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Malta's cooperative interaction patterns and influencing factors in the global economic system: a study based on principal component analysis

Cuicui Cui[1,*]
[1] School of Wenshi, Weifang University, Weifang, Shandong, 261000, China
Corresponding authors: (e-mail: hhxxttxsteacher@163.com).

Abstract This paper focuses on Malta's cooperation and interaction mode in the global economic system, and analyzes its economic characteristics and structural optimization path. Taking Malta as the research object, the index system of influencing factors is constructed, including three dimensions of regional trade development, border economic development and regional economic development. The observation period is 2020-2024, and principal component analysis is used to explore the core factors driving Malta's economic development. Pearson correlation coefficient was used to measure the linear correlation between the factor indicators, and the validity was analyzed relying on the KMO test and Bartlett's sphericity test.F1, F2, and F3 mainly explained 90.274% of the total variance, and the total amount of exports X2, total inbound tourism revenue X5, and gross regional product X6 had the greatest impact on the principal components F1, F2, and F3, with the coefficients of 0.957, 0.942, respectively, 0.896.Based on this, this paper proposes a differentiated cooperation strategy with a view to providing a theoretical basis and practical reference for Malta's integration into global value chains.

Index Terms Malta, Principal Component Analysis, Pearson Correlation, Economic Influence Factors, Cooperation Strategy

I. Introduction

At present, the world is in a period of great development, great change and great adjustment. Changes in the global economic landscape are reflected in the redistribution of economic power, the shift in trade patterns and the geographical reorganization of economic growth centers [1]. With the rise of emerging market countries and developing economies, the center of gravity of the global economy is gradually shifting from traditional developed countries to these countries [2], [3]. Changes in the economic situation have resulted in the multipolarization of global economic forces, prompting new challenges to international economic cooperation. Among them, in terms of trade patterns, the rise of the digital economy has driven the growth of trade in services, and the explosive growth of digital trade in services is reshaping the global trade structure and international supply chains [4]-[7].

The application of digital technology reduces the cost of cross-border transactions, enables small and medium-sized countries to participate in the global market more easily, and promotes the democratization of trade [8]-[10]. For this reason, some small and medium-sized countries are not only occupying a more important position in the global economy, but are also contributing to changes in the global economic governance structure [11], [12]. Malta is located in the center of the Mediterranean Sea, with a long history and splendid culture, known as “the heart of the Mediterranean” and “the back garden of Europe”. In the face of the complicated global economic situation, countries around the world should actively participate in the formulation and implementation of economic rules, accelerate the change of the global economic governance system, and promote the construction of a new type of international economic relations of mutual benefit and win-win cooperation [13]-[15].

This paper firstly elaborates the research background and constructs the index system of economic influence factors covering three dimensions. The application logic of principal component analysis is detailed, and the data processing process is specifically sorted out. Descriptive statistics are performed on the indicators of Malta to reveal its overall structural characteristics. Pearson's correlation coefficient test is carried out on the relevant indicators, and the validity of the data is judged with the help of KMO test and Bartlett's spherical test. Based on the results of principal component analysis, the driving mechanism of Malta's economic cooperation is revealed. Aiming at the principal component variables after dimensionality reduction, differentiated cooperation development strategies are proposed.

II. Construction of a system of indicators of factors affecting the Maltese economy

Against the backdrop of deepening globalization and accelerating regional economic integration, how small and medium-sized economies can achieve sustainable development through international cooperation has become an important topic of research in international economics. As a Mediterranean hub country, Malta has developed an outward-oriented economic model dominated by the service industry by virtue of its strategic location and institutional advantages. However, the reorganization of global supply chains and the rise of trade protectionism in recent years have challenged its economic resilience. In this context, it is of practical significance to analyze the influencing factors of Malta's economic cooperation and its interaction mechanism to optimize its global cooperation strategy.

This paper determines the observation period as 2020-2024, follows the principles of scientificity, systematicity, operability and orientation, and highlights the explanatory power of the indicators on the development of cooperation. Based on the international trade theory and economic growth theory, the indicators are selected from the three dimensions of regional trade development level, border economic development level and regional economic development level, and the constructed indicator system of Malta's economic influence factors is shown in Table 1. The dimension of regional trade development level contains three secondary indicators: total imports, total exports, and actual utilization of foreign capital; the dimension of regional border trade development level contains two secondary indicators: border microtrade and total income from inbound tourism; and the dimension of regional economic development level contains three secondary indicators: gross domestic product, disposable income of urban residents, and value added of the tertiary industry; each secondary indicator is numbered as X1~X8 respectively.

The data of the indicators used in this paper for the calculation of principal component analysis are compiled and calculated by the United Nations Trade Database, the National Statistics Office of Malta and so on.

Table 1: Indicator System of Economic Influencing Factors in Malta

First-level indicator	Secondary indicators	Indicator meaning
The level of regional trade development	Total import volume(X1)	The scale of foreign trade and the degree of dependence on the international market
	Total export volume(X2)	The competitiveness of products and services in the international market
	The actual amount of foreign capital utilized(X3)	The degree of participation of international capital in Malta's economic development
The development level of regional border trade	Border small-scale trade(X4)	The activity level of cross-border trade
	Total revenue of inbound tourism(X5)	Border economic vitality
The level of regional economic development	Regional gross domestic product(X6)	Macroeconomic volume and growth potential
	Disposable income of urban residents(X7)	The sustainable supporting capacity of economic cooperation
	Added value of the tertiary industry(X8)	Participate in the industrial upgrading direction of the global value chain

III. Principal Component Analysis

III. A. General

Principal Component Analysis (PCA) is a mathematical transformation method, which is based on the principle of linearly transforming the variables and arranging the new variables in order of decreasing variance, where the total variance of the variables remains unchanged. The first variable is called the first principal component because it has the largest variance; the variable with the second largest variance is the second variable, which is called the second principal component; and so on, N variables means that there are N principal components. Where Ln is a p-dimensional orthogonalized vector ($Ln \times Ln = 1$), and Zn are uncorrelated with each other and ranked in descending order of variance, then Zn is the Nth principal component of X. Let the covariance matrix of X be Σ, then Σ must be a semipositive definite symmetric matrix; find the eigenvalues λn (sorted in ascending order) and their eigenvectors, and it can be proved that the orthogonalized eigenvectors corresponding to λn are

the coefficient vectors Ln corresponding to the N th principal component Zn; Zn 's variance contribution ratio is defined as $\frac{\lambda n}{\sum \lambda m}$, and k of the principal components satisfies $\frac{\sum \lambda k}{\sum \lambda m} > 0.85$.

III. B. Analytical process

The advantage of principal component analysis is that it explains most of the variables by fewer variables, uses comprehensive indicators to explain the information, transforms many variables with high correlation into variables with zero correlation or independent of each other, and reduces the dimensionality to arrive at the analysis results. The analysis process is as follows.

(1) Assumption of sample matrix

Let the sample data year, indicator data are n and m, the original sample matrix is shown in equation (1).

$$X = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \vdots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} = (X_{pq})m \times n \tag{1}$$

In equation (1), $p = (1,2,...,m)$ is the p th row of the original sample matrix, $q = (1,2,...,n)$ is the q th row of the original sample matrix.

(2) Coefficient matrix calculation

$R = (r_{pq})m \times n$, r_{pq} is calculated in equation (2).

$$r_{pq} = \frac{1}{n} \sum_{p=1}^{m} \frac{(x_{pq} - x_p)(x_{pq} - x_q)}{\delta} \tag{2}$$

In equation (2), δ is the sample variance.

(3) R eigenvalue and eigenvector calculation

The expression of the characteristic equation is $R - \lambda I| = 0$, R, I are the correlation coefficient matrix and the unit matrix, respectively, and the descending order of the λ values yields ($\lambda_1, \lambda_2, ..., \lambda_n$), and the eigenvectors are computed.

(4) Contribution rate and cumulative contribution rate calculation

The contribution rate calculation formula is shown in equation (3).

$$e_i = \frac{\lambda_i}{\sum_{p=1}^{m} \lambda_i} \tag{3}$$

The formula for calculating the cumulative contribution rate is shown in equation (4).

$$E_m = \frac{\sum_{i=1}^{m} \lambda_i}{\sum_{p=1}^{m} \lambda_i} \tag{4}$$

(5) Principal component calculation

The principal component calculation formula is shown in equation (5).

$$Z_i = a_{iq} x_q \tag{5}$$

(6) Comprehensive analysis

After obtaining the calculation results of the cumulative contribution rate, the number of principal components (all factors greater than 80%) is determined; and then, based on the obtained indicators, the research indicator system is constructed.

IV. Analysis of factors affecting the Maltese economy based on Principal Component Analysis (PCA)

IV. A. Descriptive statistics

First of all, descriptive statistics were conducted on the sample data, and the results of descriptive statistics are shown in Table 2. Malta's average import and export volume during the period 2020-2024 reaches 873.5 and 635.1 million euros, respectively, and the average amount of actual utilization of foreign capital is 192.3 million euros, with significant characteristics of the externally oriented economy, but the structural balance to be optimized. The average border micro-trade and inbound tourism gross revenues were 0.632 and 183.8 million euros respectively,

with Malta's service trade dominating and the cross-border linkage effect appearing. The average GDP and tertiary industry added value were 1,622.7 and 1,037.5 million euros respectively, and the average disposable income of urban residents reached 24,972 euros per person, which is a synergy between structural upgrading and income growth.

Table 2: Descriptive Statistical Results

	Average value	Standard deviation	Number of cases
X1(Billion euros)	8.735	0.731	5
X2(Billion euros)	6.351	0.453	5
X3(Billion euros)	1.923	0.386	5
X4(Billion euros)	0.632	0.037	5
X5(Billion euros)	1.838	0.376	5
X6(Billion euros)	16.227	0.835	5
X7(Euro/person)	24972	1286	5
X8(Billion euros)	10.375	0.894	5

IV. B. Pearson correlation analysis

Next, correlation analysis is performed. Pearson's correlation coefficient is used to measure the linear correlation between two variables and takes values ranging from -1 to 1. Pearson's correlation coefficient between two variables is the quotient of the covariance and standard deviation of the two variables, which is calculated by the formula:

$$r_{xy} = \frac{\sum_{i=1}^{n}(X_i - \overline{X_i})(Y_i - \overline{Y_i})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X_i})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \overline{Y_i})^2}} \tag{6}$$

In this paper, the Pearson correlation coefficient test was conducted on the relevant indicators using SPSS27.0.1 software, and the test results are shown in Table 3. Where "*" indicates P<0.05 and "**" indicates P<0.01. The absolute values of correlation coefficients of the eight indicators are all higher than 0.500, P<0.05, indicating that there is a strong linear relationship, which is suitable for principal component extraction.

Table 3: Pearson's relevant test results

Explanatory variable	Influencing factor	Correlation coefficient
X1	Total import volume	0.863**
X2	Total export volume	0.902**
X3	The actual amount of foreign capital utilized	0.837*
X4	Border small-scale trade	0.864**
X5	Total revenue of inbound tourism	0.911*
X6	Regional gross domestic product	0.878**
X7	Disposable income of urban residents	0.829**
X8	Added value of the tertiary industry	0.864*

IV. C. Validity analysis

Before performing principal component analysis, KMO test and Bartlett's Spherical test need to be performed on the raw data to explore whether it is suitable for principal component analysis. Generally the KMO test result is greater than 0.5 and the P-value of Bartlett's spherical test is less than 0.05, which is suitable for principal component analysis. The results of the KMO value and Bartlett's spherical test are shown in Table 4. The KMO value is 0.708, which indicates that the data is suitable for principal component analysis. The P-value of the Bartlett's spherical test is less than 0.001, which is also in the acceptable range, and therefore the factor analysis can be perform factor analysis.

Table 4: KMO values and Bartlett sphericity test results

Project		Numerical value
KMO sampling appropriateness quantity		0.708
Bartlett sphericity test	Approximate chi-square	427.475
	Degree of freedom	82
	Significance	P<0.001

IV. D. Principal component analysis

Using SPSS27.0 software according to the steps of “analysis - dimensionality reduction - factor analysis” to get the results of principal component analysis, principal components of the variance interpretation results shown in Table 5. As shown in Table 5, the first three principal components mainly explain 90.274% of the total variance, indicating that the extraction of the first three principal components can represent eight indicators on economic impact factors. Therefore, the first 3 principal components were extracted in this study as F1, F2 and F3.

Table 5: Explanation of Principal Component Variance

Component	Initial eigenvalue			Extract the sum of the load squares		
	Total	Var.%	Cum.%	Total	Var.%	Cum.%
1	3.375	42.187	42.187	3.375	42.187	42.187
2	2.083	26.037	68.224	2.083	26.037	68.224
3	1.764	22.050	90.274	1.764	22.050	90.274
4	0.436	5.450	95.724			
5	0.205	2.562	98.286			
6	0.088	1.100	99.386			
7	0.047	0.587	99.973			
8	0.002	0.027	100.000			

The first 3 principal components were extracted to get the score coefficient matrix as shown in Table 6. Total exports X2, total inbound tourism revenue X5, and gross regional product X6 have the greatest influence on principal components F1, F2, and F3, with coefficients of 0.957, 0.942, and 0.896, respectively.

Table 6: Score Coefficient Matrix

Variable	Component		
	F1	F2	F3
X1	0.896	0.109	-0.028
X2	0.957	0.038	0.106
X3	0.853	0.115	-0.057
X4	0.108	0.895	0.101
X5	0.084	0.942	-0.038
X6	0.097	0.026	0.896
X7	0.112	-0.037	0.793
X8	-0.083	0.184	0.837

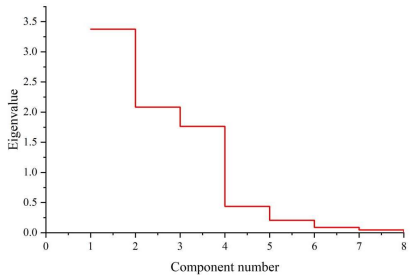

Figure 1: Visualization results of principal component eigenvalues

The results of the visualization of the principal component eigenvalues are shown in Figure 1. The degree of variation of principal components 1, 2 and 3 is the largest, representing the more information contained. Therefore, this paper chooses total exports X2, total inbound tourism revenue X5, and gross regional product X6 as the principal component variables after dimensionality reduction for subsequent targeted policy analysis.

V. Malta's cooperative development strategy in the global economic system

Principal component analysis shows that total exports (X2), gross inbound tourism receipts (X5) and gross regional product (X6) constitute the core drivers of Malta's economic development. However, Malta is currently facing problems such as a single export structure, high vulnerability of the tourism industry, and insufficient value added in the industry. For this reason, this paper proposes a tiered and progressive cooperation strategy from the three core indicators, aiming to optimize resource allocation, enhance participation in global value chains, and promote sustainable economic growth.

(1) Constructing an export system for high value-added products

First carry out industrial upgrading and technological empowerment. Develop digital trade infrastructure, build a cross-border e-commerce platform based on Malta's Digital Innovation Center, integrate local SMEs' product resources, and provide multi-language customer service and cross-border logistics one-stop services. At the same time, we will enhance market diversification and regional synergy. Promote agricultural product processing trade in response to the needs of emerging economies in Africa. Join the EU Industry 5.0 program and focus on intelligent manufacturing.

(2) Build a resilient service trade ecosystem

With the help of VR technology, develop a tourism digital platform for immersive experience of Valletta's historical sites, the Blue Hole and other attractions, and incorporate virtual ticket revenues into tourism statistics. Utilize the advantages of Mediterranean climate and English language services to attract high net worth people from the Middle East, and develop medical and recreational tourism products. Build a comprehensive port for the cruise economy and add a duty-free shopping mall and convention center. Implement a tourism service scoring system to rate the service quality of hotels and restaurants to attract ESG-oriented tourists. Cooperate with Italy and Tunisia to develop joint tickets for the three regions and build a triangular tourism zone, where tourists can visit the sites of the three major civilizations in the Mediterranean with a single ticket, boosting total inbound tourism revenue while strengthening regional cooperation.

(3) Optimize the mode of participation in global value chains

Establish the Mediterranean Digital Talent Alliance and promote mutual recognition of skilled immigrants. Relying on the advantages of Malta's international business center, develop high-end service industries such as cross-border financial arbitration and intellectual property transactions. Require technology transfer when attracting foreign investment, with the goal of driving the technological upgrading of local new energy enterprises. Utilizing Malta's zero-tariff advantage, attract multinational enterprises to set up regional headquarters in Malta and coordinate production bases in North Africa.

(4) Guarantee mechanism for strategy implementation

Real-time tracking of core indicators such as export competitiveness, tourism resilience, and industrial efficiency, and issuing quarterly policy adjustment recommendations. Incorporate the opinions of enterprises and labor unions through the citizens' jury system to ensure that the strategy is in line with public opinion.

By focusing on export structure upgrading, tourism resilience enhancement and industrial synergy and innovation, Malta can break through the bottleneck of export-oriented economy and occupy a more favorable position in the global value chain.

VI. Conclusion

This paper systematically deconstructs the core drivers of Malta's economic cooperation through principal component analysis.

Malta's average exports and imports reach €873.5, €635.1 million and the average actual utilization of foreign capital is €192.3 million during the period 2020-2024, respectively. Average border micro-trade and gross inbound tourism receipts amount to €063.2, €183.8 million respectively. The average GDP and value added of the tertiary industry were 1,622.7 and 1,037.5 million euros respectively, and the average disposable income of urban residents reached 24,972 euros per person.

The absolute values of the correlation coefficients of the eight indicators are higher than 0.500, $P<0.05$, the KMO value is 0.708, and the P value of the Bartlett's spherical test is less than 0.001, which is within the acceptable range.

F1, F2 and F3 mainly explain 90.274% of the total variance, and total export X2, total inbound tourism revenue X5 and gross regional product X6 have the greatest influence on the principal components F1, F2 and F3, with the

coefficients of 0.957, 0.942, and 0.896, respectively. For the three dimensions of X2, X5, and X6, the analysis of the targeting policy is proposed.

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