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Original Research

Coupling Coordination Degree Measurement and Spatial Distribution between Economic Development and Ecological Environment of Countries along the Belt and Road

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Abstract

The construction of the green Belt and Road is an important part for the transformation of regional economy to green development and also important objects of the United Nations 2030 Agenda for Sustainable Development. This study establishes a coupling coordination measurement model, and used entropy method combined with and spatial statistics tools, to valuate and analyze the coupling coordination level and its geographical distribution between economic development and ecological environment of 55 countries along the Belt and Road. Most countries have been making a significant progress in sustainability efforts, in a stage of basic coordination and preliminary incoordination. Regions with a relatively high coupling coordination degree are mainly concentrated in East Asia and Europe, while areas with severe ecological pollution and low coupling coordination degree are predominantly in Central and West Asia and Africa. The coupling coordination level results indicates a significant global spatial correlation and a ladder-like geographical distribution that descends from west to east along the Belt and Road region, presenting a spatial agglomeration pattern for economy-environment system high-high regions and low-low regions. This study could be helpful for policy making to promote green and coordinated development based on differentiated strategies adapt to local conditions.

Keywords: economic development, ecological environment, coupling coordination degree, spatial distribution, Belt and Road

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Introduction

The efforts to construct the green Belt and Road has gained increasingly intensive global attention for the sustainability transformation of regional economy. The vision and proposed actions outlined on jointly building Silk Road Economic Belt and 21st Century Maritime Silk Road was issued by China government in March 2015, to prompt regional economic integration [1]. This Belt and Road regional initiative has gradually transformed from China's vision to a world consensus, and has become an approach to strengthen regional economic integration with neighboring countries and participate in further economic globalization [2]. By the end of January 2020, China had signed over 200 cooperation agreements on jointly building the green Belt and Road with 138 countries and 30 international organizations along the Belt and Road. Meanwhile, with economic development, the environmental degradation and frequent occurrence of natural disasters have brought huge losses to the global economy and posed severe challenges for countries along the Belt and Road, especially developing and emerging economies, including China, to participate in global green transformation and environmental governance [3, 4].

In response to the increasing severe ecological and environmental problems and achieve sustainable development, major developed economies have proposed the green development concept and advocated the transition to a sustainable economic growth model [5-8]. As one of the regional economic cooperation paths, the Belt and Road initiative has also involved the green economy model as the focus of regional cooperation. On April, 2017, the Guidance on Promoting Green Belt and Road was jointly issued by three ministries of China, which has become the guiding programmatic document for the construction of the green Belt and Road [9]. China government announced that "the construction of the Belt and Road will advocate green, low-carbon, recycled, and sustainable production and lifestyle, strengthen cooperation in ecological protection, and build ecological civilization to achieve the 2030 Sustainable Development Goals" on May, 2017, at the first Belt and Road International Cooperation Summit Forum. Further, the green development goals were taken as main topics of the 2019 Belt and Road International Cooperation Summit Forum, such as energy-water sustainable use, pollution reduction, nature reserve, and sanitation infrastructure. Sustainable development promotion of the regions along the Belt and Road has become an international consensus among the global relevant countries.

However, there are various natural environment characteristics and economic development levels with different regional development stages along the Belt and Road. Developing and emerging economies accounted for most of the countries along the Belt and Road, generally facing the huge resource and environmental pressure with industrialization and urbanization processes, which have become major obstacles to regional sustainable development [10, 11]. Based on the Environmental Performance Index released by Yale University, the economic growth rate along the Belt and Road countries was higher than the world average level, and simultaneously the energy consumption and pollutant emissions were far higher than the world average level. Nearly half of the global carbon emissions came from the Belt and Road countries [12]. To achieve a win-win goal between economic development and ecological environment along the Belt and Road, it is necessary to quantitatively and objectively evaluate the economic-environmental coordination status of countries, and accordingly policy debating can be improved to advance the overall sustainable development level along the Belt and Road. However, to our knowledge, there were few researches on this topic, which hampered understanding the economic development and ecological environment levels of the Belt and Road countries, and restricts the promotion of the connectivity and implementation of the green Belt and Road initiative. Therefore, this study establishes a coupling coordination evaluation model and applied the entropy weighting method, combined with spatial statistics tools, to measure and analyze the coupling coordination degree and its spatial patterns between economic development and ecological environment of 55 countries along the Belt and Road. It could serve as an important reference for improving the coordinated and sustainable development level along the Belt and Road, and advance the national participation level in global environment governance, and promote the transformation of the Belt and Road economy from the extensive growth to green development.

The literature on the economic and environmental issues of the countries along the Belt and Road mainly focuses on the following aspects. (1) The geographical distribution characteristics and risk assessment of resources and environment elements. Some literature studied the spatial pattern of water resources, natural gas, energy, and gave great attention to the security governance of these elements during the implementation of the Belt and Road initiative and proposed paths for sustainable economic development of the Silk Road Economic Belt [13-16]. Besides, some scholars have also studied the current and future Eurasia environmental risks along with the construction of the Belt and Road and proposed new policy paradigms of ecological civilization to avoid these risks [17, 18]. (2) The environmental effects of the Belt and Road construction. The relevant literature focused on the possible impacts of railway, water conservancy, hydropower and other infrastructure construction on the ecological environment such as the loss of animal and plant habitats, the reduction of biodiversity, the damage of oil spills to local water and cultivated land [19-22]. Some scholars also studied some specific regional issues the environmental effects of the Belt and Road construction projects in Russia Far East and

Central Asia and discussed the development trend of regional eco-economy in the initial stage of the "Silk Road Economic Belt"[23]. (3) Climate change and green Belt and Road construction. Some literature analyzed the characteristics of climate change in countries along the Belt and Road, especially the impact of extreme natural disasters on the construction of the green Belt and Road [24, 25]. And, some scholars have explored carbon emission characteristics and its influencing factors and analyzed the impact of carbon emissions on the social-economic development of countries along the Belt and Road, and explored the low-carbon economic paths in the context of green Belt and Road [26-29]. Herein, some scholars ignored the objective mechanism of industrial transfer and demonized the Belt and Road initiative, and deemed that the Belt and Road construction could realize China's pollution transfer. (4) Green development valuation along the Belt and Road. Some impacts of financial development, trade, foreign direct investment and globalization on the green development of countries were analyzed [30-32]. It could be concluded, the most related researches focused on discussing the impact of construction projects, trade and investment on the environment, for the relationship between eco-environment and economic growth of countries along the Belt and Road. There were few studies on the internal interaction and coupling coordination mechanism between economic development and ecological environment in this region. The green development of the countries along the Belt and Road is a comprehensive and systematic subject, it is of global significance to explore coordinated development of environment-economy, based on a multi-disciplinary perspective such as geography, environment and economics.

The study differs from the preceding studies in the following aspects. Above all, a systematic assessment of the coupling coordination level of economic development and ecological environment is firstly performed, along the Belt and Road, to our knowledge. Meanwhile, a lot of poor countries are located in the Belt and Road region, with backward economy and fragile ecological environment. The research on their coordinated development level is seriously insufficient, and taken as the crux for the green Belt and Road analysis. Furthermore, this study establishes a comprehensive evaluation index system, and strives to fully reflect the level of development, involving as many economic and environmental indicators as possible, related to measurement of economic scale, structure, efficiency, and environment level, emissions, protection. In addition to the above factors, some indicators such as population using improved sanitation facilities, population with access to clean fuels and technologies for cooking, would also be especially critical to the Belt and Road, with a typical transformation feature. Third, an economy-environment coupling coordination measurement model, including the classification system, is established, using entropy method combined with and spatial statistics tools. Finally, the geographical distribution feature is valuated and analyzed. Moran index and LISA map are also presented. This quantitative estimation could be helpful to advance the basis for policy making to promote green and coordinated development along the Belt and Road based on differentiated policies adapt to local conditions.

The remaining structure of this study is as follows: Section 2 describes the methodology and data, presents the coupling coordination degree classification criterion. Section 3 gives the empirical results of coupling coordination degree and the spatial distribution. The conclusions and some policy implications are presented in section 4.

Material and Methods

Coupling Coordination Degree Evaluation Model

Coupling coordination degree refers to an evaluation index of the particular state of an complex system. Coordination describes the benign interaction between factors. This degree quantitatively evaluates the coordination status among the various subsystems or elements. The coordination level of economic development and ecological environment is the coupling result between these two systems at a particular regional development stage [33, 34]. Herein, the calculation of the coupling coordination degree involves three steps as follows: the calculation of comprehensive indexes of these two systems, the calculation of coordination level of these two comprehensive indexes, and the calculation of coupling coordination degree.

First, entropy method was used to evaluate the comprehensive index of economy-environment system [35]. The weight of each index was calculated by analyzing the dependency degree and their information contents. This could strengthen the robust and avoid the subjectivity and information overlap between multiple indicators. According to this method, the collected data was standardized by the following formula (1) and formula (2).

$$X_{ij}^{+} = \frac{X_{ij} - \min\{X_{1j},...,X_{nj}\}}{\max\{X_{1j},...,X_{nj}\} - \min\{X_{1j},...,X_{nj}\}} \tag{1}$$

$$X_{ij}^{-} = \frac{\max\{X_{1j},...,X_{nj}\} - X_{ij}}{\max\{X_{1j},...,X_{nj}\} - \min\{X_{1j},...,X_{nj}\}} \tag{2}$$

...where X_{ij} represents the value of indicator j in the region $i(i = 1,...,n; j = 1,...,m)$. $min\{X_{1j},..., X_{nj}\}$ and $max\{X_{1j},..., X_{nj}\}$ are the minimum and maximum values of index X_{ij}. X_{ij}^{+} is the positive dimension index, and X_{ij}^{-} is the negative dimension index. The value is in the range of [0, 1]. Then the sample index weight is calculated according to the formula (3).

$$p_{ij} = X_{ij} \Big/ \sum_{i=1}^{n} X_{ij} \quad (3)$$

Furthermore, the study calculates the entropy value E_j of the *j-th* index by formula (4).

$$e_j = -\sum_{i=1}^{n} p_{ij} \times Ln(p_{ij}) / Ln(n) \quad (4)$$

...where n is the number of evaluation object. $P_{ij}=0$, $P_{ij}*ln(P_{ij}) = 0$. The weight W_j could be calculated by $W_j = {1-e_j} \Big/ {n-\sum_{j=1}^{m} e_j}$.

Third, the comprehensive index Z_{ij} was considered according to the formula (5).

$$Z_{ij} = \sum_{i=1,j=1}^{n,m} \mathrm{X}_{ij}^{+} (or \mathrm{X}_{ij}^{-}) \times W_j \quad (5)$$

Fourth, the coordination degree of the comprehensive index of economic development and ecological environment were calculated by the formula (6).

$$C_{it} = \left\{ \frac{S_{ED} \times S_{EL}}{\left(\frac{S_{ED}+S_{EL}}{2}\right)^2} \right\}^r \quad (r>=2) \quad (6)$$

...where S_{ED} and S_{EL} are the comprehensive index of economic development and ecological environment respectively. And, r is equal to 2, taken as the coordination index. .

Finally, the coupling coordination degree between economic development and ecological environment was calculated by the formula (7).

$$\begin{cases} d_{it} = \sqrt{C_{it} \times q_{it}} \\ q_{it} = \alpha S_{ED} + \beta S_{EL} \end{cases} \quad (7)$$

...where d_{ij} is the coupling coordination degree of economic development and ecological environment. α and β are the weights of these two systems. The equally significant economy and environment weights were set as $\alpha = \beta = 0.5$.

The coupling coordination degree is not a definite value, but an interval value [36, 37]. In this study, the coupling coordination degree of economic development and ecological environment system along the Belt and Road regions could be divided into five types as follows (see Table 1).

Table 1. Coupling coordination degree classification.

Level	Degree	Function	Type
$0.8<d_j\leq1$	High-level coordination (V1)	$S_{ED}<S_{EL}$	Economy Lag
		$S_{ED}\approx S_{EL}$	Economy-Ecology Synchronization
		$S_{ED}>S_{EL}$	Ecology Lag
$0.5<d_j\leq0.8$	Intermediate coordination (V2)	$S_{ED}<S_{EL}$	Economy Lag
		$S_{ED}\approx S_{EL}$	Economy-Ecology Synchronization
		$S_{ED}>S_{EL}$	Ecology Lag
$0.4<d_j\leq0.5$	Basic coordination (V3)	$S_{ED}<S_{EL}$	Economy Lag
		$S_{ED}\approx S_{EL}$	Economy-Ecology Synchronization
		$S_{ED}>S_{EL}$	Ecology Lag
$0.3<d_j\leq0.4$	Preliminary incoordination (V4)	$S_{ED}<S_{EL}$	Economy Lag
		$S_{ED}\approx S_{EL}$	Economy-Ecology Synchronization
		$S_{ED}>S_{EL}$	Ecology Lag
$0.2<d_j\leq0.3$	Intermediate incoordination (V5)	$S_{ED}<S_{EL}$	Economy Lag
		$S_{ED}\approx S_{EL}$	Economy-Ecology Synchronization
		$S_{ED}>S_{EL}$	Ecology Lag
$0<d_j\leq0.2$	Extreme incoordination(V6)	$S_{ED}<S_{EL}$	Economy Lag
		$S_{ED}\approx S_{EL}$	Economy-Ecology Synchronization
		$S_{ED}>S_{EL}$	Ecology Lag

Notes: SED≈SEL means |SED-SEL|≤0.1.

Exploratory Spatial Data Analysis Methods

Exploratory spatial data analysis (ESDA) is meant to a complex of a series of spatial analysis methods and techniques. The spatial correlation and aggregation features of research variables are analyzed, through the description and visualization of the spatial distribution pattern. In this study, two spatial autocorrelation methods are applied to investigate the spatial distribution characteristics of the coupling coordination degree level along the Belt and Road countries. The spatial autocorrelation analysis model is constructed to examine the existence of spatial correlation in the study area, and then the local spatial autocorrelation index is used to identify the hot and cold spots of the coupling coordination degree.

(1) Spatial autocorrelation analysis. The global Moran index was firstly proposed by Moran in 1950 [38]. It is an exploratory spatial analysis index used to test spatial relevance and agglomeration, reflecting the similarity between each unit and its neighboring units in the whole study area. In this study, Moran's *I* index is used to observe the global autocorrelation characteristics. The model is constructed as follows:

$$I=\frac{n\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}\sum_{i=1}^{n}(x_i-\bar{x})^2}=\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{s^2\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}} \tag{8}$$

...where *I* is the regional Moran's *I* index, and its value range is [-1, 1]. $I>0$ indicates a positive correlation, and the closer to 1, the higher the degree of clustering of similar attributes. $I<0$ indicates a negative correlation, and the closer to -1, the higher the degree of clustering of dissimilar attributes. $I = 0$ indicates irrelevant.

(2) The local Moran index was firstly presented by Anselin in 1995, which could accurately reflect the scope and location of the regional agglomeration features. The model is constructed as follows:

$$I_i=\frac{(x_i-\bar{x})\sum_{j=1}^{n}w_{ij}(x_i-\bar{x})}{s^2} \tag{9}$$

...where, $I_i>0$ means a high attribute value accompanied by a high attribute value ("high-high" aggregation area), or a low attribute value along with a low attribute value ("low-low" aggregation area); $I_i<0$ means a high attribute value surrounded by a low attribute value ("high-low" aggregation area), or a low attribute value associated with a high attribute value ("low-high" aggregation area).

Variables and Data

The countries and regions along the Belt and Road showed the significant geographic differences in natural environment, economic development and ecology. Besides, the statistical systems are incomplete with missing historical data in some undeveloped countries. Presently there are various established comprehensive index evaluation system based on the coupling coordination relationship between economic development and ecological environment [40-43]. Considering the availability of data and locality, according to the principles of index representativeness and flexibility, this study established a comprehensive ecological environment-economic development evaluation index system. It includes 24 indicators as Table 2.

The level of economic development can be measured from three aspects: economic scale, economic structure and economic efficiency. The expansion of economic scale, the optimization of economic structure and the improvement of economic efficiency will be conducive to economic development. Economic scale includes GDP per capita, GDP growth rate, gross fixed capital formation and tax scale. Economic structure includes the ratio of secondary industry added value to GDP, the ratio of service industry added value to GDP, urbanization rate and the ratio of technology research and development (R&D) input to GDP. Economic efficiency includes labor productivity of secondary industry, labor productivity of service industry, GDP per energy use and GDP per water use.

Ecological environment can be measured as following three types of indicators: ecological environment level, ecological environment emission and ecological environment protection. The increase of ecological resource endowment, the decrease of pollutant emissions, and the improvement of environmental protection capacity will improve the ecological environment quality. The ecological environment level is mainly reflected by arable land per capita, forest coverage rate, renewable freshwater resources per capita and energy supply per capita. The ecological environment emission is mainly reflected by CO_2 emissions per capita, NO_2 emissions per capita, $PM_{2.5}$ exposure per capita and agricultural greenhouse gas emissions per capita. The ecological environment protection is mainly weighed up by the ratio of people using improved sanitation facilities to total population, the ratio of people access to clean fuels and technologies for cooking to the total, the proportion of terrestrial protected areas and the proportion of renewable energy consumption.

The descriptive statistics economic development and ecological environment evaluation index systems and the corresponding variables were summarized

Table 2. Variable descriptive statistics analysis.

System	Indicator	Variables	Mean	Std. Dev.	Min	Max
Economic development	Economic scale	GDP per capita (US)	14381.25	14519.92	706.24	56957.08
		GDP growth rate (%)	3.21	2.64	-6.55	7.89
		Gross fixed capital formation (million US)	186044.59	648074.07	1974.03	4721377.00
		Tax scale(million US)	85528.43	178885.44	232.75	987029.30
	Economic structure	Secondary industry added value/GDP (%)	37.28	8.17	21.08	61.06
		Service industry added value/GDP (%)	54.59	9.42	33.62	76.51
		Urbanization rate (%)	60.30	19.62	18.18	100.00
		R&D input/GDP (%)	0.94	0.93	0.04	4.29
	Economic efficiency	Labor productivity of secondary industry(US)	122.17	535.51	0.32	3866.80
		Labor productivity of service industry(US)	9.01	3.32	3.35	20.65
		GDP per energy use (US)	45921.02	45103.39	2285.48	180000.00
		GDP per water use (US)	26108.80	23526.97	1731.26	86715.59
Ecological environment	Ecological environment level	Arable land per capita(hectares)	0.25	0.28	0.00	1.71
		Cover rate of forest (%)	26.84	18.36	0.07	67.51
		Renewable internal freshwater resources per capita (cubic meters)	4267.51	5444.06	16.54	29981.99
		Energy supply per capita (gigajoules)	97.18	72.00	14.00	366.01
	Ecological environment emission	CO_2 emissions per capita(metric tons)	0.01	0.00	0.00	0.02
		NO_2 emissions per capita (million metric tons of CO_2 equivalent)	0.48	0.33	0.08	1.59
		$PM_{2.5}$ exposure per capita (micrograms per cubic meter)	0.00	0.00	0.00	0.01
		Agricultural greenhouse gas emissions per capita (million metric tons of CO_2 equivalent)	0.81	1.01	0.00	7.61
	Ecological environment protection	Proportion of population using improved sanitation facilities (%)	84.08	20.70	28.50	100.00
		Access to clean fuels and technologies for cooking/ total population (%)	82.65	24.26	13.42	100.00
		Terrestrial protected areas/total land area (%)	16.93	11.59	1.45	53.64
		Renewable energy consumption/total final energy consumption (%)	20.71	19.56	0.01	84.37

in Table 2. Countries along the Belt and Road are mainly distributed in Eurasia mainland and North Africa, and most of them are developing and emerging economies. There existed in some imperfect statistical systems and lack of continuous historical data. The authoritative data was only updated to 2014. Considering the availability of data and the geographical location of countries in this region, 55 countries were selected as research cases and divided into seven groups, as shown in Table 3. All the data used in this study were originated from World Bank Database, World Statistical Yearbook, International Statistical Yearbook and China Environmental Statistics Yearbook.

Results and Discussion

Coupling Coordination Degree

Based on the coupling coordination degree model, the study calculated the comprehensive index of economic development and ecological environment and its coupling coordination degree of 55 countries along the Belt and Road. The coupling coordination degree of sample countries were mainly concentrated between 0.3 and 0.5, according to the division features in Table 2. As shown in Fig. 1, the difference between the highest and the lowest value is about 0.33.

The coupling coordination degree of Germany, France, Italy and Singapore is relatively higher, with a value greater than 0.5. Meanwhile, Kenya, Kenya, Cambodia and Nepal have a relatively low coupling coordination level, with a value of less than 0.25. The most areas are concentrated in basic coordination (V3) and preliminary incoordination (V4), accounting for around 34.54% and 34.55% respectively of the total sample countries. The proportions of other coupling coordination types from large to small are intermediate incoordination (V5) 18.18% and intermediate coordination (V2) 12.73%, respectively. And, no one country achieve the state of high-level coordination (V1) or extreme incoordination (V6). On the whole, the coupling coordination degree of the most countries along the Belt and Road is relatively low and shows obvious regional differences. Germany, France, Italy, Singapore, Spain and Netherlands all maintain a relatively high level of coordinated and balanced development between economic and environmental factors. In particular, Singapore has

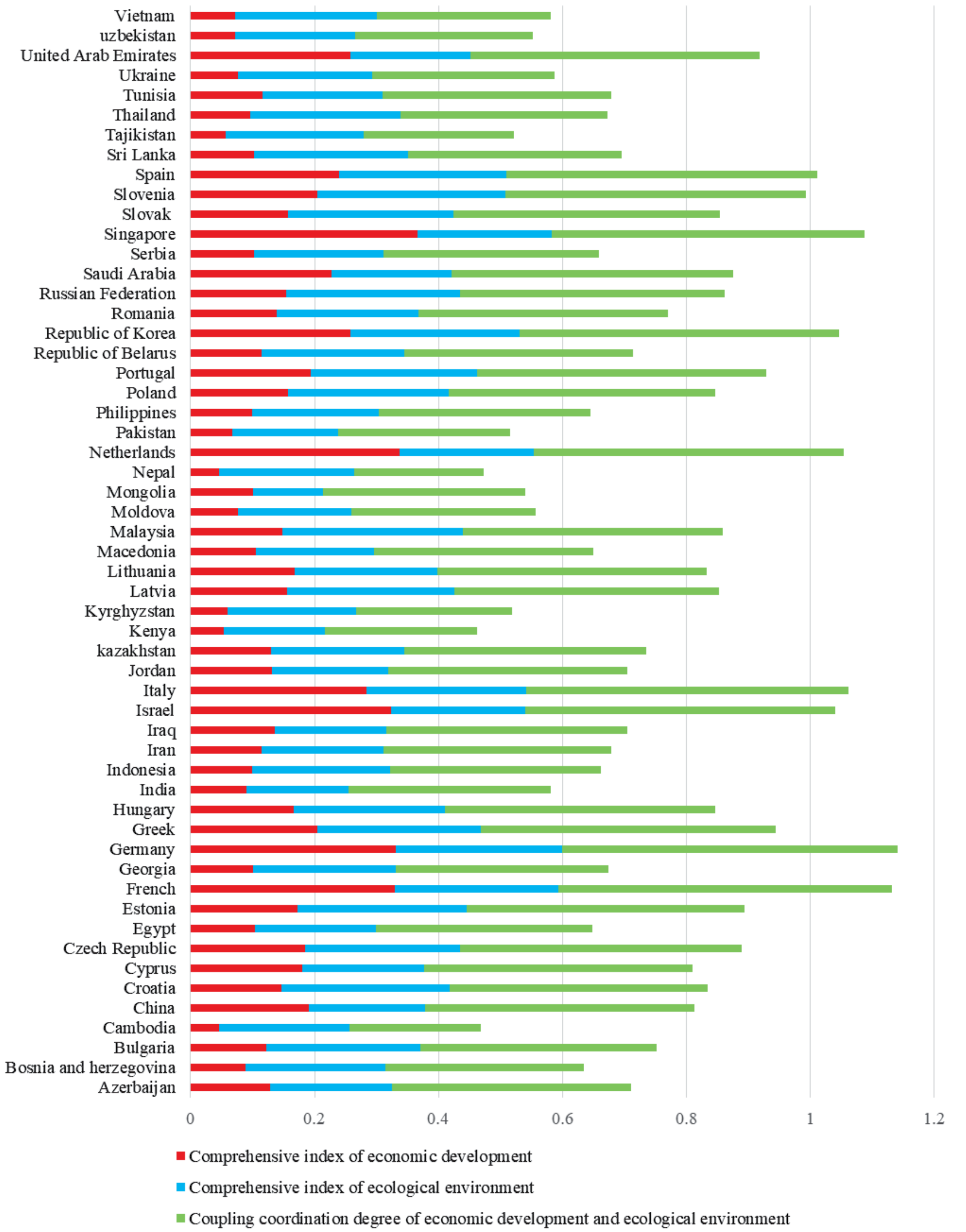

Fig. 1. Coupling coordination degree results of countries along the Belt and Road

made great efforts to develop high-end services and build a garden city, thus achieving a green economic transformation.

From the perspective of economic development, the top 10 countries are as follows: Singapore, Netherlands, Germany, France, Israel, Italy, Korea, Spain, Greece, and United Arab Emirates. Most of these countries are developed economies in Europe and East Asia, with the high-income level, and basically completed their industrialization process. The last 10 countries are Ukraine, Moldova, Uzbekistan, Vietnam, Pakistan, Kyrgyz Republic, Tajikistan, Kenya, Cambodia and Nepal. Most of these countries are poor and backward countries in Central Asia, South Asia and Africa, and their economies are basically within the pre-industrial stage. In particular, the most energy-deficient or socially turbulent countries, such as Afghanistan and Nepal, had the lowest economic development level in the world.

From the point of view of ecological environment, the top 10 countries are Slovenia, Malaysia, Russia, Estonia, Korea, Croatia, Latvia, Spain, Germany and Portugal. In addition, the last 10 countries are Saudi Arabia, Northern Macedonia, China, Jordan, Moldova, Iraq, Pakistan, India, Kenya and Mongolia. Most of these countries are located in areas with the most intensive human activities and relatively fragile ecological environment. Moreover, due to the long-term industrialization and urbanization processes in these countries, the pollutant emissions are serious and the environmental pressure is huge.

Spatial Distribution

The spatial distribution of coupling coordination degree level along the Belt and Road indicates a spatially unbalanced feature, with significant regional differences (see Fig. 2). The geographical difference characteristics could be summarized: The high-value regions are concentrated in Central and Western Europe, and some developed regions in Northeast Asia and Southeast Asia. These countries are mostly developed economies with high development levels, and have largely completed the industrialization process. Their industrial structures rely mainly on finance, insurance, tourism, and other service industries with relatively low energy consumption and pollutant emissions, and high added value. The relatively advanced environmental infrastructures, strict environmental protection policies and regulations have been constructed in these countries, and the residents basically have a strong environmental protection awareness. The low-value regions are concentrated in West and Central Asia, Africa and a member countries of the Commonwealth of Independent States. These countries along the Belt and Road generally have the typical geographical features of abundant natural resources, complex topography, and fragile ecological environment. Their economic growth always mainly rely on natural resource consumption, and the regional contradiction between environmental protection and economic development has become increasingly prominent. Among them, Central and Western Asia and Russia Asian areas, with abundant energy resource endowments, have a huge development potential, where economic growth has mainly be depending on the exploitation and trade of natural resources for a long time. However, these regions shows a dominated initial developing stage feature with low technological level, low energy use efficiency, and high pollutants emissions. Then, the number of primary coordination (V3) and basic incoordination (V4) regions is the largest, relative to that of the other regions, mainly concentrated in the Northeast Asia, Central Asia, East Asia and South Asia. Additionally, no country belongs to high-level coordination (V1) and extreme incoordination

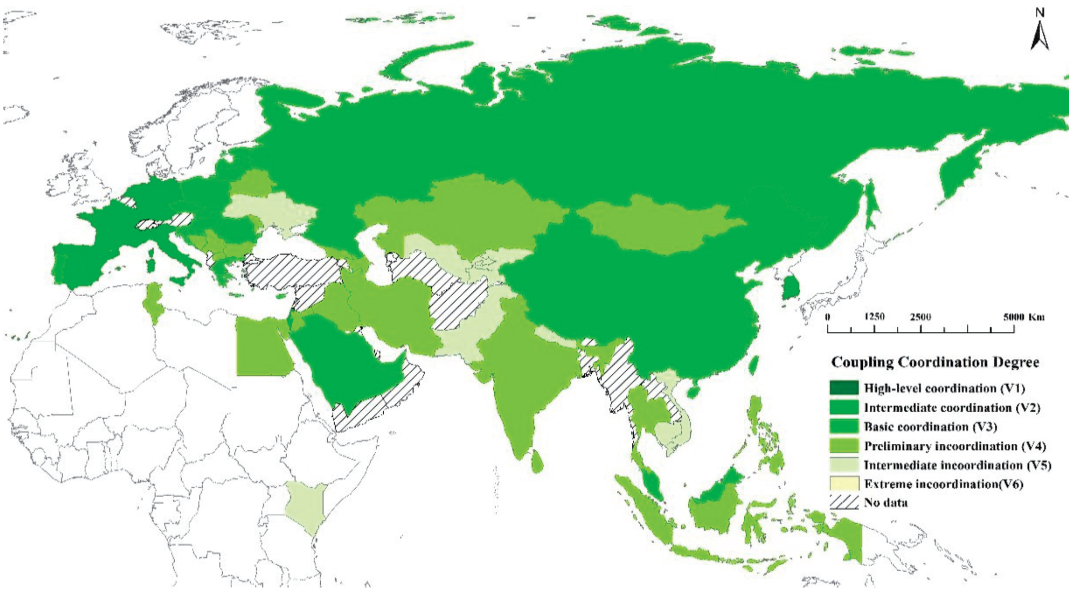

Fig. 2. Spatial distribution of coupling coordination degree.

Table 3. Sample countries along the Belt and Road.

Region	Country
Northeast Asia:	Mongolia, Russia, Korea, China
Southeast Asia	Singapore, Indonesia, Malaysia, Thailand, Vietnam, Philippines, Cambodia
South Asia	India, Pakistan, Sri Lanka, Nepal
West Asia and North Africa	United Arab Emirates, Saudi Arabia, Israel, Egypt, Iran, Jordan, Iraq, Azerbaijan, Georgia, Kenya, Tunisia
Central and Eastern Europe	Poland, Estonia, Lithuania, Slovenia, Bulgaria, Czech Republic, Hungary, Macedonia, Serbia, Romania, Slovakia, Croatia, Latvia, Bosnia Herzegovina, Ukraine, Belarus, Moldova, Spain, Portugal, Germany, Italy, Cyprus, Greece, France, Netherlands
Central Asia	Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan

Table 4. Coupling coordination Moran's I value.

Moran's *I*	Z score	P value
0.324	3.236	0.001***

Notes**:** *** denotes the statistical significance at 1% level, and the p value is obtained using Monte-Carlo simulation test for 999 times.

(V6). Overall, the region indicates a wholly increasingly coordinated development trend. This spatial pattern, on the one hand, is mainly due to the different economic development level between developed countries, developing countries and emerging economies along the Belt and Road, accompanied by the large regional differences in economic scale, economic structure, and industrial efficiency. On the other hand, the ecological and natural resource endowments, and the pollution pressure and environmental protection level, related with the various industrialization processes, vary significantly between numerous countries along the Belt and Road.

LISA Spatial Analysis

In order to observe the spatial agglomeration characteristics of various regions, the Moran's *I* index of the coupling coordination degree between economic development and ecological environment of 55 countries along the Belt and Road was calculated by GeoDa software. The value range of Global Moran's *I* is [-1, 1]. When $I>0$, it is indicated that there is a positive spatial correlation, namely, regions with a relatively high (or low) degree of coupling coordination between economic development and ecological environment system tend to be agglomerated significantly in space, and the correlation is strong. When $I<0$, it is indicated that there is a negative spatial correlation, that is, the coupling coordination degree between the region and the surrounding area has a spatial difference. When $I = 0$, it means that there is no spatial correlation and the geographical distribution is in a random state. As shown in Table 4, the global Moran's *I* index is 0.324. It rejects the null hypothesis at the 1% significance level and forms the high-high and low-low agglomeration

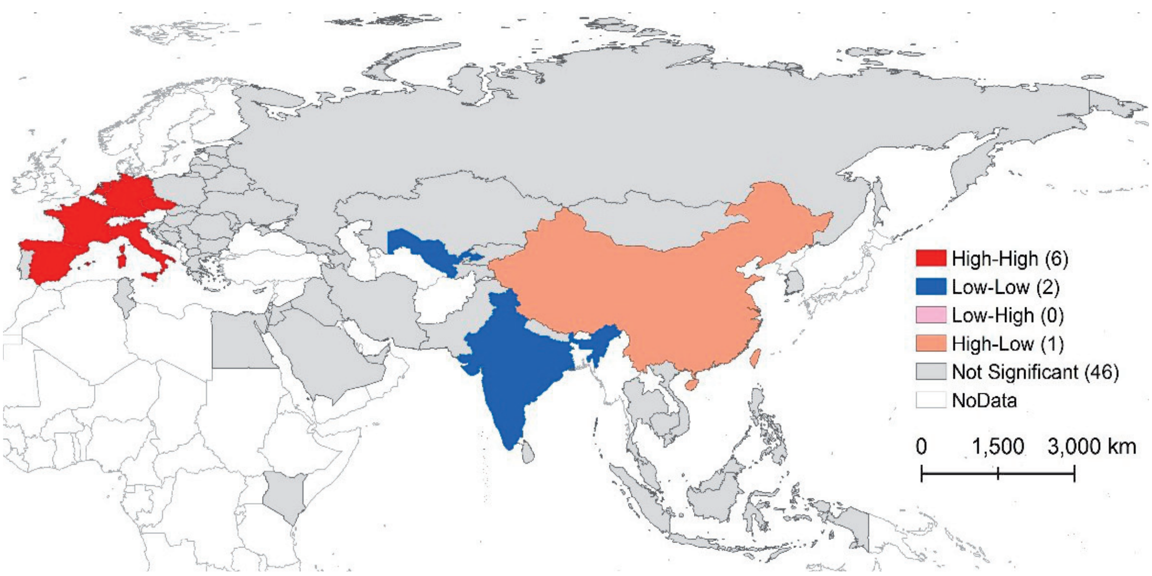

Fig. 3. LISA spatial autocorrelation.

status. This implies that the coupling coordination level of countries along the Belt and Road shows a strong positive spatial correlation feature.

Spatial differentiation of coupling coordination degree in countries along the Belt and Road is investigated based on LISA map (see as Fig. 3). In general, the level of coupling coordination degree presents at ladder-like distribution that descends from the west to the east. The high-high regions are mainly distributed in Central and Eastern Europe, and the spatial difference with the surrounding regions is small. It is shown that those countries in the Central and Eastern Europe have improved the green development level as a whole by emphasizing the coordination between economic development and environmental protection. Low-low regions are mainly distributed in West and South Asia, southeast of the Belt and Road, such as India and Uzbekistan. The coupling coordination degree of these areas and its surroundings are relatively low, and the spatial difference is also very small, and reduces the overall coupling coordination level. The aforementioned results reveals that the coupling coordination level between economic development and ecological environment of countries along the Belt and Road has the strong spatial autocorrelation and geographical heterogeneity distribution characteristics, and has developed into a relatively stable spatial pattern condition. The coupling coordination level descends from the west to the east along the Belt and Road and presents basically a spatial agglomeration feature.

Conclusions

The coupling coordination level between economic development and ecological environment of countries along the Belt and Road and the geographical distribution were studied based on coupling coordination degree model. Regions with relatively benign environmental-economic coordination degree are mainly concentrated in East Asia and Europe, with a good economic foundation and high per capita output. They pay more attention to the high-level coordinated development of economy, society, resources and the environment. Therefore, some effective experiences in water conservation, sewage treatment, and garden city and sponge city construction, in some emerging economies, such as Israel and Singapore, could be applicable to the sustainable development in the region.

Regions with serious pollution and low environment-economy coupling coordination level are mainly concentrated in Central Asia, West Asia, Africa, and the former CIS Countries, relying on huge economic aggregates and resource consumption to produce resource economic benefits for a long time, and the regional contradiction between environmental protection and economic development has become increasingly prominent. Their ecological environment infrastructure construction and industrial structure adjustment should be emphasized, such as the adjustment of the energy structure, which, in the long run, requires capital investment and technological upgrading. China could combine its own industrial advantages with the needs of the relative countries to build a green Belt and Road energy system, resorting to green energy technologies cooperation and the renewable energies investment joint projects. Some hydropower projects could be built in Southeast and South Asia countries, such as Laos and Pakistan, and EPC (Engineering Procurement Construction) projects can be carried out in African countries, to help these countries along the Belt and Road to establish green energy systems and energy-saving power systems.

Most ecological lag countries are located in the human activities intensive areas along the Belt and Road with a relative fragile ecological environment. And, the ecological and environmental problems accompanied by industrialization and urbanization have become the main obstacles to sustainable development for these countries. Meanwhile, the United Nations Environment Program, in its report, Green Waters and Clear Mountains are Gold and Silver Mountains: The Actions of China's Ecological Civilization, acknowledges China's achievements in ecological civilization construction and environmental promotion efforts. In this context, countries with continuously improving environmental protection capabilities, including China, could carry out the "Belt and Road" ecological environmental jointly protection projects, to provide the green public goods and spread green development ideology and experiences of ecological civilization to ecological lag countries along the Belt and Road.

Likewise, most economic lag countries pertain to low-income countries within the pre-industrial development stage in Central Asia, Indochina Peninsula and Africa, with an elementary industrial structure dominated by primary and tertiary industries. For these countries, poverty alleviation probably could still be the most important task for ensuring the green Belt and Road construction. Some Belt and Road related financial institutions, such as the Asian Infrastructure Investment Bank, the China-Eurasia Economic Cooperation Fund, and the Silk Road Fund could provide more financial support for their industry development and infrastructure construction, employment opportunities promotion, and drive economic growth in these countries. In addition, the jointly established Belt and Road poverty alleviation fund could be an effective resort.

The evaluation model proposed in this study could be applied quantitatively for the coordinated development analysis between the economic development and ecological environment along the Belt and Road region, combined with the entropy method and spatial statistics tools, and provide a reference to evaluate the sustainable development level and its geographical distribution for the sample countries. However, it will still be a long and ongoing process for the improvement of coupling coordination degree model. The regional environmental-economic system itself is of a dynamic and complex framework. Further evidence of technology, management and politics is still required to answer the question. With the establishment of environmental monitoring infrastructure and data acquisition, and promotion of environmental capacities in this region, environmental-economic coupling empirical issues need to be further investigated, in terms of index and mechanism.

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Conflict of Interest

The authors declare no conflict of interest.

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