The Impact of the Belt and Road Initiative on Changes in Trade Volume in Countries Along the Route: A Study Based on the Mann-Kendall Test and STL Decomposition

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Abstract. Since its proposal in 2013, the Belt and Road Initiative has become an important strategic framework for promoting global economic cooperation and development. With the in-depth implementation of the initiative, trade activities in countries along the route have increased significantly, promoting the coordinated development of the global economy. This study, based on the Belt and Road trade volume index, uses the Mann-Kendall trend test and STL decomposition methods to explore the impact of the initiative on changes in trade volume in countries along the route. Using the Mann-Kendall test, this study confirms that the Belt and Road Initiative has significantly increased trade volume, demonstrating its role in promoting trade. Further STL decomposition analysis reveals the seasonal fluctuations, long-term trends and random fluctuations in trade volume, and the data is further decomposed using the STL method with minimum weighted sorting entropy optimization. The results show that the Belt and Road Initiative has had a positive impact on promoting trade and economic growth, despite the varying economic growth performance of the countries along the route. In addition, this study also explores the heterogeneous performance of different countries in the context of the global political and economic environment, providing insights into future policy adjustments and international cooperation.

Keywords: Belt and Road Initiative; trade volume; Mann-Kendall test; STL decomposition; minimum weighted sorting entropy

1 Introduction

Since President Xi Jinping proposed the Belt and Road Initiative in 2013, it has become an important strategic platform for promoting global economic cooperation and development. The core concept of the initiative is to achieve mutual benefit, win-win results and common development by strengthening infrastructure construction, promoting trade cooperation and cultural exchanges among countries. The Belt and Road not only covers the traditional “Silk Road Economic Belt”, but also extends to the maritime trade route, the “21st Century Maritime Silk Road”. This strategy not only helps China's economic cooperation with countries along the route, but also provides new impetus for

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the coordinated development of the global economy [1]. With the advancement of globalization, international trade has become increasingly complex and volatile. In particular, cooperation in various fields such as agriculture, energy, and manufacturing has become an important topic in global economic research.

How to promote the common development of relevant countries through effective economic policies and cooperation measures has become an important topic in global economic research. Driven by the Belt and Road Initiative, economic and trade activities in countries along the route have increased significantly. However, with the development of economic globalization, the imbalance and volatility of trade volume has also become a problem that cannot be ignored. Changes in trade volume not only reflect the trend of the global economy, but also the depth and breadth of economic cooperation between different countries [2]. Against this background, this study aims to explore the specific contribution of the Belt and Road Initiative to the trade volume and economic growth of countries along the route through data analysis and trend testing. Through the analysis of the Belt and Road trade volume index and the Mann-Kendall trend test, this study further reveals the initiative's contribution to the economic development of countries along the route and its future development prospects.

In addition, this study also uses advanced time series analysis techniques, such as the STL decomposition method of minimum weighted rank entropy, to thoroughly explore the seasonality, trend and residual fluctuations of the Belt and Road trade data [3]. By processing the data with missing values and analyzing the trend, this study provides strong quantitative support for a more comprehensive understanding of the economic effects of the Belt and Road Initiative on a global scale. Through quantitative analysis, this paper reveals the role of the Belt and Road Initiative in economic growth in different regions (such as Asia, Africa, and Europe), and also examines the impact of changes in the political and economic environment on the initiative [4].

In short, this study aims to reveal the important role of the Belt and Road Initiative in promoting global trade and economic growth in countries along the route through a comprehensive analysis of economic data and trade trends under the initiative, providing a reference for policymakers and promoting deeper international cooperation.

2 Data Pre-Processing

The Belt and Road Initiative covers two major parts: the Silk Road Economic Belt and the 21st-Century Maritime Silk Road. The trade volume index is presented in the Belt and Road Trade Data, so this paper uses the Belt and Road Trade Index for analysis [5]. During data preprocessing, we found that there are missing values in the Belt and Road Trade Index of the dataset, as shown in Figure 1 below:

Fig. 1. Visualization of missing value imputation for the Belt and Road trade volume index

As can be seen from the figure above, since the Belt and Road Initiative was proposed, the trade volume index of China and countries along the route has generally shown an upward trend, reflecting the initiative's role in promoting world trade development. Among them, the growth in trade volume from 2020 to 2022 was the largest. The trade volume index for the period 2019-2020 was the only time in recent years that it fell below 100. Combining this with the current situation, it is inferred that this change is closely related to events such as the outbreak of the new crown epidemic and the intensification of Sino-US trade frictions, reflecting the fact that changes in the international situation have a greater impact on the initiative.

3 Mann-Kendall Trend Test

In order to further study the trend of trade volume between China and countries along the Belt and Road, the Mann-Kendall test will be used to determine whether the trend of the time series data is significant. The Mann-Kendall trend test is a non-parametric statistical test method that determines whether a trend exists by judging the relative sizes of the data points in the time series [6]. Its advantage is that it does not assume that the data obeys any specific distribution, so it is suitable for various data sets and is not disturbed by a few outliers.

3.1 Test Steps

Step 1 Formulate a hypothesis

$$H_0: No\ monotonic\ trend \tag{1}$$

$$H_1: Monotonic\ trend \tag{2}$$

Among them, H_0 is the null hypothesis, and this paper will conduct this test at a confidence level of 95%. If the p-value is less than 0.05, the null hypothesis is rejected, indicating that there is a trend in trade volume under the "Belt and Road" initiative.

Step 2 Calculate the S statistic

Define the statistic S as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i) \tag{3}$$

Where x_i, x_j are the corresponding observations in the time series to be tested, and sgn is the sign function, which is defined as follows:

$$sgn\ (x) = \begin{cases} 1 & if x > 0 \\ 0 & if x = 0 \\ -1 & if x < 0 \end{cases} \tag{4}$$

Step 3 Calculate the expected value and variance of the statistic S

For large sample sizes (n > 10), the expected value and variance of S can be approximately calculated as:

$$E(S) = 0 \tag{5}$$

$$Var(S) = \frac{n(n-1)(2n+5)}{18} - \sum_{t=1}^{q} \frac{m_t(m_t-1)(2m_t+5)}{18} \tag{6}$$

Among them, q is the number of groups with repeated values in the data, and m_t is the number of repeated values in the tth group.

Step 4 Calculate the standardized statistic Z

The calculation formula of Z value is as follows

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if S > 0 \\ 0 & if S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if S < 0 \end{cases} \tag{7}$$

(5) Calculate the P value and perform the test at a given confidence level

3.2 Test Results

Table 1. Mann-Kendall trend test results

Statistics	P value
9.5106	0.000

As can be seen from the above table 1, at a confidence level of 95%, the p-value is less than 0.05, rejecting the null hypothesis, which means that the time series data of the "Belt and Road Trade Volume Index" does show an increasing trend. This indicates that the Belt and Road Initiative does have a promoting effect on the increase in trade volume between China and countries along the route.

4 STL Decomposition Based on Minimum Weighted Sorting Entropy

Since Mann-Kendall is insensitive to periodicity in time series, in order to more comprehensively analyze the trend of trade volume, the following text uses STL decomposition based on minimum weighted sorting entropy (MWSE-STL) to conduct an in-depth study of the time series [7].

Sorting entropy is an indicator used to measure the complexity of a time series. The more regular the series, the smaller the corresponding sorting entropy, and vice versa. period is the main hyperparameter in STL decomposition and is closely related to the decomposition effect. Therefore, MWSE-STL can maintain the advantages of the STL decomposition method while making the decomposition effect even better by introducing the minimum weighted sorting entropy as the optimization target for period estimation.

In the process of using MWSE-STL decomposition, since the trend component ranking entropy is very small, the decomposition focuses on making the seasonal component and residual component more regular and conducive to analysis [8]. Therefore, the weights of the ranking entropies of the three components are set to 0.0, 0.6 and 0.4, respectively.

Let the trade volume index be, and decompose it using the STL method:

$$Y_t = T_t + S_t + R_t \tag{8}$$

Where T_t, S_t, R_t represent the trend component, seasonal component and residual component respectively.

The hyperparameter period can be obtained by minimizing the weighted sort entropy:

$$\min_{S_t^{(s)}} H_w\left(S_t^{(s)}\right) = -\sum_{i=1}^{m} w_i^{(s)} p_i^{(s)} \log p_i^{(s)} \tag{9}$$

Among them, $H_w\left(S_t^{(s)}\right)$ is the weighted sort entropy, $w_i^{(s)}$ is the weight of the i-th data point in the s-th iteration, and $p_i^{(s)}$ is the relative frequency of the i-th data point after sorting.

The final decomposition result is shown in Figure 2 below:

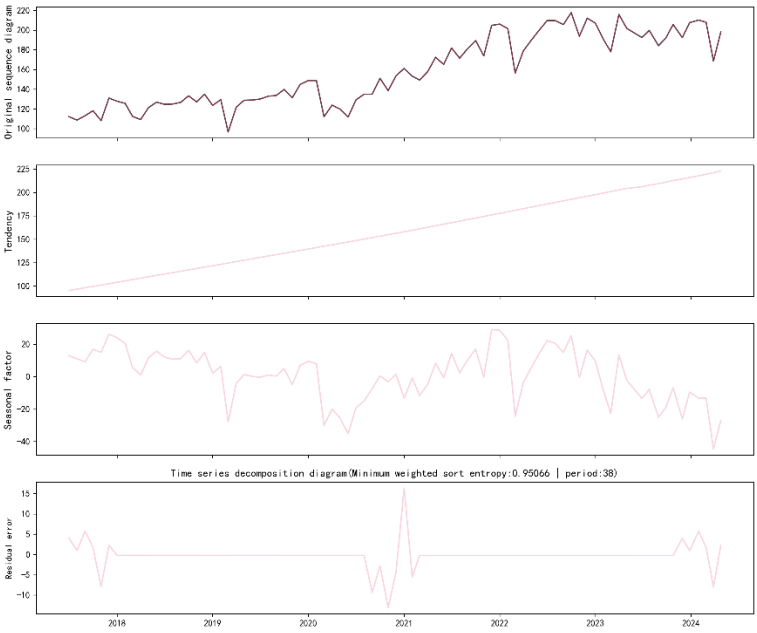

Fig. 2. MWSE-STL decomposition diagram

The trend component shows the long-term trend of the index. Since 2018, the index has shown a gradual upward trend. It shows that under the Belt and Road Initiative, the trade volume between participating countries along the route has gradually increased. It can be inferred that the Belt and Road Initiative has played a positive role in promoting trade and economic cooperation between relevant countries.

The seasonal component shows the seasonal fluctuations of the index. From the above figure, it can be seen that the index has a significant increase in the fourth quarter of each year and a downward trend in the first quarter [9]. This shows the impact of specific seasons of the year on trade volume, such as the Spring Festival holiday and changes in seasonal demand. This seasonal fluctuation suggests that relevant policymakers can consider formulating corresponding policies to boost trade in the fourth quarter and increase the trade volume in that quarter.

The residual component shows the random fluctuations of the index. That is, the remaining fluctuations outside the trend and seasonal components. From the above figure, it can be seen that the fluctuation range of this component is relatively small, indicating that the changes in the trade volume index are mainly affected by trend and seasonal factors [10]. However, these random fluctuations may still have a certain impact on the trade volume, and policymakers need to further analyze and consider.

Overall, this chart shows that the index shows an upward trend under the Belt and Road Initiative, and there are obvious seasonal fluctuations. The fluctuation range of the residual component is small, indicating that the change of the index is mainly affected by trend and seasonal factors. This information has important implications for

the trade policies and economic planning of relevant countries. It is necessary to consider the impact of long-term trends and seasonal factors on trade volume and take corresponding measures to promote trade and economic cooperation.

5 Economic Contribution of the Joint Construction of the Belt and Road Initiative to Countries Along the Route

After the above analysis, we can clearly see that the joint construction of the Belt and Road Initiative has a promoting effect on friendly trade activities among countries. This section will focus on analyzing the economic contribution of the initiative to countries along the route in Asia, Africa and Europe. Considering the importance of indicators and the demand for macroeconomic measurement, this article selects the average annual growth of national GDP as an indicator to reflect economic contribution.

Taking Pakistan in Asia as an example, after calculation, before and after General Secretary Xi proposed the joint construction of the Belt and Road Initiative in 2013, Pakistan's average annual growth of GDP has increased significantly. As shown in Figure 3 below, the average annual growth rate of the country's GDP was 12351.48 between 2005 and 2013 before the initiative was proposed, and the average annual growth rate of GDP rose to 15942.09 after the initiative was proposed. It can be seen that the "Belt and Road" initiative has played a strong role in promoting the economic development of countries along the route in Asia. As General Secretary Xi said, it has achieved mutual benefit and win-win results for the countries involved in the initiative, and has also provided new opportunities for the development of countries around the world.

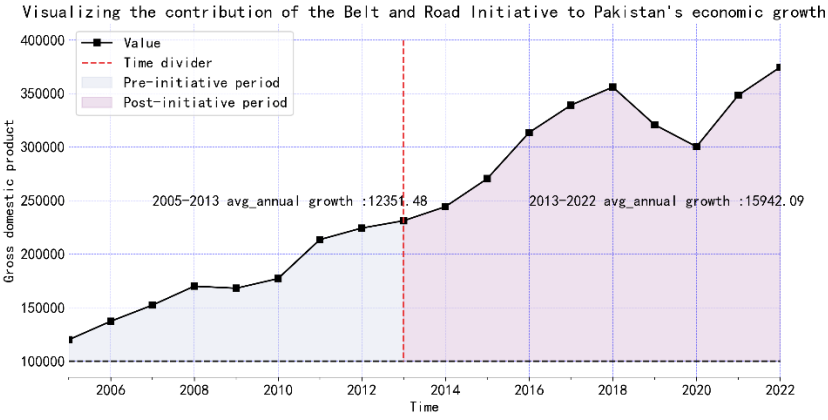

Fig. 3. Visualization of the contribution of the Belt and Road Initiative to Pakistan's economic growth

In addition to Asian countries, this section also takes the European country Russia as an example to analyze the economic contribution of the initiative to countries around the world. Unlike Pakistan, it is calculated that the average annual growth rate of Russia's GDP was 169828.46 before the initiative was proposed in 2013, but after 2013,

the value dropped sharply to -5783.42, and even showed a negative growth trend. However, this does not mean that the initiative has a counter-effect on Russia's economic development. Taking into account political, cultural, economic and other factors, after the outbreak of the Ukrainian crisis in 2014, Western countries imposed multiple rounds of economic sanctions on Russia. The sanctions led to an increase in Russia's financing costs, outflow of foreign capital, and obstruction of technology introduction, which directly affected economic growth; Russia's economy is highly dependent on energy exports, and fluctuations in international oil prices have a huge impact on its economy. Since 2014, international oil prices have fallen sharply, causing severe damage to the Russian economy. Although the Belt and Road Initiative helps Russia expand its energy export market, it is difficult to completely offset the negative impact of falling oil prices. In addition, Russia has a vast territory and relatively backward infrastructure, which limits the advancement of the "Belt and Road" project. The slow progress of cooperation is also one of the important reasons why the initiative has little effect on Russia's economic growth. It can be seen that China and Russia need to trust each other more under the framework of the initiative in the future. Russia needs to further deepen cooperation with countries along the "Belt and Road", actively improve the investment environment, promote economic structural transformation and upgrading, and make better use of the development opportunities brought by the initiative.

In addition, taking Ethiopia in Africa as an example, we can also see the huge economic contribution of the "Belt and Road" initiative to participating countries. Before the proposal, Ethiopia's average annual GDP growth rate was 3916.34, and after the proposal, the value reached a peak of 8792.81, which was twice as much as before the proposal. At the same time, the country achieved an average annual GDP growth of more than 10,000 for the first time 7 years after the proposal was put forward, showing that the initiative has injected strong vitality into the economic development of countries along the route.

Based on the above analysis, we can clearly see that the "Belt and Road" initiative has a positive role in promoting trade activities and economic growth in most participating countries. In the future, we should continue to take win-win cooperation as the goal and continue to carry out the "Belt and Road".

6 Discussion

This study clearly shows that the Belt and Road Initiative (BRI) has played a significant role in promoting economic growth and trade among the countries along the route. The Mann-Kendall trend test results reveal a significant growth in global trade volume following the initiative's implementation, with a particularly strong increase from 2019 to 2022, reflecting the deepening cooperation among participating nations. However, the economic contributions vary across countries. While the BRI has significantly boosted GDP growth in countries like Pakistan and Ethiopia, Russia's economic benefits have been limited due to external factors such as international sanctions and energy price fluctuations, demonstrating the complex interplay of political and economic conditions.

Additionally, the combination of STL decomposition and minimum weighted sort entropy optimization provided a deeper understanding of trade volume fluctuations, especially the seasonal effects on trade. These seasonal patterns, such as demand shifts during specific holidays, offer valuable insights for policymakers looking to regulate trade activities more effectively. While this study highlights the positive impact of the BRI, challenges such as overcoming cross-border cooperation obstacles and balancing diverse national interests remain. Future research should continue to explore these issues to optimize the BRI's implementation. Overall, despite the challenges, the BRI has provided new opportunities for global economic cooperation and is expected to further contribute to balanced global economic development.

7 Conclusion

This study analyzes the impact of the Belt and Road Initiative (BRI) on trade volume and economic growth among participating countries, revealing its significant role in promoting global economic cooperation. The findings show a sustained growth trend in trade volume, particularly between 2020 and 2022, highlighting the BRI's positive influence on international trade despite a complex global environment. The Mann-Kendall trend test confirmed a statistically significant growth trend, while STL decomposition, optimized by minimum weighted sort entropy, allowed for a detailed analysis of trend, seasonality, and random fluctuations in trade volume. Despite the overall positive impact, the study also emphasizes the varying economic outcomes across countries, as seen in Russia, where external factors like economic sanctions and energy price fluctuations hindered its growth. Overall, the BRI has significantly contributed to trade and economic development along the route, offering new opportunities for win-win cooperation, and with evolving international dynamics, it is expected to further drive balanced global economic growth.

References

1. Huang, Q., Zhu, X., Liu, C., Wu, W., Liu, F., & Zhang, X. (2020). Spatial-temporal evolution and determinants of the belt and road initiative: a maximum entropy gravity model approach. *Chinese Geographical Science*, *30*, 839-854.
2. Ni, Y., Huang, Z., & Hu, J. (2024). Spatial patterns and the changing law of spatial and temporal factors in the economic quality of China's Silk Road Economic Belt. *Heliyon*, *10*(14).
3. Li, J., He, S., Wang, J., Ma, W., & Ye, H. (2022). Investigating the spatiotemporal changes and driving factors of nighttime light patterns in RCEP Countries based on remote sensed satellite images. *Journal of Cleaner Production*, *359*, 131944.
4. Liu, G., Pan, J., Jiang, Y., Ye, X., & Shao, F. (2024). Exploring the Effects of Urban Development in Ten Chinese Node Cities along the Belt and Road Initiative on Vegetation Net Primary Productivity. *Sustainability*, *16*(11), 4845.
5. Chen, X., Wang, Y., Chen, Y., Fu, S., & Zhou, N. (2023). NDVI-based assessment of land degradation trends in Balochistan, Pakistan, and analysis of the drivers. *Remote Sensing*, *15*(9), 2388.

6. Xu, X., Jiao, F., Liu, H., Gong, H., Zou, C., Lin, N., ... & Wang, K. (2022). Persistence of increasing vegetation gross primary production under the interactions of climate change and land use changes in Northwest China. *Science of the Total Environment*, *834*, 155086.
7. Altouma, A., Bashir, B., Ata, B., Ocwa, A., Alsalman, A., Harsányi, E., & Mohammed, S. (2024). An environmental impact assessment of Saudi Arabia's vision 2030 for sustainable urban development: A policy perspective on greenhouse gas emissions. *Environmental and Sustainability Indicators*, *21*, 100323.
8. Wei, X., Wang, N., Luo, P., Yang, J., Zhang, J., & Lin, K. (2021). Spatiotemporal assessment of land marketization and its driving forces for sustainable urban–rural development in Shaanxi province in China. *Sustainability*, *13*(14), 7755.
9. Song, Y., Aryal, J., Tan, L., Jin, L., Gao, Z., & Wang, Y. (2021). Comparison of changes in vegetation and land cover types between Shenzhen and Bangkok. *Land Degradation & Development*, *32*(3), 1192-1204.
10. Song, Y., Tian, J., He, W., Namaiti, A., & Zeng, J. (2024). Differential Analysis of Carbon Emissions between Growing and Shrinking Cities: A Case of Three Northeastern Provinces in China. *Land*, *13*(5), 648.