Research on the Spatial Spillover Effect of Ecological Innovation Ability and Regional Economic Growth

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Abstract. This article using the spatial econometric analysis technology to build a space from the perspective of geographical feature weighting matrix, spatial correlation of the regional economic growth and integration, to explore the ecological innovation capacity and regional spatial spillover effect of economic growth, and using the spatial regression model decomposition of the partial differential method of actual effect based on 2009-2017 panel data from 29 provinces cities and autonomous regions in China. Based on the data of 29 provinces and cities in China from 2009 to 2017, this paper constructs the spatial weight matrix from the perspective of geographical features, establishes the spatial panel econometric model, and investigates the spatial correlation and clustering of regional economic growth uses spatial econometric analysis technology. We explore the spatial spillover effect of ecological innovation ability and regional economic growth, and uses the partial differential method of spatial regression model to decompose this effect. The results show that, firstly, China’s regional economic development is not balanced, and the economic development of neighboring regions is basically the same, which has a certain degree of spatial agglomeration and significant spatial correlation, and China’s economic growth has significant spatial heterogeneity. Second, the ecological innovation environment has a great spillover effect on the economic growth of neighboring regions, and the human resource level and capital investment have significant positive spillover effect between neighboring regions. The coefficient of ecological innovation output is significantly negative. Thirdly, the regional flows of capital input, labor force, the level of opening up, industrial structure and human capital not only have obvious direct effects, but also have a significant promoting effect on economic growth through the spatial spillover effect. The conclusion of this paper provides policy enlightenment for promoting sustainable economic growth among provinces and regions in China.

Keywords: Ecological innovation ability, Regional economic growth, Space spillover effect, Moran’s I index.
1. Introduction
In recent years, the contribution of ecological innovation to China’s regional economic growth has become more and more obvious with weakening of the driving effect of factor input and the increasing constraint of resources and environment. The report to the 19th National Congress of the Communist Party of China pointed out that ecological progress and green development should be highly valued and China’s ecological civilization and it will embrace new opportunities. In the critical period of economic transformation and development, while the economic growth of a province depends on local input and input from neighboring regions [1], spatial diffusion and transfer are more likely to occur due to the strong public goods characteristics of ecological innovation knowledge and technological achievements [2]. Therefore, the improvement of ecological innovation ability will not only directly affect the economic growth of the region, but also produce spillover effect on the surrounding region, and ignoring this kind of spatial spillover will lead to deviation in the evaluation of the effect of ecological innovation ability. So research on the spatial spillover effect of ecological innovation ability on regional economic growth should be carried out to expand the scope of spatial spillover effect as far as possible, so that more backward regions can enter the circle of spatial spillover of economic growth of developed regions, which is conducive to the realization that developed regions can drive backward regions and play an important role in promoting regional economic growth.

At present, scholars at home and abroad have done a great deal of research on regional economic growth from different perspectives, covering various aspects such as impact mechanism and spatial spillover effect. From the perspective of influence mechanism, existing studies have respectively discussed the specific impact of driving factors such as education [3], political instability [4], foreign direct investment [5], human capital [6], banking globalization and information and communication technology [7] on the quantitative indicators of economic growth, which providing a basis for clear the source of economic growth. From the perspective of spatial spillover effect, existing scholars have discussed the spatial spillover effect of network association [8], financial agglomeration [9-10], high-speed rail opening [11], knowledge spillover [12], industrial agglomeration [13] and non-performing loan [14] on economic growth. Therefore, the analysis of the spatial spillover effect of regional economy and surrounding areas provides a useful reference for the analysis of regional economic development level. However, it is not difficult to find that the spatial spillover effect between different regions has become an important force that cannot be ignored in regional economic development [15-16]. As one of the ways to improve the ecological environment, ecological innovation ability contributes to high-quality economic development [17]. However, when estimating the economic effect of ecological innovation ability, the direct effect and spillover effect of ecological innovation ability are still lacking.

Then, what effect does ecological innovation China will embrace new opportunities ability have on regional economic growth? How to effectively use the positive effect of ecological innovation ability to promote regional economic growth? These problems are not only the breakthrough point to study the benefits of ecological innovation in China at the present stage, but also the important to improve the allocation and utilization efficiency of resources. This paper research on the spatial spillover effect of ecological innovation ability on regional economic growth with the aid of the growth pole theory from 2009 to 2017 as the research time to accurately evaluate the effect of China’s ecological innovation ability on regional economic growth and provide the corresponding basis for scientific formulation of ecological innovation development policies and measures.

2. Theoretical analysis and modeling
2.1. Growth pole theory
The growth pole theory was first put forward by Perroux (1950), which believed that regional economic growth was caused by the unbalanced action of economic elements, which led to the emergence of a growth pole or growth center, and then spread to peripheral regions, finally driving the economic development of the whole region. The influence of growth poles on the surrounding areas is
produced by the trickle-down effect and polarization effect in opposite directions. The polarization effect is mainly in the early stage of growth pole development, the growth center quickly pulls the economic factors of the surrounding areas to gather and promote their own development, and “individual growth” appears. Trickle-down effect occurs in the middle and late stage of the development of growth poles. As the degree of agglomeration deepens and economic externalities strengthen, growth poles begin to export economic factors to the surrounding areas, and their radiation driving effect on the surrounding areas increases, leading to the overall prosperity. Trickle-down effect increases with the degree of agglomeration and economic externality which occurs in the middle and late stage of the development of growth poles. Growth poles begin to export economic factors to the surrounding areas, and their radiation driving effect on the surrounding areas increases, which leading to the overall prosperity. The spatial spillover effect of the economy can be understood as the result of the combined effect of economic factors and economic activities from the growth pole to the inward input and outward output. If the polarization effect is greater than the trickle-down effect, and the space overflow is negative, the development of surrounding areas will promote the development of growth poles. If the polarization effect is smaller than the trickle-down effect and is positive space overflow, the growth pole will greatly promote the development of surrounding regions and ultimately drive the economic development of the whole region [18].

2.2. Model setting

2.2.1. Spatial autocorrelation index. Spatial autocorrelation index. Moran’s I is mainly used for global correlation analysis, which is defined as:

\[ I = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (Y_i - \bar{Y})(Y_j - \bar{Y})}{S^2 \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}} \]

Where, \( I \) is Moran index; \( S^2 = \frac{1}{n} \sum_{i=1}^{n} (Y_i - \bar{Y})^2 \) is the variance of the attribute; \( \bar{Y} = \frac{1}{n} \sum_{i=1}^{n} Y_i \) is the average value of the attribute; \( Y_i \) represents the attribute value of an element in the i region; \( n \) is the number of regions studied; \( W \) is the weight matrix of space. The value interval of Moran index is \([-1, 1]\), greater than 0 means that the attribute distribution of things in the space has a positive correlation; Less than 0 means that the attribute distribution of things in the space has negative correlation; Close to 0 indicates that the attributes are randomly distributed and there is no spatial autocorrelation. When approaching 1, it means that similar attributes cluster together. Close to -1 means that disparate attributes cluster together. The Z value of Moran’s I exponent normal statistic represents the degree of spatial correlation. The greater the absolute value is, the greater the spatial correlation is, and vice versa.

2.2.2. Space panel model. (1) Spatial Lag Model (SLM): SLM refers to the spatial lag term of the explained variable added to the explanatory variable, and mainly discusses whether there are spatial overflow and diffusion effects on each variable. Its regression model is as follows:

\[ y = \lambda Wy + X\beta + \epsilon \]

Where, \( y \) is regional economic growth, \( \lambda \) is spatial regression coefficient, and \( \epsilon \) is random error term vector. Different from traditional OLS estimates, this model takes the multiplication of ecological innovation ability and spatial weight matrix as one of the explanatory variables.

(2) Spatial Error Model (SEM): Spatial dependence can be reflected not only in the influence on independent variables, but also through the error term. The regression form of the space error model is as follows:

\[ y = X\beta + \mu , \mu = \rho W \mu + \epsilon \]
Where, $\varepsilon \sim N(0, \sigma^2 I)$, $w_{i\mu}$ is the spatial lag error variable to measure the spatial dependence; $\varepsilon$ is the random error term vector; $\rho$ is the regression coefficient of spatial error to measured the impact of the error impact of the dependent variable in the adjacent region on the observed value of the region.

(3) Spatial Durbin Model (SDM): SDM model is the combination of the above two models, which considers not only the spatial correlation of dependent variables but also the spatial correlation of independent variables. In other words, the explained variables in this area are not only affected by their own explanatory variables, but also affected by the explanatory variables and the explained variables in the adjacent area. Its regression model is as follows:

$$y = \lambda Wy + X\beta + \delta WX + \varepsilon$$

Where, $\delta$ denotes the influence coefficient of regional observation values from other independent variables; $\lambda$ is the spatial autoregression coefficient, which is used to measure the influence of independent variables in this region on the observed values; $\varepsilon$ is the random error term vector, and the rest are the same as above.

In this paper, according to the methods of Anselin [19] et al., the common OLS model should be first used for regression analysis to obtain $LM$-lag, $R$-LM-lag, $LM$-error and $R$-LM-Error, and the applicability of the model should be judged according to their numerical values. Random effects or fixed effects are judged according to the test LR. According to Elhorst, [20] the spatial Durbin model was used as the starting point of the selected spatial measurement model for testing, and Wald test and LR test were used to determine whether it could be simplified into a spatial lag model and a spatial error model. The Hausman test was used to determine whether the random effect model or the fixed effect model. This paper combines the above two methods and selects according to the statistics of LogL, $AIC$, $SC$ and $R^2$ in the model regression.

In order to more comprehensively reflect the problems of regional economic growth, labor, capital, technology and foreign direct investment are introduced according to the production function proposed by Lucas, Rome, etc., thus the following spatial panel data model is constructed:

$$\text{Ln}y_{it} = \beta_0 + \beta_1 \text{LnR} & D + \beta_2 \text{Lnpatent} + \beta_3 \text{Lninvestment} + \beta_4 \text{Lnopen} + \beta_5 \text{Lnind} + \beta_6 \text{Lnedu} + \lambda \sum_{j=1}^{n} W_{ij} y_{jt} + \alpha_i + \gamma_t + \mu_{it}$$

where $i$ represents 29 provinces, $t$ represents the time change from 2019 to 2017, $y$ represents the economic growth of each region; $R&D$ represents the ecological innovation environment, $pulation$ represents the ecological innovation input, $patent$ represents the ecological innovation output, $rubbish$ represents the ecological effect, $investment$ represents the capital input, $open$ represents the level of opening to the outside world, $ind$ represents the industrial structure, and $edu$ represents the level of human resources. $\beta_1 \sim \beta_6$ is the coefficient of the explanatory variable; $\varepsilon$ represents the random disturbance term; $W$ is the weight matrix of space.

2.2.3. Space weight matrix construction. The weight matrix of geographical distance $W^d$ is used in this paper. The weight setting uses the reciprocal of the distance between the two provinces:

$$W_{ij}^d = \begin{cases} 1/d_{ij}(i \neq j) \\ 0,(i = j) \end{cases}$$

Among them, $d_{ij}$ is the surface distance of provincial capital city calculated by longitude and dimensional position.

2.3. Variable selection and data sources
This paper selects 29 provinces in China (considering the availability of data, the study does not include Tibet, Qinghai, Hong Kong, Macao and Taiwan), constructs a spatial econometric model, and
conducts spatial econometric analysis with Geoda software. All data in this paper are from China Statistical Yearbook, China Environmental Statistical Yearbook and China High Technology Statistical Yearbook.

(1) Explained variable: regional economic growth. Based on the viewpoints of Shuiyin Y and Lu W (2017)[21], Xiaofei L et al. (2018) [22], this paper adopts per capita GDP to reflect regional economic growth.

(2) Explanatory variable: ecological innovation ability. Based on the viewpoints of Lingyun H et al. (2017) [23], Shuiyin Y and Lu W (2017) [21], this paper adopts the ecological innovation environment, ecological innovation input, ecological innovation output and ecological innovation effect to measure the ecological innovation ability. Among them, ecological innovation environment is measured by the number of R&D research institutions, ecological innovation input is measured by the proportion of environmental pollution treatment investment in GDP, ecological innovation output is measured by the proportion of environmental pollution treatment investment in GDP, ecological innovation input is measured by the number of patents granted per 10,000 R&D personnel, and ecological innovation effectiveness is measured by the harmless disposal rate of household garbage.

(3) Control variables. Capital: According to Shuiyin Y and Lu W (2017) [21], fixed asset investment is adopted to measure capital. Labor force: measured by the number of people employed at the end of the year. The level of opening to the outside world: the viewpoints of Junhong B et al. (2017) [24] and Zhao Xiaoyu et al. (2018) [25] are adopted and measured by actual foreign direct investment. Industrial structure: based on the viewpoints of Hongyu P and Zhengchu H (2017) [26], the proportion of the added value of the tertiary industry in the GDP of the current year is adopted to measure. Human capital level: based on the point of view of Junhong B et al. (2017) [24], the average years of education of the population in all provinces is taken as the measure, and the current length of schooling is taken as the number of years of education as the weight, and the weighted average is carried out with the number of people with different educational levels.

3. Analysis of empirical results

3.1. Spatial Autocorrelation analysis of China’s regional economic growth

In order to investigate the spatial correlation and spatial agglomeration of regional economy, this paper draws a spatial quartile map of China’s regional economic growth by taking 2008, 2009 and 2017 as observation years. As can be seen from figure 1, China’s regional economic development is very uneven, and the economic development of neighboring regions is basically the same with a certain degree of spatial agglomeration. It can be intuitively found that China’s regional economic growth has significant spatial distribution characteristics.

![Figure 1. Quartile map of per capita GDP of 31 Provinces in China in 2008, 2015 and 2017.](image)

To verify the spatial characteristics of regional economic growth, this paper further studies the global spatial autocorrelation and local spatial autocorrelation analysis of regional economic growth. Cliff and word (1970) point of view, this paper, using Moran’s I index to describe the global spatial autocorrelation, 2009-2017 China’s regional economic Moran's I index value (table 1), can be concluded that, in nine years, the Moran’s I index is positive, its coefficients of volatility between
0.394 ~ 0.440, both passed the 5% significant probability test, it shows that China’s regional economic growth from 9 years has significant positive relationship between spatial correlation, provincial economic activity not from completely random state, however, with the influence of other regional economic behaviors with adjacent spatial characteristics, the agglomeration phenomenon appears in the geographical region.

Table 1. Changes of Moran’s I Index in per capita GDP from 2008 to 2017.

| per capita GDP | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2009 | 2009 | 2008 |
|---------------|------|------|------|------|------|------|------|------|------|------|
| Moran’s I     | 0.439| 0.411| 0.395| 0.394| 0.410| 0.420| 0.434| 0.440| 0.432| 0.432|

In order to further highlight the characteristics of China’s regional economic association, local Moran’s I index and local LISA cluster map are adopted to directly reflect the evolution process of China’s regional economic association model. This index is a good measure of the spatial correlation between \( i \) and \( j \) regions. The local Moran’s I scatter plot is usually used to analyze the local spatial instability. The four quadrants of the scatter plot correspond to four types of regional economic association.

![LISA of local autocorrelation of GDP per capita in 2008 and 2017.](image)

Based on the above principles, this paper draws the scatter plots of Moran’s I coefficient in China’s regional economy in 2008 and 2017 respectively (as shown in figure 2). As can be seen from figure 2, Moran’s I index varies from year to year, but most cities are located in the first and third quadrants. Among the 29 provinces in 2017, 6 provinces are in the first quadrant and 14 provinces are in the third quadrant. In other words, 68.96% of the urban economic growth in 29 provinces in China presents significant spatial correlation, which indicates that China’s economic growth has significant spatial heterogeneity. Representational to the region can be found, the regions with rapid economic growth are mainly located in coastal areas, while the regions with relatively weak economic development are mainly located in inland areas, and there are close spatial dependence and agglomeration characteristics among these regions. To more clearly describe the changes in economic development, we have drawn the local LISA agglomeration diagram of China’s regional economic association in 2011 (as shown in figure 3).

As shown in figure 3, the darker the color is, the higher the regional economic association is, and vice versa. On the whole, within the observed values, China’s economic association generally presents a development trend towards higher level, which is manifested in the reduction of double-bottom
associated cities, and the development space of regional economic association in China is relatively large. In 2008 and 2017, China’s economic relations were mainly high and low. More and more regional economic correlation degree is continuously strengthened, which promoting the development of regional economy.

Figure 3. Partial LISA agglomeration diagram in 2008 and 2017.

3.2. Analysis on the spatial spillover effect of regional economic growth

3.2.1. Regression model determination. In order to improve the accuracy of the regression results, the random effect (Model 1) and fixed effect (model 2) of the ordinary panel are firstly used for estimation in this paper, and the hausman test results show that fixed effect analysis should be used. Secondly, this paper adopts SEM (Model 3), SLM (model 4), SDM (Model 5) and SDEM (model 6) to estimate and analyze the spatial spillover effect of inter-provincial ecological innovation. The results show that all panel data should be estimated and analyzed using the random effects model. According to the judgment rule proposed by Anselin et al. (2004), natural logarithm was selected to test the fitting effect of the model. Two indexes, $R^2$ and log-likelihood, were combined to find that the SDM model has the best regression result of goodness of fit. Moreover, compared with SLM, SEM and SDEM, SDM model has more significant regression coefficients in terms of model fitting effect. Based on this, this paper adopts Matlab software and chooses the SDM model for analysis. The regression results are shown in Table 2:

We can be seen from the regression results in table 2, the level of human capital in each region has the greatest influence coefficient on the economic growth of provinces in China, and the coefficient is significantly positive. It suggests that the human capital level is still the main driving factors of the economic growth in China, that is, raising the level of human capital is helpful to promote the economic growth of each province. Labor force also plays a significant role in promoting regional economic growth, which further promotes regional economic growth by enhancing labor force and thereby increasing labor productivity [27]. The level of opening to the outside world is accompanied by the spread of production technology and operation and management concepts at home and abroad, which to a certain extent promotes the accumulation of regional knowledge and technology, and then promotes the provincial economic growth. With the spread of production technology and management concepts at home and abroad, the level of opening to the outside world promotes the accumulation of regional knowledge and technology to a certain extent, and then promotes the provincial economic growth.
Table 2. Spatial regression results.

| Explanatory variables | Model 1  | Model 2  | Model 3  | Model 4  | Model 5  | Model 6  |
|-----------------------|----------|----------|----------|----------|----------|----------|
| lnR&D                | -0.0073  | 0.0256   | 0.003    | 0.010    | 0.461    | 1.718*   |
| (-0.46)              | (1.75)   | (0.34)   | (1.28)   | (1.06)   | (2.26)   |          |
| lnPopulation         | -0.0331  | -0.430** | 0.005    | 0.001    | 0.002    | 0.004    |
| (-1.77)              | (-2.61)  | (0.68)   | (0.16)   | (0.18)   | (0.45)   |          |
| lnpatent             | 0.0197   | 0.0149   | -0.009   | -0.004   | -0.001   | -0.004   |
| (1.39)               | (1.12)   | (-1.46)  | (-0.57)  | (-0.13)  | (-0.41)  |          |
| lnrubbish            | 0.083    | 0.113**  | 0.011    | 0.044    | -0.018** | -0.017*  |
| (1.80)               | (1.12)   | (-1.46)  | (-0.57)  | (-0.13)  | (-0.41)  |          |
| lninvestment         | 0.348*** | 0.343*** | 0.146*** | 0.171*** | 0.002    | 0.292*** |
| (13.39)              | (14.51)  | (10.73)  | (11.50)  | (0.07)   | (0.07)   |          |
| lnlnemployment       | 0.0926   | 0.170*** | 0.0369** | 0.066*** | 0.167*** | 0.229*** |
| (2.41)               | (4.79)   | (2.35)   | (3.48)   | (11.56)  | (15.20)  |          |
| lnopen               | 0.102*** | 0.0979***| 0.019    | 0.056*** | 0.060**  | 0.100*** |
| (5.45)               | (4.57)   | (1.47)   | (4.95)   | (3.13)   | (4.33)   |          |
| lnlninvestment       | 0.238*   | -0.0210  | -0.305***| -0.185***| 0.015    | 0.016    |
| (2.83)               | (-0.25)  | (-6.63)  | (-4.29)  | (1.09)   | (1.07)   |          |
| lnlnopen             | 1.737*** | 1.252*** | 0.281*   | 0.360**  | 0.305*** | 0.213**  |
| (8.87)               | (6.49)   | (2.16)   | (3.37)   | (6.23)   | (3.88)   |          |
| w*lnR&D              | --       | --       | --       | --       | 0.478**  | 0.764*** |
| w*lnlnpopulation     | --       | --       | --       | --       | 0.026*   | 0.023    |
| w*lnlnpatent         | --       | --       | --       | --       | -0.017   | -0.009   |
| w*lnlnrubbish        | --       | --       | --       | --       | -0.010   | -0.018   |
| w*lnlninvestment     | --       | --       | --       | --       | 0.070*   | 0.045    |
| w*lnlnemployment     | --       | --       | --       | --       | 0.012    | 0.189*** |
| w*lnlnopen           | --       | --       | --       | --       | 0.017    | 0.104**  |
| w*lnlnind            | --       | --       | --       | --       | 0.031    | 0.056*   |
| w*lnlnedu            | --       | --       | --       | --       | 0.285*** | 0.292*** |
| Spatial rho          | --       | --       | --       | --       | 0.101    | 0.562    |
| Spatial lambda       | --       | --       | --       | --       | 0.101    | 0.562    |
| R²                    | 0.9306   | 0.9372   | 0.9943   | 0.9942   | 0.9949   | 0.9946   |
| Log-likelihood       | 323.28209| -10208.01| -887.58583| 381.42416|          |          |

Note: This table is calculated and sorted out by Matlab. The “t” statistic is in parentheses.

In terms of the influence of spatial lag term on regional economic growth, the ecological innovation environment in each region has a great spillover effect on the economic growth in neighboring regions, and secondly, the human resource level has a significant positive spillover effect between neighboring
regions. Capital input also has significant spatial spillover effect. However, the coefficient of ecological innovation output is significantly negative, mainly because of the spatial exclusivity of patent output between regions, and the lack of absorption and application capacity of some less developed provinces. However, the coefficient of ecological innovation output is significantly negative, mainly because of the spatial exclusivity of patent output between regions, and the lack of absorption and application capacity of some less developed provinces.

Since the regression coefficient of SDM model cannot directly reflect the influence of independent variables on dependent variables, direct effects, indirect effects and total effects need to be calculated. The values of the above three effects are shown in Table 3:

| Variable  | Direct effect | t    | P     | Spatial spillover effect | t    | P     | Total effect | t    | P     |
|-----------|---------------|------|-------|--------------------------|------|-------|--------------|------|-------|
| lnR&D     | 0.011         | 1.933| 0.266 | 0.056                    | 2.381| 0.024 | 0.067        | 2.337| 0.027 |
| lnpopulation | -0.007      | -0.623| 0.538 | -0.036                    | 1.145| 0.262 | -0.043       | 1.048| 0.303 |
| lnpatent  | -0.025        | -2.595| 0.015 | -0.042                    | 1.483| 0.149 | -0.067       | 1.866| 0.072 |
| lnrubbish | 0.028         | 1.090| 0.285 | 0.148                     | 2.529| 0.017 | 0.176        | 2.430| 0.022 |
| lninvestment | 0.206       | 12.432| 0.000 | 0.228                     | 5.155| 0.000 | 0.434        | 7.834| 0.000 |
| lnemloyment | 0.079       | 2.881| 0.007 | 0.111                     | 1.487| 0.148 | 0.190        | 1.943| 0.062 |
| lnopen    | 0.028         | 1.812| 0.080 | 0.0825                    | 1.948| 0.061 | 0.111        | 2.101| 0.044 |
| lndu      | -0.270        | -4.664| 0.000 | 0.219                     | 1.488| 0.148 | -0.051       | 0.274| 0.786 |
| lnedu     | 0.618         | 4.788| 0.000 | 0.797                     | 2.889| 0.007 | 1.415        | 4.241| 0.000 |

We can be seen from table 3, the direct effect and spatial spillover effect of ecology innovation environment, capital, labor, opening to the outside world level, industrial structure and human capital level are positive, it shows that the regional flows not only have obvious direct effects, but also have a significant promoting effect on economic growth by the spatial spillover effects. By observing the spatial spillover growth effect and total growth effect of capital input, labor force, opening-up level, industrial structure and human capital level, it can be found that: the spatial spillover effect of capital input, labor force, opening-up level and human capital level all accounted for more than 50% of the total growth effect, which further confirmed the important contribution of the spatial spillover effect of capital input, labor force, opening-up level and human capital level to China’s economic growth.

4. Conclusions and policy
This paper selects data from 29 provinces from 2009 to 2017, and empirically discusses the spatial spillover effect of ecological innovation ability on China’s economic growth by means of spatial econometric analysis. Studies have shown that: firstly, China’s regional economic development is very uneven, and the economic development of neighboring regions is basically the same with a certain degree of spatial agglomeration. Second, the economic growth of 29 provinces and cities in China presents significant spatial correlation, spatial dependence and agglomeration, and it indicates that China’s economic growth has significant spatial heterogeneity. Thirdly, the ecological innovation environment has a great spillover effect on the economic growth of neighboring regions, the human resource level and capital investment have significant positive spillover effect between neighboring regions. However, the coefficient of ecological innovation output is significantly negative, mainly because of the spatial exclusivity of patent output between regions, and the lack of absorption and application capacity of some less developed provinces. Fourth, the regional flows of capital input,
labor force, the level of opening up, industrial structure and human capital not only have obvious
direct effects, but also have a significant promoting effect on economic growth through the spatial
spillover effect.

Based on the above empirical analysis, efforts can be made in the following aspects to further
promote high-quality development of China’s economy: (1) To accelerate the release of the spatial
spillover effect of economic association between provinces and cities, as well as the flow of economic
factors and economic activities, and release the positive spillover effect of the economy between
provinces and autonomous regions. (2) We will promote economic development among provinces and
continue to promote urban development in China’s coastal regions, strengthen its role as a driving
force for surrounding cities, accelerate the development of small and medium-sized cities, and
improve the quality of economic development, so as to promote the overall coordinated development
of China’s economy. (3) In light of their own characteristics, all regions should give full play to their
advantages in science, technology, education and human resources, create an atmosphere of ecological
innovation, stimulate the vitality of ecological innovation, and realize the coordinated development of
economy and ecological environment. (4) We should effectively combine the spatial spillover effect of
ecological innovation and regional economic growth, for advanced regions with advanced technology
and strong ecological innovation capacity, policy making should focus on strengthening the awareness
of ecological innovation, creating a good innovation atmosphere, increasing investment in research
and development, and using local innovation advantages to maintain and promote economic
development. For the relatively backward technology, ecology innovation ability is weak in less
developed areas, policy should be to focus on ecological innovation skills training of relevant
personnel, improve the quality of the human capital overflow on the absorptive capacity and
strengthening regional space, and combining with the characteristics of the nature of the local industry
development and technology gap, geography space moving speed, timely appropriate use surrounding
areas spatial spillover effects.

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