Research on Urban Green Innovation Efficiency Measurement and Spatial-temporal Differentiation in Yangtze River Economic Belt Based on DEA-ESDA

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Abstract: With resource consumption and ecological deterioration, improving the efficiency of green innovation is seen as an important way to promote regional ecological civilization construction and promote high-quality economic development. Based on the SBM-undesirable model, the green innovation efficiency of 110 prefecture-level cities in the Yangtze River Economic Belt from 2012 to 2016 was measured. The coefficient of variation and ESDA were used to reveal the temporal and spatial evolution of the time and space. The results show that: ①From the evolution of time, the average value of green innovation efficiency of the upstream, midstream and downstream area of the Yangtze River Economic Belt is increasing gradually and the imbalance between regions is first improved and then aggravated; ②In terms of spatial evolution, urban green innovation efficiency The spatial polarization effect is gradually expanding; the global Moran's I shows a significant positive spatial correlation. Finally, it puts forward some measures such as aiming at the regional function, breaking the administrative barriers of regional green innovation spillovers, etc.

1. Introduction

As the Yangtze River Economic Belt of the country's “three major support belts”strategy, its population size, economic aggregate, innovative resources and innovative capabilities occupy an important position in China [1]. However, in the specific process of strategic advancement in recent years, the construction of the Yangtze River Economic Belt is facing the contradiction between rapid economic growth and limited environmental carrying capacity [2]. All regions are faced with different types of ecological problems [3].

At the beginning of 2016, General Secretary Xi proposed to repair the ecological environment of the Yangtze River Economic Belt in an overwhelming position. In March 2018, Premier Li also clearly pointed out in *the work report of the 19th National Government* that the development of the Yangtze River Economic Belt should be promoted with ecological priority and green development. In addition, green innovation is the fundamental path to adjust regional economic structure, transform economic development mode, and promote high-quality economic development.In view of this, studying the issue of green innovation efficiency in the Yangtze River Economic Belt region can provide theoretical support for the formulation of ecological protection policies in various regions, and it is also of great significance for promoting the ecological civilization construction of the Yangtze River Economic Belt and the high-quality development of the regional economy.

2. Data Sources and Research Methods

The research object of this study is 110 prefecture-level cities in the Yangtze River Economic Belt. In order to maintain data consistency, panel data of 110 prefecture-level cities from 2012 to 2016

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were selected. The research methods in this paper mainly include three methods: SBM-undesirable model, coefficient of variation and ESDA. Drawing on the research of relevant scholars, we have added energy input factors and undesired environmental output factors, and finally identified the following input and output indicators[4-7]:

①Input-type indicators: including labor input, capital investment and resource input to represent the degree of consumption of resources by innovative activities.

②Expected output indicators: including GDP, retail sales of consumer goods and patent applications, reflecting economic benefits, living standards and output of scientific research results.

③Unexpected output indicators: Industrial pollution is the main source of environmental pollution. Therefore, the undesired output indicators use industrial waste-water discharge, industrial smoke (powder) dust, and industrial sulfur dioxide emissions. And use the entropy weight method to comprehensively calculate an environmental pollution index, to illustrate the impact of innovation activities on the overall ecological environment.

The data is mainly extracted from the corresponding *Chinese Yearbook of Urban Statistics* and t*he Statistical Bulletin*. Finally get the following table 1:

Table 1. Input-output indicator interpretation

Indicator Attribute	Indicator Symbol	Indicator Name	Number of Samples	Evaluation Purpose
Input	X1	Average number of employees on the job (10,000 people)	550	Labor input
	X2	Fixed assets investment (ten thousand yuan)	550	Capital investment
	X3	Total water supply (10,000 tons)	550	Energy input
	X4	Electricity consumption in the whole society (10,000 kWh)	550	
Expected Output	X5	GDP (ten thousand yuan)	550	Economic benefit
	X6	Retail sales of social consumer goods (10,000 yuan)	550	Standard of living
	X7	Number of patent applications (10,000 pieces)	550	Scientific research results
Undesired Output	X8	Industrial waste-water discharge (10,000 tons)	550	Environmental pollution
	X9	Industrial sulfur dioxide emissions (10,000 tons)	550	
	X10	Industrial smoke dust emissions (10,000 tons)	550	

3. Empirical Results and Analysis

3.1 Time Evolution Analysis of Green Innovation Efficiency

First, the average and standard deviation of urban green innovation efficiency in each region from 2012 to 2016 are obtained. Secondly, the coefficient of variation is used to reflect the degree of difference in green innovation efficiency between the whole and the local area of the Yangtze River Economic Belt. Finally, the relevant trend map is drawn(Fig.1 and Fig.2). The results show that:

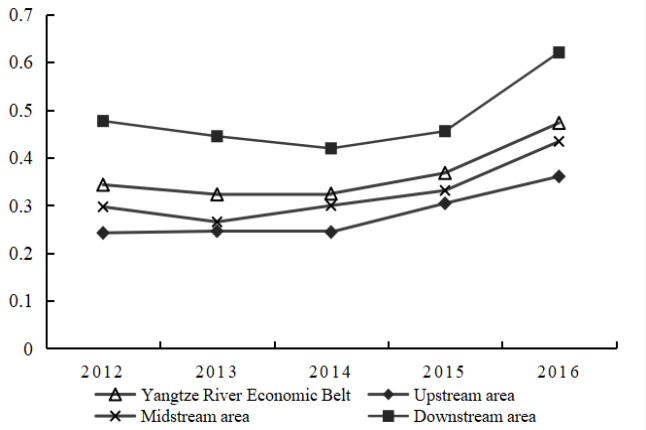

Fig 1. Green innovation efficiency mean change

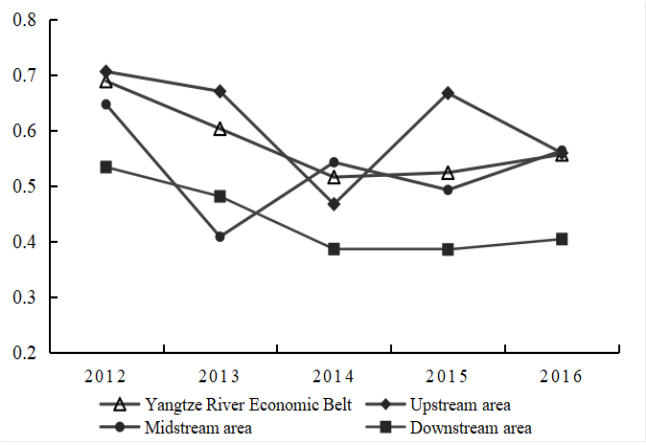

Fig 2. Line chart of coefficient of variation

①The average value of urban green innovation efficiency in the Yangtze River Economic Belt has a fluctuating upward trend, but the overall level is low.The trend of the average value of green innovation efficiency in each region is basically the same, and the overall trend is slightly fluctuating. From 0.34 in 2012 to 0.47 in 2016, the increase is close to 37.8%.

②The average level of green innovation efficiency in the upstream, midstream and downstream area of the Yangtze River Economic Belt has increased in a gradient.The gap between regions in 2012-2015 has slightly narrowed, but in 2015, it began to expand slightly. Until 2016, the average level of green innovation efficiency in the downstream regions reached 0.62, which was about 72.1% higher than the upstream and 43.0% in the middle. The situation is not optimistic.

③The imbalance of green innovation efficiency in various regions has improved in the early stage and then expanded.Imbalances improved in 2012 and 2013, but they have intensified since 2014. On the one hand, due to the fact that China's economy has entered a new normal state in 2014, the economic growth rate has slowed down; on the other hand, due to the different resource endowments, the positive effects brought about by the implementation of the Yangtze River Economic Belt policy are the positive effects brought about by the implementation of the Yangtze River Economic Belt policy are always obtained first in the downstream areas, while the relatively backward midstream and upstream area will be less obvious or later.

3.2 Spatial Evolution Analysis of Green Innovation Efficiency

This study uses ArcGIS 10.2 natural fault grading method to classify all prefecture-level cities into four categories: green innovation efficiency high level area, higher level area, lower level area and low level area.The evolution pattern of green innovation efficiency spatial pattern with 2012 and 2016 as research sections is drawn(Fig.3).

①There are differences in the evolution characteristics of the spatial pattern of green innovation

efficiency in the upstream, midstream and downstream area. Judging from the development and changes of green innovation efficiency in various regions, the downstream regions still maintain an absolute advantage in green innovation efficiency. In 2016, the green innovation efficiency of the upstream region has already appeared as a “dumbbell” development structure, which is also a typical “central collapse” phenomenon, which is due to the polarization effect of Chengdu and Chongqing[8]. The development of other small and medium-sized cities has been squeezed.In addition, the midstream cities failed to achieve the complementary of resource advantages and the formation of regional cooperation, and the average level of green innovation efficiency was lower.

②The number of four types of cities and their spatial distribution characteristics are different.The green innovation efficiency high level type area is mainly distributed in the upstream and downstream areas, while the midstream area is less, showing a “U-shaped” form. The number increased from 9 in 2012 to 30 in 2016, with an extension in both the upstream and downstream, while the midstream area stagnated.The distribution of higher-level areas is gradually spread from the downstream area to the upstream and midstream area. At the same time, the number of lower-level areas has decreased significantly from 2012 to 2016, but is still concentrated in the upstream and midstream area.

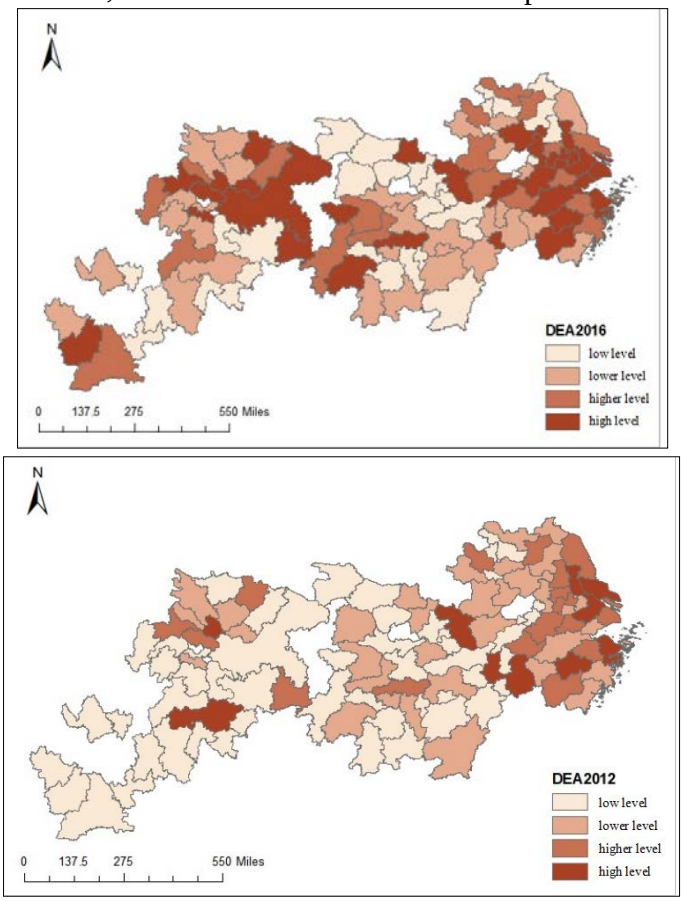

Fig 3. Spatial pattern of green innovation efficiency in 2012 and 2016

3.3 Green Innovation Efficiency ESDA Spatial Correlation Analysis

(1) Global spatial correlation analysis

With the improvement of infrastructure construction and improvement, the degree of openness and sharing of various regions has deepened, and the existence of spillover effects of knowledge and technology has promoted the spatial agglomeration of each region to some extent. In order to verify whether the green innovation efficiency of 110 prefecture-level cities in the Yangtze River Economic Belt has spatial correlation characteristics, this paper creates a second-order queen adjacent weight matrix in Geoda. Finally, the trend graph of the global Moran's I is obtained(Fig.4).

①There is significant spatial positive correlation. The space is agglomerated, indicating that the spatial innovation efficiency level of the Yangtze River Economic Belt has a relatively obvious

spatial auto-correlation spatial relationship, that is, spatial dependence.

②There is a change track of the inverted “V”shape.The global Moran's I index rose from 0.19 in 2012 to 0.28 in 2013, and then declined from 2014 to 0.22 in 2016, indicating that the positive agglomeration of this space is first strengthened and then gradually weakened[9].

③There are regional imbalances and high value clusters.The distribution of Moran's I scatter plots tends to be concentrated from the dispersion, and then from aggregation to large dispersion, indicating that the imbalance of green innovation efficiency in 110 prefecture-level cities in the Yangtze River Economic Belt still exists. And the points in the first quadrant have increased from 2012 to 2016, indicating that the high-value agglomeration of the entire region has increased.

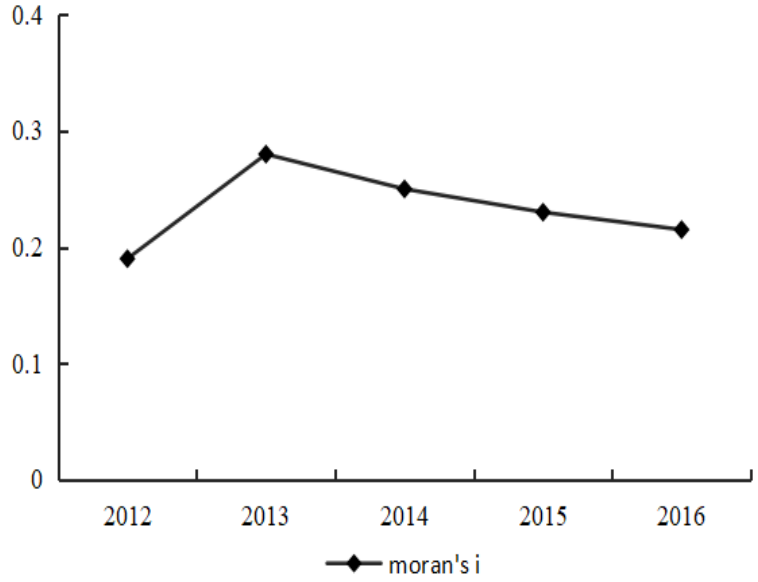

Fig 4. 2012-2016 global Moran's I dynamic change chart

(2) Local spatial correlation analysis

Taking 2012 and 2016 as research nodes, the LISA agglomeration map of green innovation efficiency of each city was produced in the same year(Fig.5), and the urban green innovation efficiency level of the Yangtze River Economic Belt was divided into four quadrants. The four quadrants corresponded to high spatial correlation(H-H), low high spatial correlation (L-H), low spatial association (L-L), and high and low spatial association (H-L).

①The spatial characteristics of green innovation efficiency evolved over time with varying degrees. Its agglomeration model has become more complicated, but in general it is high in the east and low in the middle and west.

②From the perspective of the degree of agglomeration, the number and scope of H-H and L-L have expanded, thus increasing the spatial polarization effect of urban green innovation efficiency in the Yangtze River Economic Belt.The polarized areas are mainly the major cities along the Yangtze River Delta and the main stream[10].It is directly related to the creation of the three growth poles in the “*Outline of the Yangtze River Economic Belt Development Plan*”proposed in 2016.The Yangtze River Delta urban agglomeration is regarded as the leader of the entire Yangtze River Economic Belt, which drives the development of the entire Yangtze River Economic Belt and plays a leading role in scientific and technological progress, institutional innovation, industrial upgrading, and green development. In contrast, due to the excessive radiation area in the midstream area of the Yangtze River, the impacts between cities are too scattered, and Industrial structure homogenization is serious, often showing greater competition. Relatively backward regions cannot compete for the resources needed for economic development, and strengthen the “Matthew effect” of regional development, which makes the midstream cities appear to have aggravated low-value agglomeration.

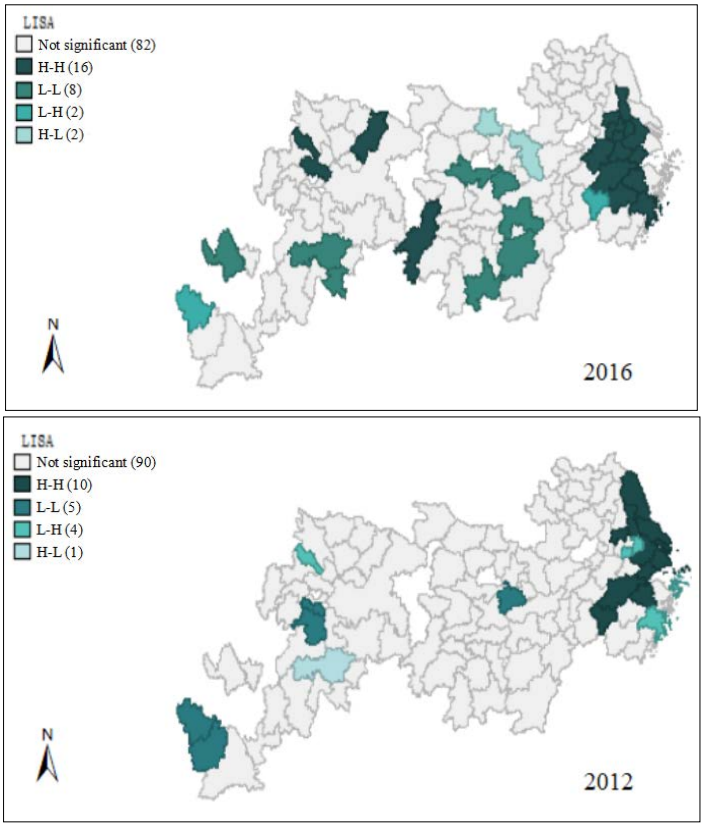

Fig 5. Lisa distribution map of urban green innovation efficiency in 2012 and 2016

4. Conclusion and Suggestion

This study has important policy implications for reducing the gap between regional green innovation efficiency and promoting the high quality development of regional economy in China:

① Targeting regional functional positioning and making differentiated decisions.There are differences in geographical location, resource endowment and industrial base in various regions. Therefore, it is necessary to rely on the functional orientation of each region, based on its own development stage, and adopt differentiated countermeasures to improve the green innovation efficiency of the entire Yangtze River Economic Belt.

② Breaking regional administrative barriers and promoting regional cooperation.For the downstream area with high green innovation efficiency, cooperation with the midstream and upstream area should be strengthened to break the market and institutional barriers of regional green innovation spillovers, expand the radiation scope and driving force of green innovation, and promote the orderly flow of green innovation input factors.

③ Actively transform government functions and strengthen environmental regulation.The governments of all regions must put the construction of ecological civilization in an overwhelming position, increase environmental protection efforts, introduce more effective resources and environmental management policies, and implement environmental regulation policies.At the same time, it encourages the support of industrial green innovation technology research and development, and gradually incorporates environmental indicators into the local official evaluation system to avoid neglecting green sustainable development in the technology research and development activities under the promotion of the championship.

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