

Economic Evaluation of Belt and Road based on Bayesian risk perspective

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Abstract. The Belt and Road strategy covers a wide range of international cooperation and infrastructure construction, and it is of great significance to conduct economic evaluation. Based on the macroeconomic data and related indices of the countries along the Belt and Road from 2005 to 2023, this research evaluates the economic performance through general factor analysis and assesses the risk using Bayesian time-varying iterative model. It is found that the industrial production capacity and service level of the countries along the Belt and Road are in the middle and lower reaches, agricultural import and export capacity needs to be improved, and the risk coefficient shows a trend of increasing and then flattening, the risk uncertainty of the Maritime Silk Road index is the smallest, the risk uncertainty of the trade volume indices is higher, and the export uncertainty is higher than that of the import uncertainty. Finally, this research puts forward policy recommendations based on the empirical result.

Keywords: The Belt and Road; Economic and risk evaluation; General factor analysis method; Bayesian time-varying iterative modeling.

1. Introduction

The Belt and Road Initiative, proposed by China in 2013, aims to promote connectivity between Asia, Europe and Africa by strengthening cooperation among countries along the route in such areas as infrastructure construction, trade and investment and financial cooperation. The initiative covers two major parts, the Silk Road Economic Belt and the 21st Century Maritime Silk Road, and involves more than 140 countries, with the goal of promoting global economic development, especially for developing countries[1, 2].

In recent years, as the uncertainty of the global economic situation has increased, many scholars have conducted in-depth economic evaluations of the Belt and Road Initiative. Economic risk has become a key factor in the evaluation. Some scholars have assessed the economic risk through debt level and investment openness, but these studies lack empirical data to prove the correlation between these variables and the economic risk of the Belt and Road [3], and only use the entropy value method when setting the weight value, which lacks the consideration of the background of the Belt and Road. In addition, some scholars have tried to categorize risks, including social stability risks, economic risks, political risks and other major categories, but they have not been transformed into a comprehensive risk index based on these categorizations, and they lack the consideration of comprehensive risks in the macro context of the Belt and Road [4, 5]. This study makes innovations on the basis of previous work by using factor analysis and Bayesian time-varying iterative modeling to assess economy and risk independently, respectively, and adopts general factor analysis to obtain the common factor and the factor scores and rankings so as to provide a comprehensive evaluation of economic performance, and for the risk part, this study pioneers the Belt and Road Index as the independent variable, and utilizes the Bayesian time-varying iterative modeling to establish a comprehensive risk assessment system, and the use of the Bayesian method can make the comprehensive risk assessment more precise, so as to deeply dissect the comprehensive economic risk of the Belt and Road strategy.

2. Research design

2.1. Economic evaluation

For economic evaluation, this research used general factor analysis. Four primary indicators and eight secondary indicators were selected, as shown in Table 1 below. Factor analysis can simplify complex variables into a number of independent public factors that cannot be measured directly but can represent the core information of the eight variables, and determine the weight of each public factor based on the variance contribution rate [6]. Global factor analysis adds a time series dimension to factor analysis and is able to analyze panel data [7]. The Belt and Road has a long history, and using multi-year data for analysis can help improve the accuracy of the research.

The data samples are macroeconomic indicators of major countries along the Belt and Road (including Asia, Africa, Europe and Oceania, totaling 71 countries). Macroeconomic indicators include gross domestic product (GDP), total imports and exports with China, China's net real utilization of foreign direct investment (FDI), value added of industry as a share of GDP, value added of agriculture as a share of GDP, value added of services as a share of GDP, per capita Gross National Income (GNI) in current prices, share of urban population, sample covers 2005-2023.

Table 1. Belt and Road Economic Performance Evaluation Indicator System

Target level	Primary indicators	Secondary indicators	Notation
Belt and Road Economic Performance Evaluation	the three main industries	Industrial value added as a share of GDP	N1
		Agricultural value added as a share of GDP	N2
		Value added of services as a share of GDP	N3
	Production and income	Gross domestic product (GDP)	N4
		GNI per capita in current prices	N5
	Import and export investment	Total imports and exports with China	N6
		Actual utilization of net foreign direct investment in China	N7
	urbanization	Share of urban population	N8

2.2. Risk assessment

For risk assessment, this research uses bayesian time-varying iterative risk model with the following equation (1):

$$Y_t = \rho_t W_t Y_t + \theta_t X_t + \varepsilon_t \quad (1)$$

Y_t and X_t are the dependent and independent variables at time t , respectively. $\theta_t = [\beta_t, a_t]$. $X_t = [1, X_t]^T$; ε_{it} is the mean of 0 and the variance of σ_t^2 of the Gaussian error term; W_t is an $N \times N$ weight matrix that can represent the cross-sectional structural information we use ρ_t to characterize the risk factor, and the parameter ρ_t can be interpreted as a composite risk factor with a particular form of volatility that captures systematic risk [8].

The dependent variable is the annual gross domestic product (GDP) of the sample countries, covering the period 2014–2023, and the independent variable is the Belt and Road trade volume index (BRTVI). The Belt and Road Containerized Sea Freight Volume Index (BRCSV). The Belt and Road Import Trade Index (IMTI). The Belt and Road Export Trade Index (ETI). The first two indices cover the period from 2017 to 2023 and the last two from 2014 to 2023.

3. Empirical analysis

3.1. KMO and Bartlett Spherical Test Results

The KMO test and the Bartlett's spherical test were used to determine if factor analysis could be performed. These two tests were performed on the sample data, resulting in the following Table 2:

Table 2. Test chart

Testing Indicators	Sample
Kaiser-Meyer-Olkin	0.6475
Bartlett's test of sphericity	4532
significant value	0.000

The test in this research yielded a KMO value of $0.6475 > 0.6$ with a significant value of 0. This indicates that the eight selected indicators are correlated and it is valid to conduct factor analysis.

3.2. Table of cumulative values of variance

Through the general factor analysis, the variance cumulative values were obtained in Table 3 below:

Table 3. Cumulative values of variance

Unit	Initial eigenvalue			Extract sum of squares loading			Rotate sum of squares loading		
	Total %	Variance %	Cumulative %	Total %	Variance %	Cumulative %	Total %	Variance %	Cumulative %
1	2.95	36.89	36.89	2.95	36.89	36.89	2.52	31.50	31.50
2	1.66	20.81	57.70	1.66	20.81	57.70	1.63	20.39	51.89
3	1.51	18.82	76.52	1.51	18.82	76.52	1.55	19.37	71.26
4	0.79	9.92	86.44	0.79	9.92	86.44	1.21	15.18	86.44
5	0.45	5.61	92.05						
6	0.28	3.49	95.54						
7	0.25	3.14	98.68						
8	0.11	1.32	100.0						

The number of explanatory factors was selected based on whether the cumulative total explanatory variance reached 80% [9], and for the selected sample, under the column of initial eigenvalues, the cumulative total explanatory variance of the four factors reached 86.44%, and thus the first four factors were selected for the rotated component matrix analysis.

3.3. Matrix of rotated components

By rotating the component matrices, the distribution of the eight indicators of sample on different main factors is analyzed, as shown in Table 4 below:

Table 4. Rotated Component Matrix

Index	Belt and Road Sample Country Public Factors			
	F1	F2	F3	F4
Industrial value added as a share of GDP	0.134	-0.040	0.943	0.004
Agricultural value added as a share of GDP	0.264	0.934	0.064	-0.030
Service value added as a share of GDP	-0.896	0.007	0.104	0.059
Gross domestic product (GDP)	0.443	-0.854	-0.065	0.066
Per capita Gross National Income	0.709	-0.114	0.063	0.022
Total imports and exports with China	0.068	0.831	0.177	0.031
Net direct investment from China	0.152	0.508	0.011	0.053
Proportion of urban population	0.884	-0.066	0.096	0.102

The results show that the first principal factor is highly correlated with the per capita Gross National Income and the proportion of urban population, which is named the urbanization national income factor (F_1); the second principal factor is highly correlated with the agricultural value added as a share of GDP and the total amount of China's imports and exports, which is named the agricultural imports and exports factor (F_2); the third principal factor is more correlated with the industrial value added as a share of GDP and the total amount of China's imports and exports, which is named the import and export industrial production factor (F_3); the fourth main factor is more related to the proportion of urban population, GDP and service value added as a share of GDP, named as production of urbanization services (F_4).

3.4. Ranking of factor scores

The average scores and rankings of the factors are shown in Table 5. The average values of the selected sample countries from 2005 to 2023 can reflect the economic development results of the countries during the “Belt and Road” period [10]. The variance contribution rate weight is defined as the variance contribution rate as a percentage of the total cumulative variance contribution rate, and the formula for the calculation of the composite score is obtained as (2):

$$FA = 0.1432 \times F_1 + 0.2240 \times F_2 + 0.2971 \times F_3 + 0.3356 \times F_4 \quad (2)$$

Table 5. Factor scores and ranking of sample countries

Nations	F1	Rank	F2	Rank	F3	Rank	F4	Rank	FA	Rank
Ukraine	0.04	44	0.24	43	0.13	25	0.27	51	0.19	40
Uzbekistan	1.28	62	0.36	19	0.45	50	0.30	9	0.14	34
Uganda	1.60	67	0.01	31	0.42	48	0.18	12	0.30	57
Yemen	0.85	56	1.15	7	0.38	36	0.06	26	0.00	22
Armenia	0.23	45	0.04	32	0.52	62	0.02	23	0.20	44
Iraq	0.35	27	1.73	4	0.03	20	0.30	54	0.34	11
Iran	0.12	36	0.67	16	0.55	12	0.35	59	0.21	16
Russia	0.12	38	0.09	34	3.61	3	1.05	70	0.72	4
Bulgaria	0.37	26	0.44	52	0.38	35	0.36	60	0.28	54
Croatia	0.23	31	0.69	55	0.40	42	0.26	49	0.33	61
Gabon	0.62	17	1.95	3	0.60	66	0.08	27	0.32	13
Hungary	0.43	24	0.32	47	0.18	26	0.31	57	0.17	36
South Africa	0.25	29	0.70	57	0.68	9	0.43	66	0.06	29
Qatar	2.16	2	1.40	6	0.69	68	0.13	15	0.46	10
Luxembourg	2.26	1	1.95	71	0.99	71	0.45	4	0.26	50
Indonesia	0.65	53	0.99	11	1.82	4	0.32	58	0.56	6
Syria	1.02	59	0.04	33	0.39	39	0.15	14	0.22	48
Kyrgyzstan	1.00	58	0.20	37	0.39	40	0.08	16	0.28	55
Kazakhstan	0.12	37	0.19	27	0.04	19	0.27	50	0.02	24
Turkey	0.18	33	0.22	40	1.19	6	0.74	69	0.08	19
Tanzania	1.51	66	0.20	26	0.41	45	0.29	10	0.19	42
Egypt	0.54	52	0.28	23	0.16	16	0.31	56	0.07	30
Cyprus	0.83	11	1.60	69	0.56	64	0.24	47	0.49	70
Seychelles	0.24	30	1.33	66	0.52	61	0.15	35	0.47	69
Austria	1.03	10	0.70	56	0.08	18	0.21	43	0.06	28
Bangladesh	0.95	57	0.20	38	0.13	17	0.21	41	0.21	47
Nigeria	1.06	60	0.22	41	0.39	13	0.13	33	0.13	33
Nepal	1.82	71	0.79	62	0.42	47	0.29	11	0.47	68
Palestine	0.13	35	0.72	59	0.49	58	0.20	38	0.36	64
Pakistan	1.35	64	0.62	54	0.17	15	0.03	24	0.29	56
Bahrain	1.22	7	0.69	15	0.62	67	0.21	40	0.08	20
Greece	0.77	13	1.36	67	0.06	22	0.42	64	0.36	63
Italy	0.68	16	1.18	65	3.79	2	1.35	71	0.51	8
Latvia	0.49	22	0.94	63	0.49	57	0.23	45	0.36	65
Czech	0.72	15	0.03	30	0.06	21	0.36	62	0.03	27
Morocco	0.29	47	0.20	36	0.27	29	0.13	32	0.21	45
Brunei	1.17	8	2.42	1	0.72	69	0.02	19	0.50	9
Slovakia	0.39	25	0.21	39	0.30	31	0.30	55	0.18	39
Slovenia	0.48	23	0.29	45	0.47	56	0.23	46	0.21	46
Sri Lanka	0.78	55	0.30	46	0.25	28	0.21	39	0.32	59
Singapore	1.43	5	0.71	58	0.79	70	6.08	1	1.85	2
New Zealand	1.07	9	0.78	61	0.33	33	0.05	18	0.10	31
Cambodia	1.77	70	0.37	18	0.42	46	0.31	7	0.19	41
Saudi Arabia	0.80	12	1.63	5	1.24	5	0.30	53	0.75	3
Poland	0.28	28	0.24	42	0.68	10	0.59	68	0.01	23
Thailand	0.44	50	0.25	24	1.09	7	0.02	20	0.32	12
Zimbabwe	0.70	54	0.32	48	0.39	38	0.12	31	0.33	60

Estonia	0.59	19	0.53	53	0.53	63	0.22	44	0.27	52
Belarus	0.22	32	0.61	17	0.44	49	0.20	37	0.03	26
Kuwait	1.74	3	1.07	9	0.47	55	0.10	29	0.32	14
Lithuania	0.51	21	0.42	49	0.46	51	0.28	52	0.25	49
Jordan	0.62	18	0.44	51	0.41	44	0.40	63	0.26	51
Namibia	0.28	46	0.25	44	0.46	52	0.11	30	0.27	53
Myanmar	1.72	69	0.35	20	0.31	32	0.37	6	0.14	35
Romania	0.05	39	0.08	29	0.07	23	0.36	61	0.12	32
Laos	1.18	61	0.34	21	0.46	54	0.17	13	0.17	38
Kenya	1.29	63	0.77	60	0.28	30	0.05	17	0.42	67
Sudan	1.67	68	0.28	22	0.40	43	0.37	5	0.17	37
Philippines	0.53	51	0.17	35	0.57	11	0.06	25	0.04	21
Portugal	0.58	20	1.05	64	0.07	24	0.43	65	0.32	58
Mongolia	0.32	48	0.75	13	0.49	60	0.01	22	0.02	25
Zambia	0.37	49	0.14	28	0.36	34	0.21	42	0.20	43
Azerbaijan	0.02	43	2.16	2	0.46	53	0.19	36	0.28	15
Algeria	0.02	42	1.03	10	0.18	27	0.14	34	0.12	17
Oman	0.02	41	0.93	12	0.39	37	0.01	21	0.10	18
UAE	1.50	4	1.13	8	0.36	14	0.10	28	0.54	7
South Korea	0.13	34	0.25	25	3.97	1	4.08	2	2.62	1
Malaysia	0.02	40	0.74	14	1.06	8	0.50	3	0.65	5
Malta	1.23	6	1.42	68	0.59	65	0.25	48	0.40	66
Madagascar	1.44	65	0.42	50	0.49	59	0.30	8	0.34	62
Lebanon	0.77	14	1.61	70	0.39	41	0.47	67	0.53	71

The first public factor F_1 , which represents the urbanization national income factor, has 40 countries with scores greater than 0, the bottom three being Nepal, Cambodia, and Myanmar. The second factor F_2 represents the factor of agricultural exports and imports, with 30 countries having a score greater than 0. The top three countries are Brunei, Azerbaijan, and Gabon. The third factor F_3 is the factor for import and export industrial production, with 20 countries having a score greater than 0. The fourth factor F_4 is the production of urbanization services, with 22 countries having a score greater than 0. The top three countries are Singapore, South Korea, and Malaysia. The fifth factor, FA is a weighted factor for the level of integrated development, with 22 countries scoring greater than 0. The top three countries are Korea, Singapore and Saudi Arabia, followed by Lebanon, Cyprus and Seychelles.

3.5. Risk factor time series chart

Based on the results of the model iterations, this research produces a time series plot of risk based on six different indices, as shown in Figure 1-4 below, where gray indicates 5%-95% confidence intervals and blue-purple indicates 16%-84% confidence intervals.

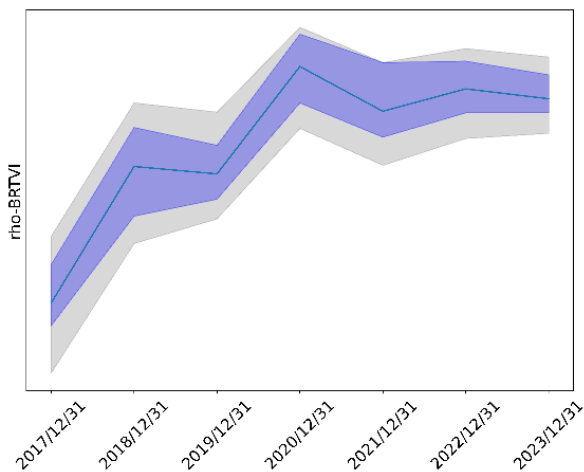


Figure 1. BRTVI

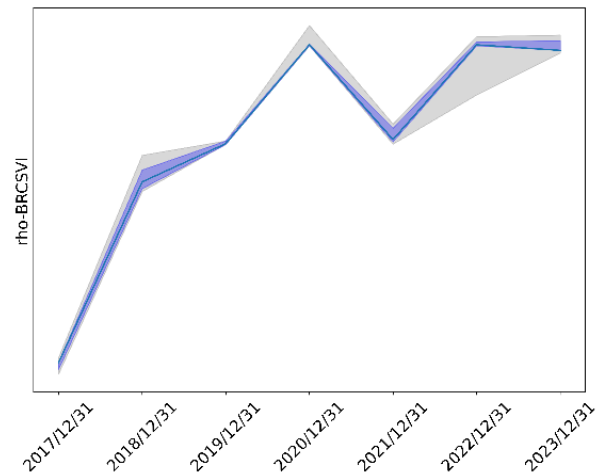


Figure 2. BRCSVI

Figure 1 shows the changes in the risk coefficient of the Belt and Road Trade Volume Index between 2017 and 2023, showing an upward trend, peaking in 2020 and then declining slightly. The wider confidence interval indicates that the risk coefficient is more uncertain and more influenced by external factors. Figure 2 shows the change in the risk factor of the Belt and Road Containerized Shipping Volume Index, which rises significantly from 2017 to 2023, especially between 2021 and 2022. Narrow confidence intervals indicate low risk uncertainty, which may be related to less volatility in the global supply chain and more fixed ocean freight costs.

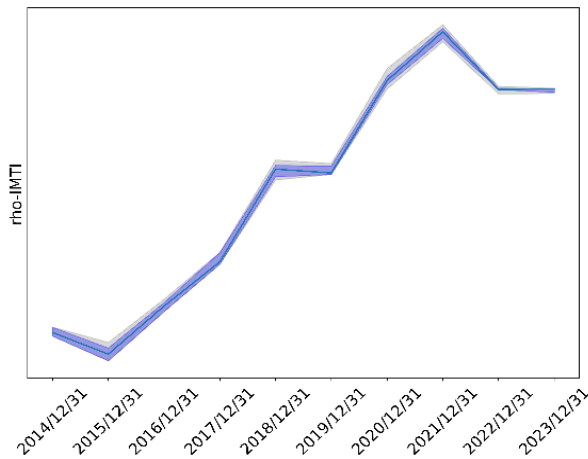


Figure 3. IMTI

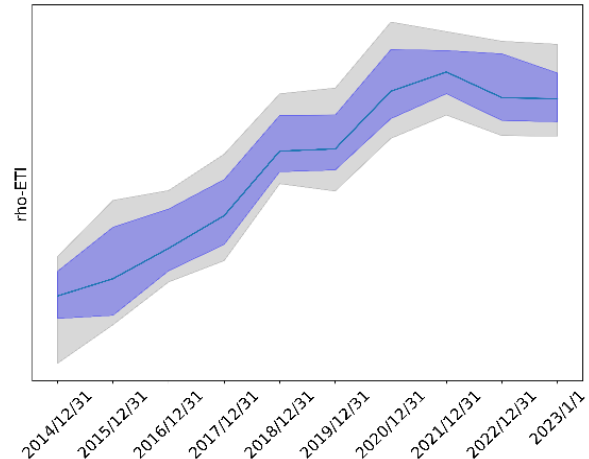


Figure 4. ETI

Figure 3 shows that the risk coefficient of the Import Trade Index (IMTI) has risen steadily since 2014, peaking in 2021, with a narrower confidence interval, suggesting that import trade risk uncertainty is less volatile and less affected by global supply chain pressures and import policy adjustments, and Figure 4 shows that the risk coefficient of the Export Trade Index (ETI) of the Belt and Road countries continues to rise, especially after 2019, and peaks in 2021, with wide confidence intervals reflecting higher uncertainty about the risk of epidemics to exports.

4. Policy recommendations

This research proposes two policy recommendations based on the empirical results for the factor rankings and risk factor time series chart:

1. Optimizing agricultural import and export trade through technological upgrading and international cooperation: Based on factor rankings and overall scores, it is recommended that support for agricultural export capacity be strengthened, especially for these underperforming countries [11], to elevate the position of their agricultural economies in the Belt and Road Initiative and to promote agricultural cooperation and trade growth through technology transfer, agricultural training and market access support.
2. Establishing a trade monitoring and logistics optimization system to cope with the risk of international trade and logistics fluctuations: Based on the results of the risk index analysis in the chart, it is recommended to strengthen the construction of international logistics and trade networks in countries along the Belt and Road Initiative, especially in countries where trade volume and transportation costs fluctuate greatly, and to take measures to reduce market uncertainty. Cooperation with these countries should be strengthened to optimize maritime and land transport networks, improve trade efficiency, reduce trade risks, and promote stable growth in trade volume and economy.

5. Conclusion

Based on the economic evaluation and risk assessment, the research reached the following conclusions: the import and export industrial production capacity and urbanization service industry of the countries along the Belt and Road are at the middle and lower levels, while the import and

export of agricultural products and urbanization are at the normal level. From 2017 to 2023, the risk of the Belt and Road index first rose and then flattened, the uncertainty of the maritime index is small, the risk uncertainty of trade volume is large, and the uncertainty of export risk is higher than that of imports.

The feasibility of this study lies in providing recommendations that can be implemented by countries along the Belt and Road Initiative, such as the issuance of policies to optimize the logistics chain to cope with the risk of uncertainty, and the promotion of bilateral agricultural import and export trade through diplomacy and the signing of trade agreements. Future research could focus on the comparative economic performance of different regions and the long-term impact of the Belt and Road Initiative on the global economic landscape. This will help to further improve the implementation path of the Belt and Road strategy and promote its sustainable development in international economic cooperation.

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