluation index system

The "diamond model" is often used to assess the competitive advantage of a country or region in a particular industry, and includes factors of production, demand conditions, related industries, corporate strategy and competition, as well as two complementary factors, namely government and opportunity. However, since government and opportunity are difficult to quantify in practice, they are often not taken into account in empirical analysis. A systematic analysis of these key factors can reveal the current status of international trade competitiveness and identify key facilitating and constraining factors. Therefore, this paper constructs a comprehensive evaluation index system for international trade competitiveness, which is set as shown in Table 1, with production factors, demand factors, related industries, enterprise strategies and competition identified as first-level indicators.

Table 1. Comprehensive evaluation index system of trade competitiveness

Target layer	First level indicator	Secondary index	Indicators of measurement
Influencing factors of international trade competitiveness	Factor of production	Level of human capital(X1)	Years of schooling per capita
		Basic measures(X2)	Logistics index
		Stock of capital(X3)	The proportion of fixed asset investment in GDP
	Factor of demand	Domestic Market size(X4)	Total market demand
		Rate of change in consumer demand(X5)	Percentage(%)
	Related industries	Supply chain completeness(X6)	Industrial chain participation
		Level of technological innovation(X7)	Proportion of R&D investment
		Enterprise cluster effect(X8)	Degree of industrial agglomeration
	Corporate strategy and competition	Intensity of enterprise competition(X9)	Degree of market competition
		Ability to innovate(X10)	Ratio of innovation input to output
		Strategic cooperation and alliance(X11)	Density of cooperative network

3.1.1. Factors of production. Factors of production refer to the basic productive resources that a country or region can provide to firms in international trade that support their production and enhance their global competitiveness. The level of human capital, basic measures and capital stock are selected as factors of production in international trade. The level of education directly affects the quality of the labor force, and a high-quality labor force is the basis for improving productivity and technological innovation. The completeness of logistics infrastructure directly affects the circulation efficiency of commodities, and a perfect transportation and logistics network can reduce transportation costs and improve the mobility of production factors. Adequate capital accumulation supports enterprise expansion and technological innovation, and the larger the capital stock, the stronger the enterprise's competitiveness in the international market.

3.1.2. Elements of demand. The demand factor refers to the demand situation in the domestic market, which can affect the innovation ability of enterprises and the competitiveness of products. Domestic market size and the rate of change of consumer demand are chosen as demand factors for international trade. The scale of demand in the domestic market can promote the innovation of products and services of enterprises, especially for emerging markets and high-end products, large-scale market demand can effectively promote enterprises to meet diversified needs and improve the competitiveness of the international market. The rate of change in consumer demand determines an enterprise's ability to respond to market trends, which can prompt enterprises to accelerate innovation and provide more competitive products, and a market with fast-changing demand can help enterprises adapt to the challenges of globalization and market diversification.

3.1.3. Related industries. Related industries include industries that can provide support for the leading industries, and high-quality related industries and supply chains can enhance the international competitiveness of enterprises. Supply chain completeness, technological innovation level and

enterprise cluster effect are selected to measure related industries. A complete industrial chain and supply chain can effectively reduce production costs, and the number and quality of suppliers directly affect the production capacity and innovation ability of enterprises. A high level of R&D investment can promote the emergence of new technologies and products, which in turn can promote the upgrading of the whole industry and enhance international competitiveness. Industrial clusters, on the other hand, can facilitate the flow of knowledge, technology and talent, reduce production costs, improve innovation efficiency and enhance competitiveness in the global market.

3.1.4. Corporate strategy and competition. Corporate strategy and competition refers to how firms develop strategies, build competitive advantages and fight against other competitors in the international market. Enterprise competitive intensity, innovation capacity and strategic cooperation and alliance are selected to reflect enterprise strategy and competition. The intensity of market competition can promote enterprises to improve their technology and product level, and the strong competitive market can motivate enterprises to continuously improve their competitive advantages. The input-output ratio of innovation reflects the efficiency of firms in technological innovation and affects their performance in the global market. Strategic cooperation and alliances between firms can facilitate resource sharing, risk sharing and technology transfer, and the density of inter-firm cooperation networks can help accelerate the entry of firms into international markets and enhance their competitiveness.

3.2. Methodology for calculating competitiveness in international trade

At present, there are many calculation methods for evaluation indexes in academia, and the main difference lies in how to determine the weight size of each index, and the mainstream methods for determining the weight have two kinds of subjective assignment and objective assignment. Subjective assignment method, such as common hierarchical analysis (AHP), expert scoring method, such as expert scoring method, this method has more personal subjective color, and the relevant experts may not necessarily find, subjective scoring method by the above limitations, the use of less in academic research; and for the objective scoring method, there are common mean squared deviation weighting, entropy value method and principal component analysis method. According to the characteristics of the data itself, through the relevant calculation methods, the weights calculated are more scientific. This is also the mainstream of the current academic community about the comprehensive evaluation class calculation method, which is welcomed by the scholars' research. In view of this, this paper adopts the principal component analysis method to calculate the weights of international trade competitiveness indicators and the comprehensive score. The entropy value method and principal component analysis method are introduced below.

3.2.1. Entropy method. Entropy, itself a physical concept in thermodynamics, is a measure of chaos or disorder in a system. Entropy weighting is an objective weighting method, which is more objective and accurate than expert scoring.

The first step is to construct the original data matrix

In this paper, the data from 2020-2024 of ten sample countries, including China, the United States, Germany and Japan, are selected. Eleven indicators are selected, and the original data matrix is formed as follows:

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{110} \\ x_{21} & x_{22} & \cdots & x_{210} \\ \vdots & \vdots & \ddots & \vdots \\ x_{111} & x_{112} & \cdots & x_{1110} \end{pmatrix} \tag{1}$$

A sample of 10 countries with 11 evaluation indicators was selected, with X_{ij} denoting the i rd indicator for the j nd country. where $(i=1,2,3,\ldots,21, j=1,2,3,\ldots,24)$.

The second step, the standardization of raw data

Because the indicators are different in terms of magnitude and order of magnitude, it is necessary to eliminate the influence of different magnitudes, so it is necessary to standardize the data. However, this paper chooses the panel data entropy value method, which is different from the cross-section data and time series data, the panel data has both time span and inter-country span. If we only consider a single factor for data standardization, it will inevitably cause inaccuracy in data processing and form the problem of data bias. Therefore, we need to consider the dual factors of time and country. Therefore, the following method is used for data standardization of panel data entropy method.

We set: R_{nk} to be the normalization matrix for country and indicator attributes. That is, country-indicator normalization;

R_{tk} be the normalization matrix for time and indicator attributes. That is, time-indicator standardization.

The formula for standardization is shown below:

If: x_{ij} is a positive indicator attribute: $X'_{ij}=\dfrac{x_{ij}-Min\{x_{ij}\}}{Max\{x_{ij}\}-Min\{x_{ij}\}}$

x_{ij} is the negative indicator attribute: $X'_{ij}=\dfrac{Max\{x_{ij}\}-x_{ij}}{Max\{x_{ij}\}-Min\{x_{ij}\}}$

Finally, we get the normalized values as:

$$R_{ntk}=\sqrt{R_{nk}\times R_{tk}} \tag{2}$$

In the third step, the characteristic weight or contribution of the i nd indicator of the j st country is calculated. Then:

$$p_{ij}=\frac{R_{ntk}}{\sum_{n=1}^{10}\sum_{t=1}^{5}R_{ntk}} \tag{3}$$

In the fourth step, find the entropy value e_i:

$$e_i=-\frac{1}{\ln nt}\sum_{n=1}^{10}\sum_{t=1}^{5}p_{ij}\ln(p_{ij}) \quad 0\le e_i\le 1 \tag{4}$$

In the fifth step, find the coefficient of variation g_i:

$$g_i=1-e_i \tag{5}$$

Step 6: Find the weights w_i:

$$w_i=\frac{g_i}{\sum_{i=1}^{10}g_i} \quad i=1,2,\cdots,10 \tag{6}$$

Step 7: Calculate the final score:

$$S=\sum_{j=1}^{10}\omega_i\times R_{ntk} \tag{7}$$

3.2.2. Principal Component Analysis. Principal component regression analysis is mainly a multivariate statistical method that uses dimensionality reduction to transform multiple indicators

into several comprehensive indicators using orthogonal rotational transformation while ensuring less loss of information.

Assuming that there are n indicators involved in the study of a given problem, denoted by $X_1, X_2, X_3, \cdots, X_n$ respectively, the n-dimensional random vector consisting of these n indicators is $X = (X_1, X_2, X_3, \cdots, X_n)'$. We assume that the random vector X has mean β and covariance matrix $\sum$.

A new linear transformation of X yields a new composite variable Y, viz:

$$\begin{cases} Y_1 = \beta_{11}X_1 + \beta_{12}X_2 + \cdots + \beta_{1n}X_n \\ Y_2 = \beta_{21}X_1 + \beta_{22}X_2 + \cdots + \beta_{2n}X_n \\ \vdots \\ Y_n = \beta_{n1}X_1 + \beta_{n2}X_2 + \cdots + \beta_{nn}X_n \end{cases} \tag{8}$$

wherein, (1) $\beta_{i1}^2 + \beta_{i2}^2 + \beta_{i3}^2 + \cdots + \beta_{in}^2 = 1 (i = 1, 2, 3, \cdots, n)$, (2) Y_i and Y_j are not related to $(i \neq j, i, j = 1, 2, 3, \cdots, n)$; (3) Y_1 is the largest variance of all linear combinations of $X_1, X_2, \cdots, X_n$ that satisfy principle (1); Y_2 is the largest variance of all linear combinations of $X_1, X_2, \cdots, X_n$ that are uncorrelated with Y_1; and so on; Y_n is the largest variance of all linear combinations of $X_1, X_2, \cdots, X_n$ that are uncorrelated with $Y_1, Y_2, \cdots, Y_{n-1}$.

The composite variable $Y_1, Y_2, \cdots, Y_n$ obtained based on the above three principles is called the first principal component, the second principal component, and the n principal component of the original variable, respectively.

The principal component analysis method has the following main steps:

The first step is the standardization of data;

Assuming that there are n indicator variables for principal component analysis: $X_1, X_2, X_3, \cdots, X_n$, a total of m evaluation objects, and that the value of the j th indicator for the i th evaluation object is x_{ij}, and that each indicator x_{ij} is transformed into a standardized indicator $\tilde{x}_{ij}$.

$$\tilde{x}_{ij} = \frac{x_{ij} - \overline{x}_j}{s_j}, \left(i = 1, 2, \cdots, m; j = 1, 2, \cdots, n\right) \tag{9}$$

Where, $\overline{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}$, $s_j = \frac{1}{n-1}\sum_{i=1}^{n}(x_{ij} - \overline{x}_j)^2$, $\left(j = 1, 2, \cdots, n\right)$, i.e. $\overline{x}_j$, s_j are the sample mean and sample standard deviation of the j th indicator. Correspondingly, $\tilde{x}_{ij} = \frac{x_{ij} - \overline{x}_j}{s_j}$ is the standardized indicator variable.

In the second step, a matrix of correlation coefficients between the variables is established R;

Correlation coefficient matrix $R = (r_{ij})_{n \times n}$

$$r_{ij} = \frac{\sum_{t=1}^{n} \tilde{x}_{ti} \times \tilde{x}_{tj}}{n-1} \left(i, j = 1, 2, \cdots, n\right) \tag{10}$$

Where, $r_{ii} = 1$, $r_{ij} = r_{ji}$, r_{ij} are the correlation coefficients of the i th and j th indicators.

In the third step, the eigenvalues and eigenvectors of the correlation coefficient matrix R are calculated;

Calculate the eigenvalues $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_n \geq 0$ of the matrix of correlation coefficients R, which are the corresponding eigenvectors $\beta_1, \beta_2, \cdots, \beta_n$, where $\beta_j = \left(\beta_{1j}, \beta_{2j}, \cdots, \beta_{nj}\right)'$, from the eigenvectors are composed n new indicator variables:

$$\begin{cases} Y_1 = \beta_{11}X_1 + \beta_{12}X_2 + \cdots + \beta_{1n}X_n \\ Y_2 = \beta_{21}X_1 + \beta_{22}X_2 + \cdots + \beta_{2n}X_n \\ \vdots \\ Y_n = \beta_{n1}X_1 + \beta_{n2}X_2 + \cdots + \beta_{nn}X_n \end{cases} \tag{11}$$

In the above equation, Y_1, Y_2, Y_n is referred to as the first principal component, second principal component, and n principal component of the original variable, respectively.

In the fourth step, the principal components are written and the composite score is calculated;

1) Calculate the eigenvalue $\beta_j (j = 1, \cdots, n)$ information contribution rate and cumulative contribution rate;

Call $b_j = \dfrac{\beta_j}{\sum_{k=1}^{n} \beta_k} (j = 1, \cdots, n)$ the information contribution rate of principal component Y_j; $\eta_p = \dfrac{\sum_{k=1}^{p} \beta_k}{\sum_{k=1}^{n} \beta_k}$ the cumulative contribution rate of principal component $Y_1, Y_2, \cdots, Y_n$.

2) Calculate the composite score;

Composite score $Z = \sum_{j=1}^{p} b_j \times Y_j$, where b_j is the information contribution rate of the j th principal component.

Summarizing the comparison of the process of the two calculation methods we can find that the advantage of the principal component analysis method is that it can transform multiple correlated variables into a few irrelevant principal components by way of dimensionality reduction, which is easy to analyze and understand the data. Through principal component analysis, the correlation in the original data can be extracted to obtain more information, remove redundant information and simplify the data structure. Principal component analysis can model the distribution of data and can discover the inherent structure and patterns of data. In view of this, this paper adopts the principal component analysis method to comprehensively evaluate the international trade competitiveness of 10 countries, including China.

For a country to improve its international trade competitiveness, it is necessary to understand what factors constrain the improvement of trade competitiveness. In order to clarify this issue, it is necessary to conduct relevant quantitative research. In view of this, this paper pre-adopts principal component analysis and combines multiple linear regression model for regression analysis to quantitatively study which factors have a greater impact on the improvement of international trade competitiveness.

3.3. Comprehensive results analysis

3.3.1. Common factor variance. The common factor variance refers to the sum of the squares of the loadings of the original variables on all the common factors, which indicates the degree to which the principal components can be extracted to explain the information of each variable, and the common factor variance of the indicator variables is shown in Table 2. The common degree of the selected indicator variables is higher than 0.8 except X5 and X9 (the common degree of the indicator variables

of X5 and X9 is also higher than 0.6), which indicates that the extracted principal components have reflected more than 80% of the information of the original variables, and the resulting principal components concentrate more information of the original variables, which is suitable for principal component analysis.

Table 2. Common factor variance

Common factor variance		
	At the beginning	Extraction of
X1	1.000	.857
X2	1.000	.912
X3	1.000	.864
X4	1.000	.855
X5	1.000	.727
X6	1.000	.923
X7	1.000	.958
X8	1.000	.863
X9	1.000	.716
X10	1.000	.898
X11	1.000	.912

3.3.2. Extraction factors. Using SPSS software to carry out dimensional factor analysis, the eigenvalues and the percentage of variance are obtained as shown in Table 3, meanwhile, in accordance with the principle that the eigenvalue is greater than 1, four male factors are extracted, and the cumulative variance contribution rate reaches 86.038%, so the extraction of the four principal components can cover the previous indicators and provide a better explanation of the competitiveness of international trade, and the variance of the first principal component accounts for 45.913% of the whole variance, the weight is the highest; The second principal component is second to the first principal component in terms of its combined ability to explain the original variables, accounting for 18.963% of the weight of all variance, while the third and fourth principal components account for 11.921% and 9.241% of the weight of all variance, respectively.

Table 3. Total variance interpretation

Ingredient	Total	Percent variance of initial eigenvalue	Accumulate to %	Total	Extract the load square sum of variance percentage	Accumulate to %
1	5.053	45.913	45.913	5.053	45.913	45.913
2	2.087	18.963	64.876	2.087	18.963	64.876
3	1.312	11.921	76.797	1.312	11.921	76.797
4	1.017	9.241	86.038	1.017	9.241	86.038
5	0.623	5.661	91.699			
6	0.417	3.789	95.488			
7	0.263	2.390	97.878			
8	0.147	1.336	99.214			
9	0.071	0.645	99.859			
10	0.011	0.096	99.955			
11	0.005	0.045	100			

3.3.3. Component matrix. The principal components are calculated linearly on the basis of individual indicators, and the component score coefficient matrix is utilized to derive the principal component scores of each group, and the component matrix is shown in Table 4. The first principal component mainly reflects the information of 5 indicators, respectively X1, X3, X4, X7, X10, covering 45.913% of the information of all the indicators; the second principal component mainly reflects the information of 2 indicators, respectively X2, X6, covering 18.963% of the information of all the indicators; the third principal component mainly X8, X11, a total of 2 indicators, covering 11.921% of the information of all the indicators; the fourth principal component mainly reflects X5, X11, a total of 2 indicators, covering 11.921% of the information of all the indicators; the fourth principal component mainly reflects X5, X6, a total of 2 indicators, covering 11.921%; the fourth principal component mainly reflects the information of 2 indicators, X5 and X9, covering 9.241% of all indicator information.

Table 4. Component matrix

	1	2	3	4
X1	.849	.386	-.287	.563
X2	.284	.908	.585	-.397
X3	.718	-.344	-.297	.186
X4	.747	.185	-.228	-.301
X5	-.483	-.294	.287	.732
X6	-.269	.867	.338	.286
X7	.746	.228	.197	.135
X8	.339	-.286	.736	.097
X9	.182	.197	.281	.693
X10	.837	-.305	.376	-.264
X11	.183	.240	.803	.165

3.3.4. Factor scores. Through the eigenvalues of the three principal components extracted, the eigenvector of each principal component, i.e., the weight of each corresponding factor, is calculated, after which the standardized raw data are substituted into the principal component expression to calculate the principal component score of each sample. The result after weighted average of the contribution of each principal component is the weight, from which the comprehensive score is obtained. Comprehensive score and ranking of the international trade competitiveness of countries as

shown in Table 5, in the comprehensive score of the level of international trade competitiveness of countries, there are many countries with negative scores, which is the result of the standardization of the data, but does not mean that its competitiveness is negative, and the positive and negative here only indicates the position of the country's international trade competitiveness in relation to the average level.

In terms of the magnitude of change in ranking, Germany, the United Kingdom and the United States have relatively stable rankings without major fluctuations, while the rest of the countries rank up and down significantly. Among them, the United States has basically ranked first in the last five years (except for 2021), Singapore has always ranked last, and China's ranking has fluctuated in a small range between 5-7 places, with the overall ranking showing an upward trend.

From the point of view of the score, the gap between countries' international trade competitiveness scores is still relatively large, the United States' international trade competitiveness is far ahead, with an average score of 3.67 in 2020-2024, which is 0.57 points higher than that of second-place Germany. 2024, Germany, Japan, and the United Kingdom's international trade competitiveness composite score are in the second to the fourth place, and the difference between the scores of the three countries is not large, and all of them are more than two points; China, France, and the UK ranked second to fourth. China, France and the Netherlands all have positive scores and rank fifth to seventh respectively; the remaining countries have negative international trade competitiveness scores, the lowest being Singapore with a score of only -2.17, with the latter ranking in the order of India, Ireland and Singapore.

Table 5. Overall scores and rankings

Country	2020		2021		2022		2023		2024	
	Score	Ranking	Score	Ranking	Score	Ranking	Score	Ranking	Score	Ranking
China	0.81	7	1.31	5	1.33	6	1.52	6	1.98	5
France	0.35	8	2.55	4	3.06	2	1.98	5	1.72	6
Germany	2.98	2	3.53	1	2.93	3	3.01	2	3.03	2
India	-1.92	9	0.98	6	0.73	7	0.12	8	-0.88	8
Ireland	1.23	6	-0.33	8	-1.77	9	-1.33	9	-1.49	9
Japan	2.16	4	0.21	7	1.47	5	2.11	4	2.75	3
Netherlands	1.78	5	-1.35	9	-0.92	8	0.83	7	1.12	7
Singapore	-2.37	10	-2.44	10	-2.19	10	-2.22	10	-2.17	10
Britain	2.58	3	2.83	3	2.55	4	2.63	3	2.61	4
America	3.57	1	3.51	2	3.66	1	3.83	1	3.77	1

3.4. Kernel density estimation

Kernel density estimation is a nonparametric estimation method, the core idea is to use the kernel density curve to capture the distribution characteristics of the data, portraying the dynamic distribution of the random variable, with strong stability, correlation, etc., and can effectively circumvent the subjectivity of the function setting, thus enhancing the credibility of the model, this paper chooses the Gaussian kernel function which is currently more widely used, and analyzes it with the help of Matlab software. Assuming that the density function of random variable X is f (x), the probability density formula of X is as follows:

$$f(x)=\frac{1}{NK}\sum_{i=1}^{n}H(\frac{X_i-x}{k}) \tag{12}$$

Kernel density is:

$$H(x)=\frac{1}{\sqrt{2\pi}}\exp(-\frac{x^2}{2}) \tag{13}$$

Where k denotes the bandwidth, N denotes the number of observed countries, in this paper N=10; X denotes the independent and identically distributed observations, which in this paper refers to the comprehensive score of international trade competitiveness of each country.

This paper takes the comprehensive score of international trade competitiveness of ten countries in 2020-2024 as the object of investigation, and analyzes the non-equilibrium and dynamic evolution trend of the level of international trade competitiveness of each country according to its kernel density distribution curve.

The kernel density estimation of the overall evolution trend of international trade competitiveness of the ten countries is shown in Figure 4, from the distribution location, the center of the density function has no obvious shift, indicating that the level of international trade competitiveness of each country presents a relatively stable development trend in space; from the change of the wave peaks, the highest value of the wave peaks is decreasing and then increasing in the distribution curve, at the same time, the width of the wave peaks is also becoming narrower, which indicates that each country's The polarization and unbalanced phenomenon of the development of the level of international trade competitiveness has been gradually improved.

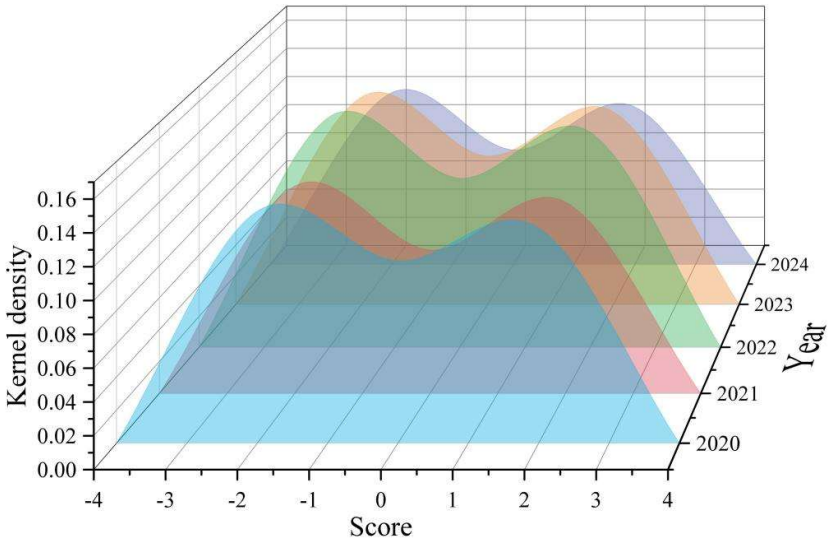

Fig. 4. Evolution trend of international trade competitiveness

4. Analysis of factors affecting competitiveness in international trade based on multiple linear regression

4.1. Study design

4.1.1. Research hypotheses. Based on the theory of Porter's "diamond" model, Porter believed that factors of production were categorized into senior and junior factors, with senior factors being those that could be acquired through long-term investment, and that senior factors of production were one of the sources of competitiveness of a country's industries. In terms of demand factors, if a country's economy is larger and better developed, the demand for trade will increase. Porter believes that

whether a country has strong competitiveness is related to its related and supporting industries, and the agglomeration effect between upstream and downstream enterprises is an important source of a country's competitive advantage, especially when local enterprises form a complete and perfect industrial chain. Due to the differences in the environment between economies, the organizational structure and management mode of enterprises in different countries are not the same, and enterprises can only gain a lasting competitive advantage if they find a suitable management development strategy. External factors may adversely affect the development of China's digital services trade due to the existence of international environmental changes such as anti-globalization, cross-border regulation, and trade barriers. Combined with the above analysis, the following hypotheses are proposed.

Research hypothesis: production factors, demand factors, related industries, corporate strategies and competitive factors can all promote international trade competitiveness.

4.1.2. Model setup. In this paper, the comprehensive index of international trade competitiveness of ten countries in 2020-2024 and its four indicators of comprehensive factors are regressed and analyzed, which is set as the following empirical model:

$$IC_t = C + \beta_1 F_{1t} + \beta_2 F_{2t} + \beta_3 F_{3t} + \beta_4 F_{4t} + \varepsilon_t \tag{14}$$

Where IC_t denotes the composite index of international trade competitiveness, $F_{1t} - F_{4t}$ denotes each of the four composite factor indicators, t denotes the year, C denotes the constant term, $\beta_1 - \beta_4$ denotes the coefficients of each explanatory variable, and ε_t denotes the disturbance term.

4.2. Analysis of regression results

On the basis of the above empirical model, the independent variables in the constructed model are represented by F1-F4 indexes as influencing factors, and the dependent variable is represented by IC indexes as the comprehensive international trade competitiveness level, and regression analysis is carried out.

The regression results are shown in Table 6, R^2 is 0.989, indicating that the degree of explanation of the selected independent variables F1, F2, F3 and F4 in this paper on the composite index of international trade competitiveness (IC) of the dependent variable reaches 98.9%, and the model fitting effect is good. Each independent variable has a strong explanatory ability to the dependent variable and meets the expectation.

Table 6. Regression results

Variable	IC
F1	2.347***
	(4.14)
F2	0.386***
	(4.92)
F3	1.137***
	(5.48)
F4	1.264***
	(3.05)
C	0.694***
	(50.35)
R2	0.989

First, the correlation coefficient of factors of production (F1) is 2.347 and significant at 1% confidence level, and an increase of 1% in factors of production increases the index of international trade competitiveness by 2.347%, indicating that factors of production such as the level of human capital of the country and basic measures play an important role in improving international trade competitiveness.

Secondly, the demand condition (F2) is positively correlated with international trade competitiveness at the 1% confidence level, with a coefficient of 0.386, i.e., every unit of increase in the demand factor can correspondingly increase the index of international trade competitiveness by 0.386 units, which indicates that the expansion of the scale of the domestic and foreign markets will help to improve the status of the country's trade in the global market. At the same time, it also confirms that under the new development pattern of “double cycle”, the improvement of domestic residents' consumption level will greatly promote the development of national trade.

Thirdly, the correlation coefficient between related industries (F3) and international trade competitiveness is significantly positive at the 1% confidence level, with a correlation coefficient of 1.137, indicating that every 1% increase in the production of related industries will drive the international trade competitiveness index up by 1.137%, which means that international trade competitiveness is interdependent with related industries.

Fourth, enterprise strategy and competition (F4) also significantly affects international trade competitiveness at the 1% confidence level, with a coefficient of 1.264, indicating that for every 1 unit of enterprise business strategy and market competition factors, the international trade competitiveness index will increase by 1.264 units, indicating that if enterprises can formulate targeted internationalization strategies and divide the company's market structure, they will greatly improve the company's operational efficiency and thus form a competitive advantage.

Based on the above analysis, the estimated coefficients of each dependent variable are more significant, and all four factors will have a promoting effect on international trade competitiveness, in the following order: factors of production (F1) > corporate strategy and competition (F4) > related industries (F3) > demand factors (F2). At this point, the research hypothesis is verified.

4.3. Robustness Tests

In order to further verify the above conclusions, this section conducts a robustness test on the regression results obtained in the previous paper, applying the method of re-measuring the international trade competitiveness indicators by assigning the average weights to the IMS index, TC index, and RCA index, and conducts a regression of the replaced explanatory variables, and the regression results are shown in Table 7, with a R^2 of 0.984, and the test results of the individual variables are basically similar to those in the previous paper, even though there is a slight difference

of the variables in the values are slightly different, but they are basically consistent with the results of the previous paper in terms of sign direction and significance, so the test results confirm the reliability and robustness of the results of this paper.

Table 7. Robustness test

Variable	IC
F1	1.048***
	(4.36)
F2	0.123***
	(4.69)
F3	0.327***
	(3.64)
F4	0.428***
	(6.24)
C	0.257***
	(59.39)
R2	0.984

5. Conclusion

This paper takes ten countries as the research object, evaluates and analyzes the international trade competitiveness of each country through principal component analysis and kernel density estimation, and empirically investigates the influencing factors of international trade competitiveness through multiple regression analysis.

The results of principal component analysis show that the United States has basically ranked in the first place in the past five years (except for 2021), Singapore has always ranked in the last place, and China's ranking fluctuates in a small range between 5-7 places, with the overall ranking showing an upward trend. The U.S. is a distant second, with an average score of 3.67 in 2020-2024, 0.57 points higher than second-place Germany. 2024, Germany, Japan, and the U.K. rank second to fourth in terms of international trade competitiveness in the aggregate, while China, France, and the Netherlands all score positively, and the rest score negatively, with the lowest score being that of Singapore, at -2.17 points. The lowest score is Singapore with only -2.17 points.

The multiple regression results show that R^2 is 0.989, indicating that the selected independent variables F1, F2, F3 and F4 explain 98.9% of the dependent variable. 4 factors will have a promotional effect on the international trade competitiveness, in the following order: factors of production (F1) > corporate strategy and competition (F4) > related industries (F3) > demand factors (F2).

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