# Regional Spatial Econometric Empirical Comparison for the Input and Output of Research and Development on Environment-friendly Innovation

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**Abstract**

With the economic growth and increasing improvements of supporting measures, the innovation, as well as research and development (RD) exhibit apparent output and spillover effects. By taking the patent grand in environment-friendly innovation and RD as a dependent variable, and the factors such as personnel and innovation capital of RD as independent variables, the empirical comparison and validation based on regional spatial econometric model were conducted. The results showed that environment-friendly RD presents a prominent positive implicative effect on the RD innovation output with spatial spillover. Meanwhile, the spatial error model is proved to be more convinced than spatial lag model and ordinary least square methods. Besides, this research also provides some suggestions and countermeasures for promoting further environment-friendly innovation RD and economic growth.

*Keywords*: Environment-friendly; RD Input; RD Output; Spatial Econometric

## 1 Introduction

With increasing development of socialism market economy system in China, supporting facilities and reasonable allocation of the resources in the fields of Science and education, culture and health have been gradually improved to support the rapid development of economy. As industrial economy continues to be put forward, environment-friendly RD has been the major goal of realizing low-polluting industry, and the research into production effects of environment-friendly innovation RD technologies is conducive for promoting the evolution of industrial planning adjustment to reasonable ecology development.

## 2 Literature Review

Since 1950s, Solow proposed a Solow's residual method which approximates to contribution analysis. Based on this method, the science and technology can accelerate the economic growth. In 1980s, Roemer considered knowledge and manpower capital as the key factors of promoting sustainable economic growth, and constructed endogenous growth theory by applying technology and innovation progress as impetuses of national economy; while, Krugman et al. in 1990s [1] , as a representative of new economic geography school, gradually put forward the escalation effects which forms scale economy and the economic growth in regional industry by integrating micro-enterprise innovation, the resource agglomeration of macro-economy, and exogenous effect of innovation.

Based on the economical development situations, the researchers in China conducted the studies on environment-friendly innovation and economic growth in the rapid economical developing areas including Yangtze River delta and Pearl River Delta. Cai Weidong, Wang Mei and Zhao Haixia [2] verified that the external economy property of rapid developing areas represented by Yangtze River delta has the effects on the efficiency improvement of environment-friendly RD for the regional microeconomic entities using quantitative analysis method for ArcGIS spatial division. Their research aimed to improve the innovation output and economic growth of regional economy; Wu Guisheng [3] confirmed that the great differences in the agglomerating distribution of regional innovation capabilities, and pointed out that the innovation inputs and outputs in environment-friendly RD for the science and technology in national level, coastal area and the main land were higher than regional economic growth ; Sheng Yanchao[4] used a backward induction method to construct a three-stages based independent innovation model concerning environment-friendly innovation by combining the restricting factors such as environmental tax and environment-friendly subsidy, validated that employing environmental taxes to replace the punishments to environment destruction contributed to increase the marginal efficiency of environment-friendly innovation in enterprises, and suggested that governments put forward further environment-friendly industrial innovation through environmental regulation. For the spatial correlation and environment-friendly innovation RD, Anselin considered that innovation aggregation could lead to that the attributes in spatial related units gradually produced common interest association. Li Guoping et al.[5] investigated the differences of regional innovation RD using the factors measurement of

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patents grand number based on vocational Gini coefficient, Moran I indexes and concentration degree; while Tu Hongxing and Xiaoxu[6] established a negative binomial model for the fixed effects of environment- friendly innovation based on the patent construction established by excessive decentralization examination, and proved that there was no win-win results obtained between environmental regulations and the U relation of Kuznets curve and Porter hypothesis. Meanwhile, regional differences were prominent in East and mid-west areas. By analyzing the Gini coefficients in environmental area, Wei Souhua, Zhou Jinji and He Yuan [7] confirmed that the aggregation trends, and association between innovation absorption capability of regional industrial technologies and environment-friendly preference of public policies and environment-friendly innovation effects. Peng Xuerong, Liu Yang, and Zhao Lilong [8] et al. determined innovation ranks, position and the environment-friendly innovating efficiency measuring standard in the ecological perspective. Based on dual externalities, they analyzed the spatial dimension and measuring standards concerning environment-friendly innovation in the view of ecological environment-friendly innovation.

In summary, the existing researches mainly focus on the contribution of environment-friendly innovation on regional economic growth, however, the studies on the spatial correlation between economic growth and the input and output of innovation factors such as environment-friendly RD input, manpower capital and patents have rarely been made. Aiming to solve this problem, this research performed an empirical comparative research by using the model.

## 3 Spatial Econometric Analysis for The Production Effects of Environment-friendly Innovation RD

### 3.1 CONSTRUCTION OF THE MODEL

Based on the analysis abovementioned , and the aggregation of the indexes including environment-friendly RD innovation and patent grand in each city, the correlation significance of corresponding indexes can be further studied. By integrating the spatial distribution characteristics of each variable, nonrandom spatial distribution law for the indexes can be verified to propose the countermeasures coping with the problems in the innovation input of environment-friendly RD.

It is generally known that spatial distribution of each sample is conducted the tests on the corresponding spatial **statistics** indexes, which mainly including **statistics** by considering the association of global spatial variables and the samples, the difference of regional samples. This is mainly because that the sample measurement values (-1~+1) based on Moran I is likely to be reportted. The results obtained show the prominent degree and direction of correlation. Based on the classification of Moran I **statistics**, the measurement values of corresponding sample present spatial aggregation in similar regions when the results are positive; While if the results are negative, it is indicated that the measurement values exhibit spatial separation in the similar regions as

$$\text{Moran I}=\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}W_{ij}(Y_i-\overline{Y})(Y_j-\overline{Y})}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n}W_{ij}} \quad (1)$$

When $S^2=\frac{1}{n}\sum_{i=1}^{n}(Y_i-\overline{Y}),\overline{Y}=\frac{1}{n}\sum_{i=1}^{n}Y_i,Y_i$ is taken as the value corresponding to ith unit, n is corresponding value to the unit; the spatial weights matrix is presented by $W_{ij}$ .

### 3.2 THE SPATIAL CORRELATION OF ENVIRONMENT-FRIENDLY RD PRODUCTION

To prove the accuracy of data, the input and output of environment-friendly RD innovation are usually assessed based on RD innovation personals, the scientific research papers, achievements, and funds, as well as all environment-friendly aspects such as the numbers of applied patents and patents grand, technological contracts assignment, and registration related indexes and the concerning environment protection. This research applies the professional talents storage in sample city as the input of environment-friendly RD, denotes as L; for the funds of environment-friendly innovation RD, they are not only correlated both with relevant expenditures in sequential years and the scientific research funds to some extent in past years. On the basis of the research by Wu Yanbing et al.( 2008), we performed indexes conversion using perpetual inventory method by integrating the effects of sequential years on the input of environment-friendly innovation RD.

$$K_{it}=(1-\delta)\times K_{i(t-1)}+I_{it} \quad (2)$$

Where $K_{it},K_{i(t-1)}$ correspond to the RD inputs of the sample points in current period and previous several periods. While $I_{it}$ denotes the input factor of the innovation RD for the *i* sampling area at t time sequence. According to the research, depreciation rate $\delta$ is proved to be 15%. The sampling data which are used to construct the model are selected from The Environmental statistics Yearbook in China, The statistics Yearbook in Yangtze River delta, The Statistics Yearbook in Heilongjiang province, Jilin province and Liaoning Province and Mid-West Statistics Yearbook during 2004 to 2013.

### 3.3 THE SPATIAL DIFFERENCES FOR THE RD PRODUCTION

Owing to the **econometric** characteristics of each spatial **econometric model** are not influenced by spatial correlation of environment-friendly innovation. Cobb-douglas(CD) function is used as basic model.

$$K_i=A_iRD^{\partial 1}Z^{\partial 2}e_i \quad (3)$$

$K$、$RD$、$Z$ refer to the integrated variables including the output, input and social economy of the innovation RD in sample points to be tested respectively; $e$ is random perturbation. Meanwhile, the spatial lag model and spatial error model are utilized to facilitate the Log-linear test of selected variables. The tested results are applied to validate the model and conduct the further research on correlation effects.

Compared with the basic model proposed in this research, existing researches mainly take OLS as typical model framework, so

$$\ln Y = \beta_0 + \beta_1 \ln K + \beta_2 \ln L + \sigma \quad (4)$$

$Y$, $K$, $L$ correspond to the patents output, RD innovation funds' input and the talents input respectively: regression parameters of each variable are $\beta_0$, $\beta_1$, $\beta_2$. $\sigma$ is the random perturbation of spatial difference for production effects of the innovation RD.

In this research, the section data of the sample points are acquired in 31 sample cities. Since the application, production and grand of patents are employed to measure the innovation productivity, the research and data show time delay to some degree. By referring the researches by Feldman &Forida (1994), Gao Lina and Li Xibao, the delays for the inputs and outputs are four, two and three periods respectively, this research finally determines that the delay for two periods is taken as the time sequence of the RD inputs of innovation production in the sample points of 11 cities abovementioned. Therefore, this study conducts the regression analysis on the patents grand and production manpower input in 2012 and the data relating to the innovation RD fees in 2010 using GEODA. As shown in Table 1, the RD spatial differences of ordinary least square methods (LSM), spatial lag model (SLM) and space error model (SEM) are reported.

TABLE 1 the econometric model concerning the spatial effect of the innovation RD

| variable | OLS | SLM | SEM |
|---|---|---|---|
| lnL | 1.92(0.84) | 3.57**(2.08) | 0.53(0.43) |
| lnK | 0.33(1.32) | 0.07(0.36) | 0.47**(3.72) |
| $W_y$ | 0.66**(2.76) | 0.61**(3.63) | 0.31**(3.11) |
| LAMBDA | | 0.21**(3.24) | 0.91***(16.87) |
| $R^2$ | 0.75 | 0.86 | 0.93 |
| Adj $R^2$ | 0.7 | | |
| Log L | -14.13 | -9.88 | -8.66 |
| AIC | 34.25 | 27.7 | 23.28 |
| SC | 36.57 | 30.77 | 25.60 |
| F-Value | 18.55** | | |

Judging from the regression results in the table 1, the spatial **econometric results obtained using** SLM and SEM show more advantages than that of LSM. The fitting results regarding the index $R^2$ are 0.86 and 0.93 respectively while the original value is merely 0.75. In addition, the corresponding spatial coefficients in both models are positive and pass the significant test of 1%. This result indicates that the indexes variables including patent grand for the cities with sample points present positive correlation with corresponding innovation output. The positive correlation index Moran I is confirmed. In comparison with verifying advantages of SLM, SEM and LSM in sample points regions in terms of environment-friendly innovation, general LSM is inferior to that of SEM and SLM in demonstration of correlation effects. Comparing with the regression validation results in this research, the goodness of whole fit $R^2$ in SEM is 0.93, while it is 0.86 in SLM; while the logarithmic likelihood value $LogL$ for the former is -8.66, while the latter is -9.88, they correspond to 23.28 and 25.60 in Akaike′s Information Criteria(AIC), lower than that of SLM. It is confirmed that SEM shows the advantages of verifying the input and output of environment-friendly science and technology compared with other **spatial econometric models**.

## 3.4 THE ESTIMATIONS OF THE INNOVATION SPILLOVER AND ABSORPTION CAPABILITY

Based on the industrial network situations, this research constructed a matrix for the transferring amount of the environment-friendly innovation spread corresponding to sequential years. The initial sequential matrix of the each parameters abovementioned is represented by $i$. It mainly illustrates the innovation quantity of other departments in industry. The production ratio of $i$ th department is the innovation quantity without concerning innovation spread. By summing the innovation quantities of above two departments, the innovation spread quantity in this department can be obtained. On this basis, the measuring standards for the degree and capability for the spillover and absorption of innovation transfer and spread in each department can be acquired.

As shown in Table 2, the domestic industries exhibit relative higher spillover and absorption capabilities for the innovation spread. Among which, the secondary and tertiary industries show higher spread and absorption capability on the environment-friendly innovation. The labor and capital-intensive industries are 1.0547and 1.1012 respectively. In the secondary industry including finance, the highest spread and absorption of the innovation capabilities in business service industry is reported to be lower than that of the primary industry. This phenomenon presents that the proportion for the absorption of production and technology through network increases step by step. The structural differences of effects in regional industry is mainly due to the effects of network transferring and spreading mechanisms on the environment-friendly innovation; while the region with high spillover capability and poor absorption ability has been the main sources of the innovation spread and spillover in each industry in whole area. Information service industry can be transferred from the role of spillover to the innovation absorption. This is attributed by the rapid developing information industry in the region in recent years. Besides, the supports to those industries lead to that IT industry has been developing into the important function of the innovation spread and spillover, characterized by knowledge-intensive industry.

TABLE2 The assessing indexing of the innovation spread capability

| Departments | Main innovation modes | | Capability conversion for the spread and spillover | | Capability conversion of the spread, spillover and absorption of innovation | |
|---|---|---|---|---|---|---|
| | 2002 | 2007 | 2002 | 2007 | 2002 | 2007 |
| Primary industry | P | P | 1.0618 | 1.3001 | 1.3957 | 1.9239 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Material | A | A | 0.4439 | 0.0519 | 0.9458 | 0.8211 |
| Energy | A | A | 0.5240 | 0.0350 | 0.5716 | 0.6329 |
| Secondary industry | A | A | 1.0611 | 1.2078 | 1.3718 | 1.9232 |
| Labor-intensive | A | A | 0.2104 | 0.0550 | 1.1146 | 1.0547 |
| Capital-intensive | A | A | 0.8378 | 0.1862 | 0.9619 | 1.1012 |
| Technology-intensive | P | A | 0.9649 | 0.0918 | 0.6148 | 0.8716 |
| Traditional service industry | A | A | 0.2354 | 0.4507 | 1.0063 | 1.0849 |
| Tertiary industry | P | P | 5.3429 | 12.2503 | 1.2389 | 1.0122 |
| Finance service | A | A | 0.0217 | 0.0100 | 1.2037 | 1.2014 |
| Business service | P | A | 1.6474 | 0.5796 | 1.5715 | 1.5217 |
| Science and technology Service | P | P | 55.9152 | 77.1781 | 0.8733 | 0.2121 |
| Information service | A | A | 0.0533 | 0.0557 | 1.2168 | 1.1616 |

Note: A and P refer to the external acquisition and internal RD for innovation.

### 3.5 STRUCTURAL QUALITY OF THE SPREAD AND SPILLOVER OF THE ENVIRONMENT-FRIENDLY INNOVATION

Based on the analysis above, those industries show the transfer, spread and spillover trends. By taking traditional service industry as an example, and repeatedly calculating the spillover effects, the condition for judging the innovation spread of industry innovation is $k = 0.00007$ . The characteristics of innovation spread and transfer can be obtained when the RD innovation input concerning innovation spread in $j$ department is equal or less 0.7 Yuan. The results are shown in Table 3.

TABLE 3 The network structural indexes for innovation spread

| Department | 2002 | | | | 2007 | | | |
|---|---|---|---|---|---|---|---|---|
| | Indegree | Outdegree | Relative centrality | Role hierarchy | Indegree | Outdegree | Relative centrality | Role hierarchy |
| Primary industry | 2 | 4 | 0.25 | Ordinary | 1.00 | 2.00 | 0.15 | Ordinary |
| Material | 4 | 5 | 0.50 | Ordinary | 1.00 | 0.00 | 0.05 | Terminal |
| Energy | 4 | 9 | 0.65 | Core | 1.00 | 0.00 | 0.05 | Terminal |
| Secondary industry | 4 | 8 | 0.61 | Ordinary | 1.00 | 2.10 | 0.14 | Ordinary |
| Secondary industry | 6 | 0 | 0.30 | Terminal | 2.00 | 0.00 | 0.10 | Terminal |
| Labor-intensive | 4 | 4 | 0.40 | Ordinary | 2.00 | 0.00 | 0.10 | Terminal |
| Capital-intensive | 6 | 9 | 0.70 | Core | 1.00 | 0.00 | 0.05 | Terminal |
| Technology-intensive | | | | | | | | |
| Traditional service industry | 4 | 8 | 0.70 | Core | 1.00 | 4.00 | 0.25 | Ordinary |
| Tertiary industry | 5 | 0 | 0.25 | Terminal | 1.00 | 0.00 | 0.05 | Terminal |
| Finance service | 3 | 1 | 0.25 | Ordinary | 2.00 | 0.00 | 0.10 | Terminal |
| Business service | 6 | 10 | 0.70 | Source | 1.00 | 10.00 | 0.55 | Source |
| Science and technology Service | 6 | 0 | 0.35 | Terminal | 3.00 | 0.00 | 0.15 | Terminal |
| Total Sum | 50 | 50 | | | 16.00 | 16.00 | | |
| Average degree | 4.55 | 4.55 | | | 1.45 | 1.45 | | |
| Variance | 1.87 | 17.07 | | | 0.47 | 9.67 | | |
| Standard deviation | 1.37 | 3.64 | | | 0.69 | 3.11 | | |
| Network density | 45.39% | | | | 14.54% | | | |
| Central potential | 0.51 | | | | 0.79 | | | |
| Distribution index | 0.021 | 0.02 | | | 0.041 | 0.61 | | |
| Hierarchy index | 0.31 | 0.65 | | | 0.18 | 1.02 | | |

To further carry out the network structural quality analysis for the spread and spillover of environment-friendly innovation in the regions selected, the each index density and average degree for the networks of the innovation spread and spillover are mainly analyzed. The results show that the conversion in 2007 is apparently lower than that of 2002. The conversion values $M$ and $P$ which denote the input and output for the network and index densities of the environment-friendly innovation nodes in 2002 and 2007 are 4.55, 1.45, 45.39% and 14.54% respectively. This results present that the technology innovation spillovers in same region are different with varied time sequences. The data indicate that the input and output in 2002-2007 increase by 58.12% compared with 1997-2001. Among which, the IT industry increases by 118.94%; the inputs of ordinary materials and energy decrease apparently. The regional economical growth scale factors involve from the input to the cooperation and innovation spread of enterprises. In each department of regional industry, the intensive degree for the benefits arising from the spread and spillover of innovation rises gradually.

## 4 Countermeasures

### 4.1 IMPROVEMENTS OF THE ASSOCIATION AND FUSION OF THE INNOVATION INPUT AND OUTPUT IN THE CITIES WITH REGIONAL SAMPLE POINTS

The prominent, positive correlation results obtained through the model demonstration and correlation verification indicate that the information interchange among different cities should be strengthened b ased on the spatial association of each city. The information share of the innovation talents and corresponding patent technology is expected to be realized step by step. If the conditions are allowed, platform construction for improving this system should be fulfilled. Moreover, the various innovation resources integration in domestic industrial structure adjustment needs to be enhanced to promote the opportunities and possibilities of cooperated innovations among different cities. Besides, this will reduce the repeated allocation resulting from the cooperation of different cities; consequently, the final production innovation of environment-friendly RD enterprises is greatly inspired.

### 4.2 THE SCALE AND EFFICIENCY OF THE INPUT ELEMENTS ALLOCATION FOR IMPROVING THE REGIONAL INNOVATION RD

Based on the results verified by SEM, it is press to accelerate the innovation manpower capital input in the innovation of industrial enterprises. So, by integrating practical production in industrial structure adjustment, the role of talents in the environment- friendly innovation production shall be greatly promoted; As an emerging industry, more attentions require to be paid on the RD talents and teams construction. It is suggested to provide more facilitates on policy, funds and relevant preferring measures so as to attract more talents to participate in the environment-friendly innovation of industry cluster; moreover, the skill and quality of ordinary staffs need to improve through trainings to improve the efficiency of each production innovation in whole production chain. In addition, the input of the innovation RD needs to be developed actively and stably. In this way, the high efficiency and scientific utilization of capitals and relating resources allocation is ensured with the sufficient talents. Furthermore, the enterprises are suggested to absorb the private capitals into the environment-friendly RD so as to promote full development of enterprises'' innovation production.

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