Dynamic evolution and spatial differentiation of the allocation efficiency of Science and Technology Resources in the countries along the “Belt and Road”

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Abstract. Science and technology resources are the strategic resources for the development of today's society and the basic conditions for improving the ability of independent innovation. For scientific and technological innovation, the optimal allocation of science and technology resources is crucial. For countries along the “Belt and Road”, the efficiency of the allocation of science and technology resources has become the key to the development of innovative international construction. Therefore, this study takes the countries along the “Belt and Road” as the research area, and takes the period of rapid development of science and technology resources from 2005 to 2018 as the research period, comprehensively using the DEA-SBM model and ArcGIS spatial analysis methods to deeply analyze the allocation of science and technology resources in the countries along the “Belt and Road”. The long-term dynamic evolution law and spatial differentiation pattern of efficiency. The research methods and conclusions can provide useful reference for the efficient allocation of the international science and technology resources along the “Belt and Road” and realization of the “the innovative Belt and Road”.

1. Introduction
Science and technology resources are the strategic resources for the development of today's society and the basic conditions for improving the ability of independent innovation [1]. The Chinese President Xi Jinping pointed out at the meeting with Chinese scientists that the scientific and technological innovation is an important force for the sustainable development of modern economic society, science and technology are the primary productive forces, and scientific and technological progress and innovation are playing a pivotal role in promoting the comprehensive, coordinated and sustainable development of society. As of 2020, the contribution rate of China’s scientific and technological progress is 59.6 %, and the contribution rate of scientific and technological progress in innovation-oriented countries is generally as high as 70 %, and even as high as 80 % in the United States and Germany [2]. Therefore, it is obvious that an optimal allocation of science and technology
resources is crucial in science, technology, and innovation. It is particularly critical to improve the efficiency of science and technology resource allocation [3].

In September and October of 2013, the Chinese government put forward the strategic concept of building the “New Silk Road Economic Belt” and the “21st Century Maritime Silk Road” to the world. Soon after the initiative was proposed, great cooperation potentialities of trade, resources, science, and technology emerged. It has become a new engine for the regional technological progress and innovation [4]. At present, in-depth and detailed studies on the economic and trade cooperation and cultural exchanges between the countries along the “Belt and Road” [5–8] have been conducted, but the studies on the efficiency of the allocation of science and technology resources remain few. Therefore, the evolutionary trend, spatial patterns and differences in the allocation efficiency of science and technology resources in the countries and regions along the “Belt and Road”, have become issues that urgently need to be studied for science and technology innovation of the “Belt and Road” [9–13].

Based on this urgent need, this study takes the major countries along the “Belt and Road” as the research object, and years of 2005–2018 as the main research period. Through the use of the DEA-SBM model and ArcGIS spatial analysis methods, a comprehensive analysis of the efficiency of the allocation of science and technology resources in the major countries along the “Belt and Road” is conducted. The overall evolution trend and the spatial dynamic distribution pattern of the country’s science and technology resources are also studied which focus on the regional differences and dynamic evolution of the science and technology resource allocation efficiency in the countries along the “Belt and Road”. The paper aims at establishing a more effective allocation and improving the efficiency of science and technology resources for the countries along the “Belt and Road”, balancing the differences in technological development between the regions and building the “Belt and Road” into a way of innovation.

2. Models and Methods

2.1. Data Sources

The indicators for evaluating the efficiency of the allocation of science and technology resources in this study involve human resource input, capital resource input, information resource input, science and technology achievement output, and science and technology conversion output. The data source is the World Bank.

| Input-output | Index name | Index name |
|--------------|------------|------------|
| Science and technology resource investment | Human resources investment | Technicians in R&D (per million people) |
| | Capital resource input | Researchers in R&D (per million people) |
| | Information resource input | Research and development expenditure (% of GDP) |
| | Scientific and technological achievement output | Charges for the use of intellectual property, payments (BoP, current US$) |
| | Technology transformation output | Fixed telephone subscriptions (per 1 million people) |
| | | Mobile cellular subscriptions (per 1 million people) |
| | | Secure Internet servers (per 1 million people) |
| | | Fixed broadband subscriptions (per 100 people) |
| | | Individuals using the Internet (% of population) |
| | | Scientific and technical journal articles |
| | | Patent applications, residents |
| | | High-technology exports (current US$) |
| | | Medium and high-tech Industry (including construction) (% manufacturing value added) |
2.2. Research methods
The main research method used in this study is the DEA-SBM model, which has the attributes of freedom of dimensions and variable units. It can weight input and output variables and increase undesired output. Taking the countries along the “Belt and Road” as the research space unit, each space unit in the analysis of resource allocation efficiency includes input and output vectors, expressed as \( x \in \mathbb{R}^m, y \in \mathbb{R}^s \), and the definition matrices \( X = [x_1, \ldots, x_n]^T \in \mathbb{R}^{m \times n}, \ Y = [y_1, \ldots, y_n]^T \in \mathbb{R}^{s \times n}, \ X > 0, \ Y > 0 \). Define the production possibility set \( P = \{(x, y)|x \geq \lambda x, y \leq \lambda Y, \lambda \geq 0\} \).

3. Results analysis

3.1. The overall evolution trend of the allocation efficiency of science and technology resources in the countries along the “Belt and Road”
Through the DEA-SBM model, the allocation efficiency of science and technology resources in the countries along the “Belt and Road” from 2005 to 2018 was calculated, and it turned out that in the past 14 years, the allocation efficiency of science and technology resources in these countries has shown an overall fluctuating trend. From 2005 to 2013, it showed a fluctuating upward trend, reaching the highest value in 2013, then suddenly falling to the lowest value in 2014, rising again in 2015, and then rising slowly after 2017 (Figure 1). This shows that economic globalization and the instability of the global economy that it brings have an impact on the allocation efficiency of science and technology resources in the countries around the world. There is a positive relationship between the investment in science and technology and economic growth, and the spatial distribution of science and technology resources often has a strong correlation with regional economic development, and there is usually positive feedback. In the past 14 years, the science and technology resources as strategic resources have been affected by economic, political and other factors. The ratio of input and output has always remained at about 40%, but it has shown an overall downward trend. This shows that the vertical development of science, technology and economy has cyclical fluctuations. In the great cycle of science, technology and economy, every economic boom is the result of science and technology entering the production process after transforming into direct productivity.

![Figure 1. The overall evolution trend of the allocation efficiency of science and technology resources in the countries along the “Belt and Road”](image-url)
3.2. The spatial pattern of the allocation efficiency of science and technology resources in the countries along the “Belt and Road”

Among the countries along the “Belt and Road”, the countries with high levels of the allocation efficiency of science and technology resources have been concentrated in Asia, eastern Europe and Africa from 2005 to 2018. Some South American countries also had relatively high allocation efficiency of science and technology resources. Among them, the allocation efficiency of science and technology resources in northern Asia and Africa has increased significantly.

Specifically, in 2005, the countries along the “Belt and Road” with high allocation efficiency of science and technology resources were mainly concentrated in the countries in Asia, eastern Europe and Africa, and some South American countries had also high allocation efficiency of science and technology resources (Figure 2a). From a regional perspective, Asia and Eastern Europe showed significant spatial agglomeration. In Asia, the countries with high allocation efficiency of science and technology resources were concentrated in western Asia and eastern Asia, and in eastern Europe, the countries with high allocation efficiency of science and technology resources were concentrated in the Mediterranean and Black Sea coasts; From a quantitative point of view, there were 10 Asian countries with high allocation efficiency of science and technology resources (> 0.8), including China, the Philippines, Vietnam, Kyrgyzstan, Afghanistan, Iran, Bangladesh, Nepal, Saudi Arabia and Turkey. There were only 3 eastern European countries with high allocation efficiency of science and technology resources (> 0.8), including Belarus, Hungary and Ukraine. In contrast, the countries with high allocation efficiency of science and technology resources in the African region were relatively scattered in space and had not shown a significant spatial agglomeration rule. By contrast, the number of African countries with high allocation efficiency of science and technology resources (> 0.8) had reached 9, including Tunisia, Morocco, Mali, Niger, Nigeria, Cameroon, National Republic of Congo, Uganda and Namibia. Although the GDP of many African countries has grown vigorously, most African countries still lag behind in investment and achievements in key areas of social and economic development, and the allocation efficiency of science and technology resources needs to be greatly improved.

Among a few South American countries involved, the allocation efficiency of science and technology resources in Peru, Chile and Guyana was higher than 0.8, attributing to a relatively good level. Peru and Chile are located on the eastern coast of the Pacific Ocean in the southern hemisphere. They have natural coastal trade advantages. Their geographical locations are similar to that of China’s eastern coast, which could better help them participate in the international trade and in the science, technology and culture exchange with different countries, which leads to better allocation efficiency of science and technology resources in Peru and Chile.

In terms of the spatial distribution map of the allocation efficiency of science and technology resources in the countries along the “Belt and Road” in 2018 (Figure 2b), the allocation efficiency of science and technology resources in central and northern Asia and Africa has increased significantly. Compared with 2005, the most obvious feature of change is that Russia’s allocation efficiency of science and technology resources has changed from less than 0.2 in 2005 to the current state greater than or equal to 1.0. Russia’s rapid improvement in the allocation efficiency of science and technology resources was in line with the construction of “Belt and Road”, Silk Road Economic Belt, and the China-Mongolia-Russia Economic Corridor. The China-Mongolia-Russia Economic Corridor connects Russia's Trans-Eurasian Railway, the "Prairie Silk Road" proposed by Mongolia, and China's "Silk Road Economic Belt". Since it was proposed in 2014, the science and technology exchanges between northeastern Asian countries have continued to deepen, regional economic cooperation has been continuously strengthened, and the allocation efficiency of science and technology resources in the countries along the route has also been continuously improved. After 14 years of development, the allocation efficiency of science and technology resources in Benin and Zimbabwe has also rapidly improved.
Before the launch of the "Belt and Road" initiative in 2012, the Chinese government clearly announced that it was willing to work together with the African Union to strengthen cooperation in the fields such as cross-border and cross-regional infrastructure construction in Africa. Generally speaking, although African countries have participated in the joint construction of the “Belt and Road” late, their development has been quite rapid. Since 2011, Zimbabwe has become a hot spot for the Chinese investment in Africa. China has been Zimbabwe’s largest source of foreign investment for many years. In 2018, the relationship between the two countries was upgraded to a comprehensive strategic partnership. Zimbabwe hopes to further strengthen the economic cooperation between the two countries through the “Belt and Road” initiative, which has allowed more Chinese technology, knowledge, and investment to enter Zimbabwe, further improving the allocation efficiency of science and technology resources [3]. Located in western Africa, Benin is one of the least developed countries identified by the United Nations. The “Belt and Road” initiative has brought new opportunities for the development of China-Benin relations. In the “Belt and Road” initiative, China is willing to share the experience and technology gained in various fields, such as economic development, poverty reduction, and industrial development. Based on the “Belt and Road” initiative, China-Benin will continue to strengthen cooperation in the fields of science, technology, and innovation, further improving the allocation efficiency of science and technology resources in Benin.

![Figure 2.](image)

Figure 2. The spatial pattern of the allocation efficiency of science and technology resources in the countries along the “Belt and Road”

Overall, there were large regional differences and imbalances in the allocation efficiency of science and technology resources in the countries along the “Belt and Road”. The high allocation efficiency of science and technology resources was concentrated in a few countries, and the average level of the allocation efficiency of science and technology resources in most countries was still low. The gap means large potentiality of improvement.

From the regional perspective, among the 15 countries with the best allocation efficiency of science and technology resources (allocation efficiency ≥ 1), Asian countries account for the highest proportion, including China, the Philippines, Kyrgyzstan, Iran, Saudi Arabia and Turkey. The European region followed closely, including Italy, Slovenia, Hungary, Romania and the Czech Republic. African countries accounted for 3 seats, including Ethiopia, Nigeria and Mali; Peru is the only country in South America whose allocation efficiency of science and technology resources has remained at a high level for a long time.

The level of allocation efficiency of science and technology resources largely determines scientific and technological capabilities, which will further affect the growth rate and potential of a country's economy. Therefore, the countries should strengthen the science and technology exchanges and cooperation, learn from each other, and improve the allocation efficiency of their own science and technology resources.
4. Conclusion

4.1. The overall evolution trend of the allocation efficiency of science and technology resources in the countries along the “Belt and Road”

From 2005 to 2018, the allocation efficiency of science and technology resources in the countries along the “Belt and Road” showed an overall fluctuating trend. Economic globalization and the instability of the global economy raised had an impact on the allocation efficiency of science and technology resources in the countries around the world, and the science and technology investment was directly proportional to economic growth. The spatial distribution of science and technology resources often has a strong correlation with regional economic development, and the feedback effect is usually positive.

4.2. As a strategic resource, scientific and technological resources are affected by multiple factors

As a strategic resource, science and technology resources are affected by economic, political and other factors. The ratio of input to output has always remained at about 40 %, but it has shown an overall downward trend. The vertical development of science, technology and economy shows alternating cycles of rise and fall. In the great cycle of science, technology and economy, every economic boom is the result of science and technology transferred to the production process after transforming into direct productivity.

4.3. There are large regional differences and imbalances in the allocation efficiency of science and technology resources in the countries along the “Belt and Road”

Overall, there are large regional differences and imbalances in the allocation efficiency of science and technology resources in the countries along the “Belt and Road”. The allocation efficiency of high-tech resources is only concentrated in a few countries and the average level of allocation efficiency of science and technology resources is low in most countries. There is still a lot of room for improvement. Among the 15 countries with the best allocation efficiency of scientific and technological resources, Asian countries account for the highest proportion, including China, the Philippines, Kyrgyzstan, Iran, Saudi Arabia and Turkey. The allocation efficiency largely determines
the scientific and technological capabilities which further affect a country's economic growth and potentiality.

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