Research on the Spatial Effect of Green Economic Efficiency in China from the Perspective of Informatization

Xinbao Tian (tianxinb@126.com)
Shanxi University https://orcid.org/0000-0001-8984-627X
Chuanhao Yu
Shanxi University

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Research on the Spatial Effect of Green Economic Efficiency in China from the Perspective of Informatization

Xinbao Tian * Chuanhao Yu

School of economics and management, Shanxi University, Taiyuan 030006, China

* Correspondence: tianxinb@sxu.edu.cn.com; Tel.: +86-351-7010500

Abstract:

Background: Green economy has been paid more and more attention in the information age. Informatization plays an important role in the development of green economy by the transmission of industrial structure rationalization and upgrading. Because of the spatial mobility of information, it is necessary to study the spatial spillover effect of information on the efficiency of green economy. In this paper, the non-radial directional distance function and the comprehensive index method are used to evaluate the efficiency of green economy and informatization respectively. On this basis, the spatial characteristics of the two are analyzed. Finally, the spatial econometric model is used to analyze the spatial impact of informatization on the efficiency of green economy.

Results: The following findings can be drawn: (i)The spatial distribution of the green economy efficiency and informatization are unbalanced; (ii) There is a significant spatial spillover effect in the efficiency of green economy; (iii) The development of informatization plays an important impact on the efficiency of green economy.

Conclusions: It can be seen that informatization plays an important role in the development of green economy, so we can get the following suggestions: (i) Developing green economy according to different conditions of different places. (ii) Establishing regional coordination mechanism of green economic development. (iii) Using informatization to promote the development of green economy.

Keywords: Green Economy Efficiency; Informatization; Spatial Econometric Model

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1. Introduction

The traditional development mode of industrialization is high-input and high-output. However, the rapid growth of the world economy also brings a series of resource consumption and environmental pollution problems, and the environmental carrying capacity is in the period of overload. In order to solve this crisis, the Chinese government promotes the green transformation of the economy by means of strengthening investment in environmental pollution control, eliminating backward production capacity and promoting green consumption. The Chinese government has raised the construction of ecological civilization to the national level, indicating the necessity and firmness of the construction of ecological civilization. Smart cities, mobile payments, high-speed railways, the low-carbon economy, and green development are now synonymous with social and economic development in the new era [1].

Information has become an equally important strategic resource for energy and new materials in the era of information economy. The development of informatization can not only save energy, improve production efficiency, optimize and upgrade the structure, but also improve production capacity to promote economic development. Informatization has become an important factor to promote economic development. Green development has become the main theme of economic and social development, and informatization has a unique correlation and driving role in green development. The reason why informatization promotes the development of green economy is mainly due to the following reasons: (i) Informatization provides the resource base for the sustainable development of green economy. With the progress of information technology and the industrialization of its achievements, people's ability to use information as an intermediary to allocate resources is constantly enhanced, and the utilization rate of resources is greatly improved, which provides a material basis for the sustainable development of green economy; (ii) Informatization promotes the development of new industries in green economy. The penetration of information technology into various industries has led to the development of high-tech such as biotechnology, marine technology, space technology, etc., which has promoted the mature industrial economy to the information economy and further to the knowledge economy[2]; (iii) Informatization promotes the green development of traditional industries. With the revolutionary change of information development, application and transmission, information technology can effectively reduce the operation cost of the whole society, greatly improve the efficiency, promote energy conservation and consumption reduction, and provide strong support for the green development of traditional industries.

The term "green economy" was first proposed by David Pierce, the British environmental economist, in the blue book of green economy in 1989, who stressed that economic development should not be at the expense of environmental pollution[3]. Subsequently, many green economists extended their views to the direction of social ecology, holding that human beings should respect the constraints of social and ecological conditions, and emphasize that economic development should be affordable[4]. The International Green Economy Association defines green economy as a kind of economic development model to guide the transformation of human social form from "industrial civilization" to "ecological civilization", which includes the direction of achieving economic development, social progress and environmental protection, the basis of the low-carbon development, green development and circular development of industrial economy and the form of sustainable development in which resource conservation, environmental friendliness and economic growth are in direct proportion[5]. Yu et al. proposed that green growth can be divided into relative green growth and absolute green growth. Relative green growth means that in the process of economic growth, the efficiency of resource utilization is improved, but the total amount of resource consumption and the quality of ecological environment are not necessarily improved. Absolute green growth means that not only the efficiency of resource utilization is improved, but also the total amount of resource consumption is reduced, and the ecological environment is improved[6]. The evaluation of green economic development has also been launched, such as some scholars evaluate green economy by using an integrated indicator based on the methodology of Rudneva[7-9]. However, whether and how the green economy promotes the construction of China's ecological civilization still needs to be verified by theoretical and practical analysis. Wang et al. used super efficiency DEA model to calculate the efficiency of China's regional green economy, using GMM model to verify that environmental regulations have different characteristics on the national samples and the eastern, Western and eastern regions of the green economy [10]. Ren et al. used the SBM model to calculate the provincial green economic efficiency, and used the spatial Durbin model to analyze the influencing factors of the provincial green economic efficiency, proving that there was a significant spatial spillover effect [11].

With the continuous development of information technology, countries are actively seizing the new round of development opportunities of information technology. The application of mobile Internet, e-commerce, cloud computing, big data and artificial intelligence has not only further developed the global information society, but also brought new vitality to economic development. In 2017, the global "information society index" was 0.5748, while it was 0.4749 in China, which was in the accelerating transition period from industrial society to information society.More and more researches focus on the relationship between informatization and economic and social development, the spatial relationship of informatization and its influencing factors. The research mainly includes three aspects as follow:

(i) Research on the level of information development. From the existing research results, the research on measuring the level of information technology has been a long time, mainly including

Markrup's macro information economy measurement theory, Borat's information economy measurement algorithm, EOS economic information activity correlation analysis method, Komatzaki index method, International Telecommunication Union (ITU) index, etc. Most studies focus on the comparison of macro scale, while the index system is relatively imperfect. Li et al. evaluated the development level and regional distribution of China's informatization by establishing an informatization index system composed of 19 specific indicators and using the mean square deviation weight method[12].

(ii) Research on the impact of information development on economy. Through the theoretical and empirical analysis of the contribution of information industry to economic growth, Some scholars believed that accelerating the development of information industry as a new economic growth point would play an important role in promoting the sustainable development of national economy[13-15]. Xu et al. found that there was a threshold effect in the impact mechanism of informatization development level on the spillover process of foreign direct investment[16]. Through the econometric analysis of informatization and economic growth, Liu found that informatization had become the main growth pole to promote the sustainable and rapid development of China's economy by the econometric analysis of informatization and economic growth, and the higher the level of informatization, the more significant the role of promoting regional economic growth[17].

(iii) Research on the spatial effect of informatization on economic development. Yan et al. found that there was a significant regional imbalance in the development of informatization in China by studying the evolution trend, dependence degree and mutual effect of the spatial correlation of informatization in each province of China. With the passage of time, the regional differences gradually narrowed, the information correlation became increasingly close, and the mutual influence gradually increased[18]. Yan et al. used the spatial regression partial differential method proposed by Lesage and Pace[19] to empirically test the significant positive spatial correlation between China's informatization development and regional economic growth[20].

It can be seen that the measurement of green economic growth can reflect the current situation and process of economic green development. From the perspective of informatization, the research on the spatial distribution of green economy will have a certain guiding significance on how to play the role of information technology in the development of green economy. From the existing literature, the research focuses on two relatively independent fields: informatization and green economy. The evaluation of green economic efficiency is mainly measured by TFP, SBM and other models[21-24]. At the same time, the measurement of non-radial direction distance function mostly uses outdated data for analysis. Although there are studies on the impact of informatization on economic development, there are relatively few studies on the impact of informatization on green economy. In order to reveal the impact of informatization on the spatial distribution of green economic efficiency, this paper will do the following work: (i) Measuring the development efficiency of green economy and the development level of regional informatization. Based on the panel data of 29 provinces in China from 2008 to 2017, this paper constructs the green economic growth measurement index by using non-radial distance function, considering the three basic connotations of green economic growth, economic growth, resource conservation and environmental improvement. In the measurement of regional informatization development level, the "comprehensive index method" is used to measure the information society index, which includes four secondary indexes: information economy index, network society index, online government index and digital life index. (ii) Using Moran's I and Moran's I scatter plots to analyze the spatial agglomeration characteristics of green economic development and informatization. The overall spatial agglomeration of 29 provinces and cities in China is analyzed by Moran's I index, and the local agglomeration of each province is analyzed by Lisa scatter diagram. (iii) Analyzing the spatial effect of informatization on the efficiency of green economy. Firstly, this paper analyzes the mechanism of the impact of informatization on the efficiency of green economy by two intermediary variables of industrial structure upgrading and industrial structure rationalization.

Secondly, the spatial econometric model is selected from SLM, SEM and SDM. Finally, the spatial effect of informatization on the efficiency of green economy is empirically analyzed.

The remainder of this paper is structured as follows. Section 2 is the measurement method and analysis of green economic efficiency. Section 3 is the evaluation and analysis of informatization index. Section 4 is the spatial agglomeration characteristics of green economy efficiency and informatization. Section 5 is the spatial econometric analysis of the impact of informatization on the efficiency of green economy. Section 6 is the conclusions, suggestions and limitations.

2. Measurement of Green Economic Efficiency

2.1 Selection of variables and measurement of green economy efficiency

In this paper, panel data sets of 29 provinces from 2008 to 2017 are used for analysis. The input factors, expected output and unexpected output data are as follows:

(a) Capital deposit investment. The total amount of fixed assets of the whole society is taken as the capital deposit of the year. In this paper, the international perpetual inventory method is used to estimate the capital stock of each year. The formula is as follows:

$$K_{it} = I_{it} + \left(1-\delta_i\right)K_{it-1} \tag{1}$$

Where K_{it} is the capital deposit of region i in year t; I_{it} is the fixed asset investment amount in year t of region i; δ_i is the capital depreciation rate of region i.

According to the research method of Young, for the base period capital deposit, divide the initial year investment amount by 10% as the base year capital deposit[25]. The depreciation rate refers to the average depreciation rate of each province in 1995-2009 in Xiang [26]. Fixed assets investment amount is reduced to 2008 by adopting investment price index.

(b) Labor input. Annual labor input adopts the number of employees at the end of each province.

(c) Energy input. Lin proposed that the data of electricity consumption automatically recorded by electricity meter is more accurate, and there is a high correlation between electricity consumption and energy consumption[27]. In this paper, the electricity consumption of each province is used as an indicator to measure energy.

(d) GDP. This paper uses the nominal GDP and GDP index of each province to calculate the real GDP of each province based on the constant price in 2008.

(e) Soot emissions amount. The amount of smoke and dust in each province.

(f) Sulfur dioxide emissions amount. In this paper, sulfur dioxide emissions of each province are used.

(g) Wastewater discharge amount. Considering that industrial production is only a part of production activities, this paper adopts the total amount of waste water discharged in each province.

2.2 Green economy efficiency measurement model

To construct the function of measuring green economic efficiency, we need to consider multiple input variables and multiple output variables, and take into account the production results that there is a certain degree of association between the expected products and the unexpected products such as pollutants. In this paper, the distance function of DEA method is used to measure the green economic efficiency. Combined with the actual situation of China, the production technology with capital (K), labor (L) and energy (E) as input variables, GDP (Y) as expected output variables, and "three wastes" - smoke (D), sulfur dioxide (S) and waste water (W) as unexpected output variables is as follows:

$$P=\{(K, L, E, Y; D, S, W) : (K, L, E) \text{ can produce } Y \text{ and undesired output } D, S, W\} \quad (2)$$

In addition to meeting the basic axioms of production function theory, it is also assumed that the production technology set P should meet the following conditions: first, the joint set of expected output and unexpected output needs to meet the weak disposability, which characterizes the cost of pollutant emission reduction; second, the zero intersection of expected output and unexpected output indicates that pollutants are inevitable in the production process. That is:

$$\text{① If } (K, L, E, Y; D, S, W) \in P \text{ and } 0 \le \theta \le 1, \text{ then } (K, L, E, \theta Y, \theta D, \theta S, \theta W) \in P;$$

$$\text{② If } (K, L, E, Y; D, S, W) \in P \text{ and } D, S, W = 0, \text{ then } Y = 0.$$

Next, the distance function is defined, and the non-radial direction distance function is constructed with reference to Zhou et al.[28].

$$\overrightarrow{ND}(K,L,E,Y,D,S,W;\mathrm{G})=\sup\left\{w^T\beta:\left((K,L,E,Y,D,S,W)+g\bullet\mathrm{diag}(\beta)\right)\in P\right\} \quad (3)$$

Where $w=(w_K,w_L,w_E,w_Y,w_D,w_S,w_W)^T$ is the weight vector, $\beta=(\beta_K,\beta_L,\beta_E,\beta_Y,\beta_D,\beta_S,\beta_W)^T\ge 0$ is relaxation variable, $g=(g_K,g_L,g_E,g_Y,g_D,g_S,g_W)$ is the direction vector, $\mathrm{diag}(\beta)$ represents diagonalization of vector β.

According to Zhou et al., it is reasonable to treat all elements equally without any other prior information. Therefore, input element, expected output and unexpected output account for 1/3 of each[29]. Lin et al. proposed the construction of energy and environmental efficiency indicators, where capital and labor should keep unchanged, and the proportion of energy input and unexpected output should be reduced as much as possible, and the expected output should be expanded as much as possible[30]. Therefore, the weight of energy elements is 1/3, and the weight of dust, sulfur dioxide and waste water in the unexpected output is 1/3, and the weight vector of each index is $w=\left(0,0,\frac{1}{3},\frac{1}{3},\frac{1}{9},\frac{1}{9},\frac{1}{9}\right)^T$. The direction vector corresponding to the weight vector is defined as $g=(0,0,-\mathrm{E},\mathrm{Y},-\mathrm{D},-\mathrm{S},-\mathrm{W})$. Establish the following model:

$$\overrightarrow{ND}\left(K,L,E,\mathrm{Y},\mathrm{D},\mathrm{S},\mathrm{W}\right)=\max\left\{\frac{1}{3}\beta_E+\frac{1}{3}\beta_Y+\frac{1}{9}\beta_D+\frac{1}{9}\beta_S+\frac{1}{9}\beta_W\right\}$$

$$\begin{aligned}
s.t.\ &\sum_{i=1}^{N}\sum_{i=1}^{T}\lambda_{i,t}K_{i,t}\le K,\quad \sum_{i=1}^{N}\sum_{i=1}^{T}\lambda_{i,t}L_{i,t}\le L,\quad \sum_{i=1}^{N}\sum_{i=1}^{T}\lambda_{i,t}E_{i,t}\le E-\beta_E\,\mathrm{g}_E\\
&\sum_{i=1}^{N}\sum_{i=1}^{T}\lambda_{i,t}Y_{i,t}\le Y+\beta_Y\,\mathrm{g}_Y,\qquad \sum_{i=1}^{N}\sum_{i=1}^{T}\lambda_{i,t}D_{i,t}=D-\beta_D\,\mathrm{g}_D\\
&\sum_{i=1}^{N}\sum_{i=1}^{T}\lambda_{i,t}S_{i,t}=S-\beta_S\,\mathrm{g}_S,\qquad \sum_{i=1}^{N}\sum_{i=1}^{T}\lambda_{i,t}W_{i,t}=W-\beta_W\,\mathrm{g}_W\\
&\lambda_{i,t}\ge 0,\ \ \mathrm{i}=1,2,\ldots\ldots,\mathrm{N},\ \ \mathrm{t}=1,2,\ldots\ldots,T,\ \ \beta_E,\beta_Y,\beta_D,\beta_S,\beta_W,\ge 0
\end{aligned}\tag{4}$$

The optimal solution $\beta^*=\left(\beta_E^*,\beta_Y^*,\beta_D^*,\beta_S^*,\beta_W^*\right)^T$ can be obtained by substituting the input and output data into formula (3). If region *i* achieves optimal production in year *t*, the target values of energy input, expected output and unexpected output are $E_{it}-\beta_{E,it}^*\times E_{it},\mathrm{Y}_{it}+\beta_{\mathrm{Y},it}^*\times\mathrm{Y}_{it},D_{it}-\beta_{D,it}^*\times D_{it},S_{it}-\beta_{S,it}^*\times S_{it},W_{it}-\beta_{\mathrm{W},it}^*\times W_{it}$ respectively. The GEPI (green economy performance index) of region *i* in year *t* can be further calculated as follows:

$$\begin{aligned}
GEPI_{it}=&\frac{1}{2}\Big(\frac{\left(E_{it}-\beta_{E,it}^*\times E_{it}\right)/\left(\mathrm{Y}_{it}+\beta_{\mathrm{Y},it}^*\times\mathrm{Y}_{it}\right)}{E_{it}/Y_{it}}\Big)+\frac{1}{2}\Big(\frac{1}{3}\frac{\left(D_{it}-\beta_{D,it}^*\times D_{it}\right)/\left(\mathrm{Y}_{it}+\beta_{\mathrm{Y},it}^*\times\mathrm{Y}_{it}\right)}{D_{it}/Y_{it}}+\\
&\frac{1}{3}\frac{\left(S_{it}-\beta_{S,it}^*\times S_{it}\right)/\left(\mathrm{Y}_{it}+\beta_{\mathrm{Y},it}^*\times\mathrm{Y}_{it}\right)}{S_{it}/Y_{it}}+\frac{1}{3}\frac{\left(W_{it}-\beta_{\mathrm{W},it}^*\times W_{it}\right)/\left(\mathrm{Y}_{it}+\beta_{\mathrm{Y},it}^*\times\mathrm{Y}_{it}\right)}{W_{it}/Y_{it}}\Big)\\
=&\frac{\frac{1}{2}\left(1-\beta_{E,it}^*\right)+\frac{1}{2}\left(\frac{1}{3}\left(1-\beta_{D,it}^*\right)+\frac{1}{3}\left(1-\beta_{\mathrm{S},it}^*\right)+\frac{1}{3}\left(1-\beta_{\mathrm{W},it}^*\right)\right)}{1+\beta_{\mathrm{Y},it}^*}
\end{aligned}\tag{5}$$

The higher the Gepi, the better the performance of energy and environment.

2.3 Result and Analysis of Green Economic Efficiency

The original input-output data of green economic efficiency in this paper are all from *the China Statistical Yearbook* published by the National Bureau of statistics, in which GDP is converted into the base period in 2008, and the capital deposit is accounted by the perpetual inventory method. In this paper, the regional classification standards combined with geographical location and economic development level are selected. Specifically, the three regional classifications of the East, the middle and the West are the commonly used 11:8:12 classification standards in national statistics[31]. In this paper, Maxdea software is used to calculate the green economic efficiency of each province. The results are shown in Table 1.

Table 1. Green economic efficiency of 29 provinces in China from 2008 to 2017

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Beijing	0.58	0.59	0.59	0.62	0.65	0.70	0.70	0.73	0.81	1.00
Tianjin	0.44	0.49	0.52	0.57	0.74	1.00	1.00	1.00	1.00	1.00
Hebei	0.26	0.27	0.27	0.26	0.27	0.28	0.29	0.33	0.36	0.40
Shanxi	0.19	0.20	0.20	0.21	0.21	0.22	0.23	0.24	0.26	0.28
Inner Mongolia	0.25	0.28	0.27	0.26	0.28	0.29	0.28	0.30	0.34	0.34
Liaoning	0.29	0.32	0.33	0.34	0.36	0.38	0.38	0.40	0.42	0.43
Jilin	0.37	0.40	0.42	0.44	0.50	0.52	0.54	0.58	0.68	0.67
Heilongjiang	0.37	0.40	0.43	0.44	0.46	0.49	0.51	0.54	0.58	0.60
Shanghai	0.41	0.45	0.48	0.57	0.65	0.73	0.70	0.71	0.81	1.00
Jiangsu	0.34	0.37	0.38	0.36	0.38	0.40	0.41	0.44	0.50	0.56
Zhejiang	0.36	0.36	0.37	0.34	0.37	0.37	0.39	0.43	0.51	0.58
Anhui	0.31	0.32	0.34	0.32	0.33	0.33	0.35	0.37	0.42	0.45
Fujian	0.34	0.37	0.37	0.34	0.38	0.40	0.40	0.44	0.52	0.59

Jiangxi	0.34	0.35	0.36	0.32	0.35	0.36	0.36	0.37	0.40	0.44
Shandong	0.39	0.41	0.42	0.41	0.44	0.45	0.46	0.43	0.47	0.55
Henan	0.29	0.31	0.31	0.31	0.34	0.35	0.37	0.40	0.49	0.59
Hubei	0.32	0.35	0.36	0.36	0.39	0.40	0.42	0.46	0.54	0.60
Hunan	0.35	0.36	0.37	0.38	0.41	0.43	0.46	0.50	0.57	0.63
Guangdong	0.37	0.42	0.50	0.55	0.59	0.60	0.53	0.52	0.54	0.56
Guangxi	0.25	0.27	0.27	0.29	0.31	0.33	0.34	0.36	0.42	0.45
Hainan	0.44	0.46	0.48	0.43	0.43	0.44	0.43	1.00	0.51	0.55
Chongqing	0.29	0.31	0.32	0.34	0.39	0.39	0.41	0.45	0.52	0.56
Sichuan	0.31	0.33	0.34	0.35	0.39	0.41	0.41	0.45	0.49	0.54
Guizhou	0.17	0.17	0.19	0.18	0.19	0.20	0.20	0.23	0.26	0.25
Yunnan	0.24	0.26	0.27	0.22	0.23	0.24	0.26	0.29	0.32	0.34
Shanxii	0.30	0.33	0.34	0.33	0.35	0.36	0.36	0.39	0.42	0.43
Gansu	0.18	0.19	0.20	0.19	0.20	0.21	0.22	0.24	0.28	0.28
Qinghai	0.12	0.13	0.12	0.13	0.13	0.14	0.14	0.16	0.17	0.18
Ningxia	0.09	0.10	0.10	0.09	0.10	0.10	0.11	0.13	0.14	0.15
Eastern	0.36	0.38	0.40	0.41	0.45	0.49	0.48	0.55	0.55	0.61
Middle	0.32	0.34	0.35	0.35	0.37	0.39	0.41	0.43	0.49	0.53
Western	0.20	0.21	0.22	0.22	0.23	0.24	0.25	0.27	0.31	0.32
National average	0.31	0.33	0.34	0.34	0.37	0.40	0.40	0.44	0.47	0.52

Note: the green economy efficiency in eastern, middle, western and national areas is calculated using the average value of the year.

It can be seen that there are great differences in green economic efficiency among provinces. From the regional perspective, the eastern region is higher than the central region, and the central region is higher than the western region. In terms of time, from 2008 to 2017, the overall efficiency of green economy shows a gradual upward trend.

3. Evaluation and analysis of informatization index

3.1 Measurement and selection of informatization index

Some scholars use the total amount of post and telecommunications business as an indicator to measure the agent variables of inter-provincial informatization. The total amount of post and telecommunications business includes Internet, fixed telephone, mobile phone, computer and infrastructure construction, etc[32]. In this paper, the information development index (IDI) calculated and generated by the Institute of statistics and scientific research of the National Bureau of statistics will be used. The development index of information society includes the comprehensive evaluation coefficient of economy, politics, network and life. This index comprehensively measures the level of informatization from four first-class indexes: information economy index, network society index, online government index and digital life index.

In this paper, the comprehensive index method is used to measure the information society index. First, the three-level indicators are standardized. The calculation formula of the index value of the three-level indicators is as follows.

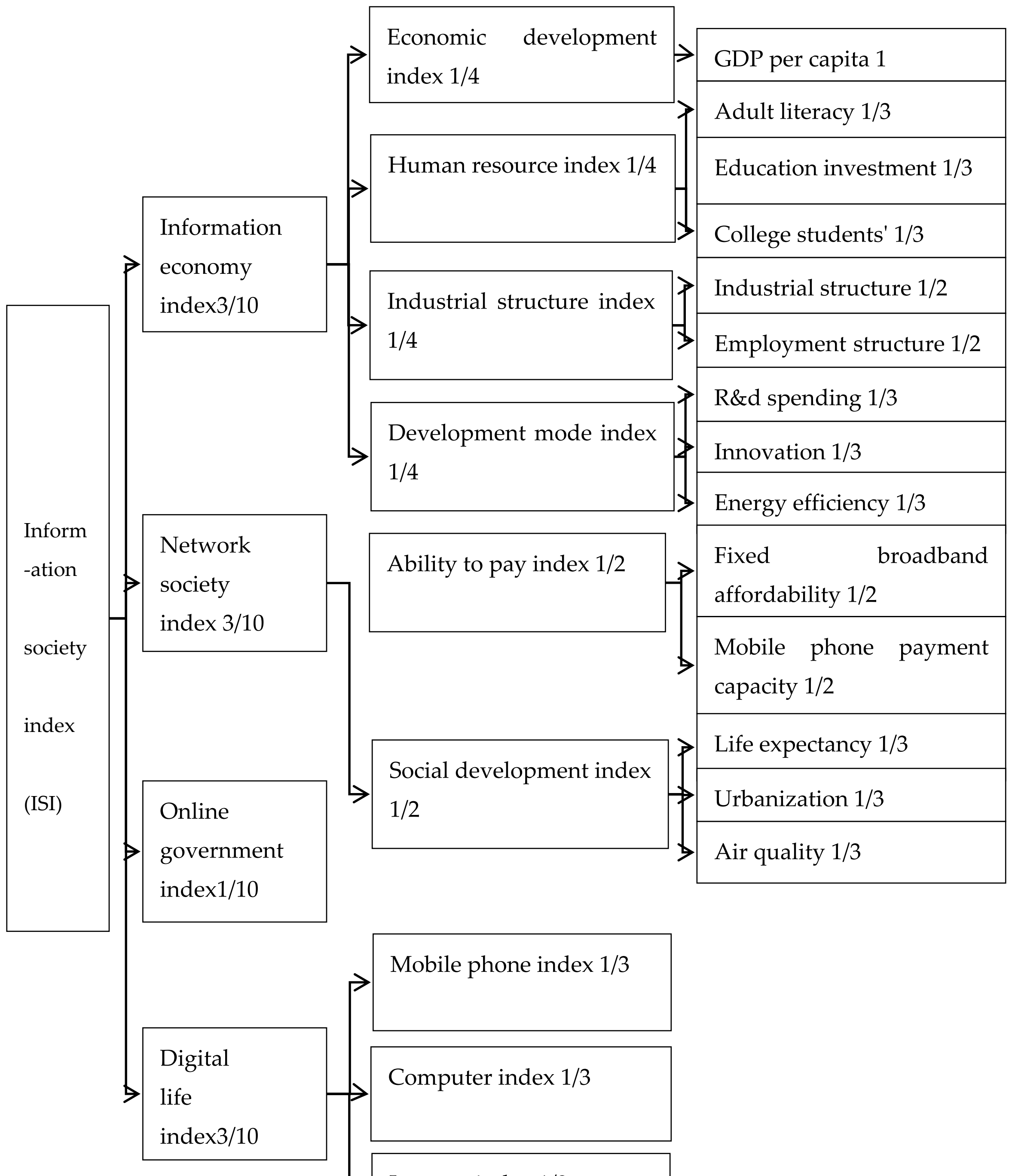
$$Q_{\mathrm{j}} = \frac{X_j}{Y_j} \tag{6}$$

$$ISI = \sum_{i=1}^{m} A_{\mathrm{i}} P_i \tag{7}$$

Where Q_j is the index value of a three-level indicator, X_j is the specific value of a three-level indicator, and Y_j is the standard value of the three-level indicator. ISI is the total index of information society, P_i is four first-class indicators, and A_i is the weight of each indicator value.

The calculation method of index value of primary and secondary indexes is the same. The comprehensive index of information society is shown in Figure 1.

Figure 1. Index system of information society



The index data of the information society comes from the *global and Chinese information society development report* published by the National Information Center Press, and the information society index is calculated by the given weight. The results are shown in Table 2 and Figure 3.

Table 2. Information society index of 29 provinces in China from 2008 to 2017

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Beijing	0.58	0.62	0.60	0.64	0.68	0.70	0.75	0.78	0.79	0.81
Tianjin	0.40	0.43	0.45	0.49	0.51	0.55	0.60	0.64	0.66	0.68
Hebei	0.26	0.26	0.27	0.30	0.31	0.34	0.37	0.38	0.40	0.44
Shanxi	0.25	0.26	0.28	0.32	0.33	0.36	0.39	0.42	0.42	0.45
Inner Mongolia	0.25	0.26	0.28	0.32	0.34	0.38	0.42	0.45	0.46	0.50
Liaoning	0.28	0.30	0.33	0.37	0.40	0.43	0.47	0.49	0.50	0.51
Jilin	0.30	0.30	0.29	0.32	0.33	0.36	0.40	0.42	0.44	0.45
Heilongjiang	0.28	0.29	0.29	0.32	0.33	0.34	0.39	0.41	0.43	0.44
Shanghai	0.51	0.61	0.60	0.65	0.67	0.67	0.71	0.73	0.74	0.76
Jiangsu	0.33	0.35	0.35	0.40	0.43	0.48	0.52	0.55	0.57	0.59
Zhejiang	0.38	0.41	0.42	0.45	0.48	0.51	0.55	0.59	0.60	0.64
Anhui	0.25	0.25	0.26	0.28	0.30	0.33	0.37	0.39	0.40	0.43

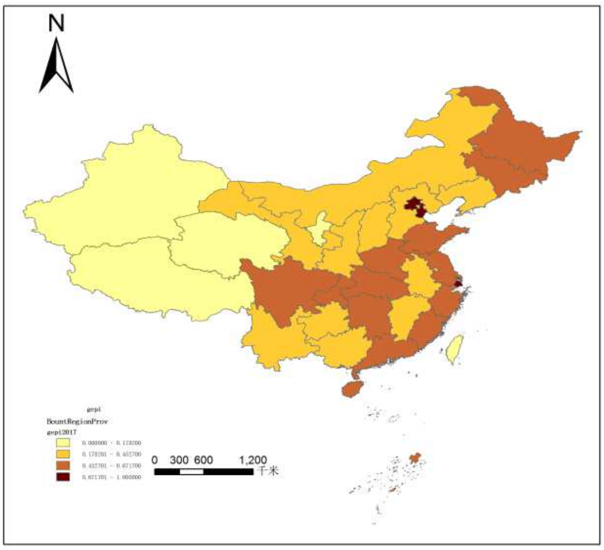
Fujian	0.28	0.32	0.36	0.40	0.43	0.47	0.51	0.55	0.55	0.57
Jiangxi	0.24	0.25	0.25	0.28	0.28	0.31	0.34	0.37	0.38	0.42
Shandong	0.28	0.28	0.30	0.32	0.34	0.40	0.43	0.45	0.47	0.50
Henan	0.23	0.24	0.25	0.28	0.27	0.31	0.33	0.37	0.38	0.40
Hubei	0.25	0.27	0.28	0.31	0.33	0.37	0.41	0.43	0.44	0.47
Hunan	0.24	0.26	0.27	0.30	0.32	0.34	0.38	0.40	0.41	0.43
Guangdong	0.44	0.41	0.42	0.45	0.48	0.50	0.54	0.60	0.62	0.65
Guangxi	0.21	0.23	0.25	0.28	0.27	0.32	0.36	0.37	0.39	0.42
Hainan	0.26	0.28	0.32	0.34	0.35	0.39	0.43	0.44	0.45	0.48
Chongqing	0.28	0.28	0.28	0.32	0.33	0.36	0.40	0.42	0.44	0.47
Sichuan	0.22	0.25	0.26	0.29	0.31	0.34	0.38	0.40	0.41	0.43
Guizhou	0.20	0.20	0.21	0.24	0.25	0.29	0.32	0.34	0.36	0.40
Yunnan	0.23	0.23	0.24	0.26	0.26	0.29	0.33	0.36	0.37	0.39
Shanxii	0.27	0.29	0.31	0.34	0.36	0.39	0.42	0.44	0.46	0.47
Gansu	0.20	0.20	0.21	0.24	0.25	0.29	0.33	0.34	0.35	0.39
Qinghai	0.22	0.23	0.25	0.27	0.30	0.34	0.37	0.39	0.40	0.41
Ningxia	0.23	0.24	0.26	0.29	0.30	0.33	0.36	0.38	0.40	0.41
Eastern	0.28	0.34	0.41	0.46	0.52	0.58	0.62	0.69	0.70	0.71
Middle	0.12	0.16	0.19	0.24	0.28	0.34	0.38	0.44	0.46	0.48
Western	0.11	0.15	0.19	0.23	0.29	0.34	0.38	0.43	0.45	0.46
China	0.27	0.30	0.30	0.32	0.36	0.39	0.42	0.44	0.45	0.47

It can be seen that in 2017, according to the social classification standard of China information society development index, Beijing is the only city in the intermediate stage of informatization, Shanghai, Tianjin, Guangdong and Zhejiang are cities in the primary stage of informatization, and other cities are in the transition period - the diffusion of main information technology and products will accelerate and reflect a certain impact. From the regional perspective, the overall trend is that the eastern region is higher than the central region, and the central region is higher than the western region.

4. Spatial Agglomeration Characteristics of Green Economy Efficiency and Informatization

4.1 Spatial distribution characteristics of Green Economy efficiency and Informatization

In order to have an intuitive sense of the spatial distribution of China's green economic efficiency, the green economic efficiency is divided into four levels by using the natural breakpoint method, and the Gepi distribution map in 2017 is drawn by using ArcMap software as follow Figure2. We can also draw the Isi distribution map in the same way.



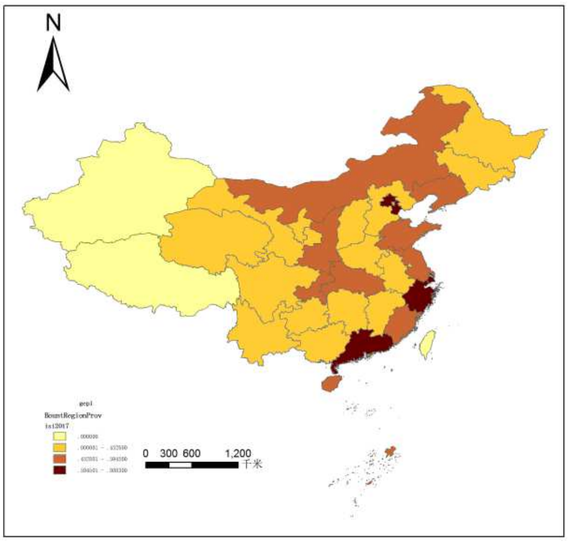


Figure 2. Gepi distribution map in 2017 **Figure 3.** Isi distribution map in 2017

It can be seen from Figure 2 that China's green economic efficiency has significant spatial distribution characteristics, with Beijing and Shanghai having the highest development level. It can be seen from Figure 3 that the level of social informatization also has significant spatial distribution characteristics, with Beijing, Tianjin, Shanghai and Guangdong in the first tier.

4.2 Overall Spatial Agglomeration Characteristics of Green Economy efficiency and Informatization

In order to understand the spatial relationship of logistics development more intuitively, the overall Moran's index value, probability P value and Z value reflecting the level of spatial relationship of Green economy efficiency and informatization from 2008 to 2017 are calculated through the overall autocorrelation analysis of 29 provinces in China by the spatial measurement software Geoda, as shown in Table 3 and Table 4. It can be seen that the overall autocorrelation test from 2008 to 2017 was positive and passed the significance test, which means that the efficiency of green economy and the level of informatization have a agglomeration effect in space, showing a significant positive correlation. As can be seen from Figure 4, the overall efficiency of green economy shows a downward trend, including 2009-2011, 2012-2013, 2014-2015, 2016-2017, which shows that the spatial correlation is weaker than before, 2008-2009, 2011-2012, 2013-2014, 2015-2016 shows an upward trend, which shows that the spatial correlation is gradually strengthened. The overall level of information technology shows an upward trend, 2008-2011, 2012-2017 shows an upward trend, which shows that with the continuous development of the level of information technology, the spatial correlation gradually increases, 2011-2012 shows a slight downward trend, which shows that the spatial correlation is weaker than before.

Table 3. Overall Moran's Index of Green Economy efficiency

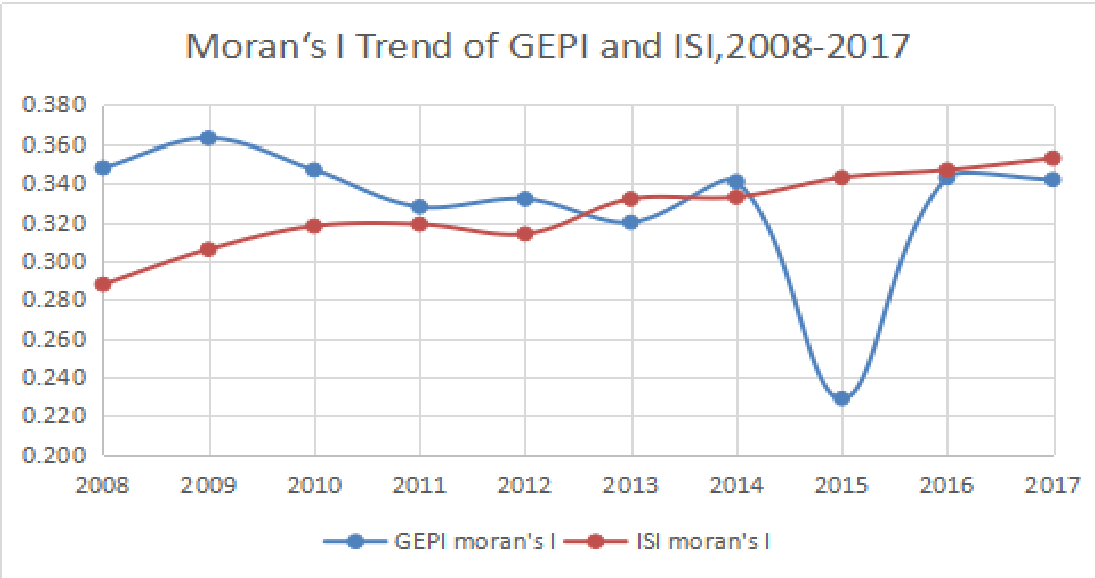
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Moran's I	0.348	0.363	0.347	0.328	0.332	0.320	0.341	0.229	0.343	0.342

Z	4.124	4.245	4.042	3.846	3.912	3.967	4.234	2.899	4.094	4.042
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000

Table 4. Overall Moran's Index of Informatization

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Moran's I	0.288	0.306	0.318	0.319	0.314	0.332	0.333	0.343	0.347	0.353
Z	3.635	3.892	3.975	3.968	3.878	4.037	4.033	4.106	4.153	4.212
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Figure 4. Overall Moran's Index of GEPI and ISI from 2008 to 2017



4.3 Local Spatial Agglomeration Characteristics of Green Economy efficiency and Informatization

Overall Moran's index mainly calculates the spatial agglomeration effect in 29 provinces, but it cannot determine the degree of spatial correlation between each province and its surrounding provinces. Therefore, the spatial correlation among provinces should also be analyzed. Through the empirical analysis of Moran index, we can see that there are great differences in different years. Therefore, in order to have a more detailed understanding of its development at different stages, the three years of 2008, 2013 and 2017 are chosen as the time section to analyze on the basis of the principle of average distribution, and uses local Moran's index to analyze the spatial correlation in 2008, 2013 and 2017, and estimates the heterogeneity and homogeneity. The results are showed from Fig.5 to Fig.10.

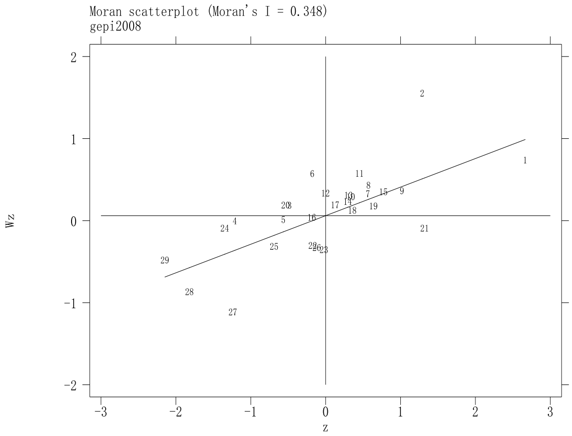


Figure 5. GEPI Local scatter plot in 2008

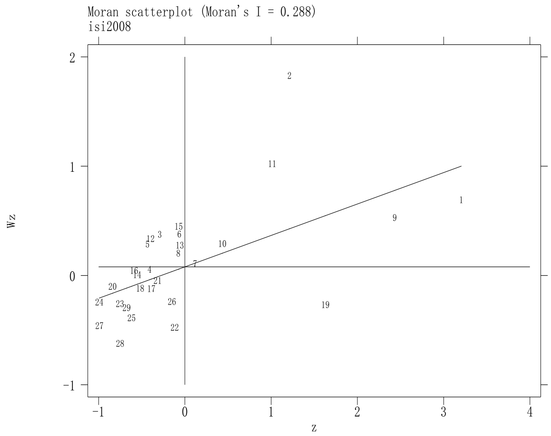


Figure 6. Isi Local scatter plot in 2008

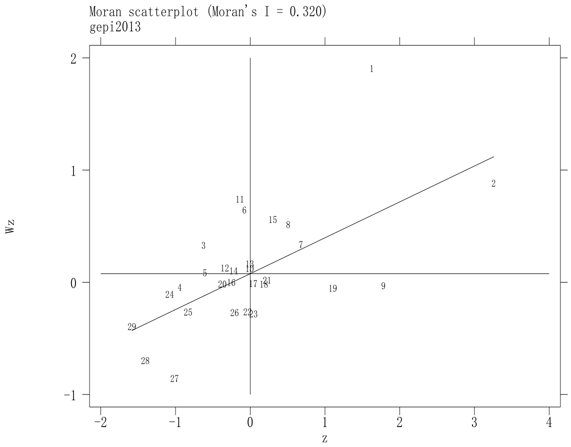


Figure 7. GEPI Local scatter plot in 2013

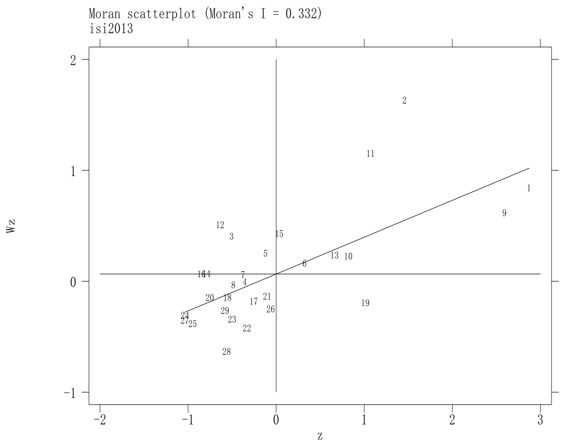
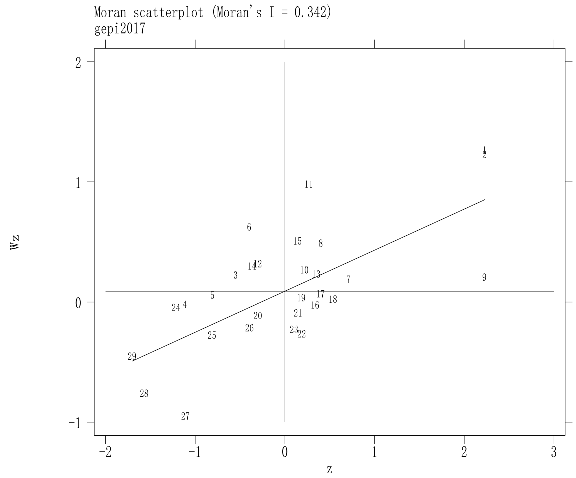


Figure 8. Isi Local scatter plot in 2013



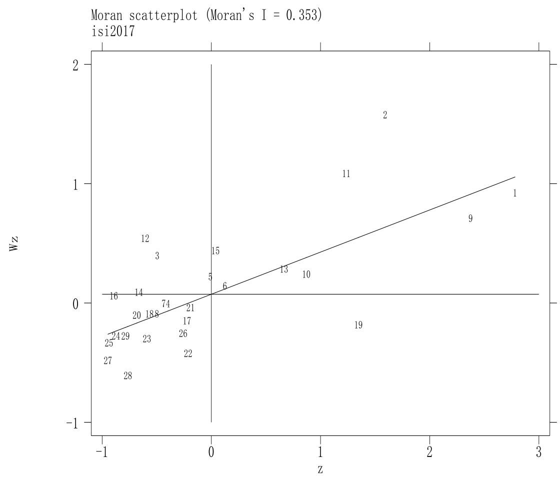


Figure 9. GEPI Local scatter plot in 2017

Figure 10. Isi Local scatter plot in 2017

It can be seen that most of them are in the first quadrant and the third quadrant, and a few are in the second quadrant and the fourth quadrant. The first quadrant and the third quadrant represent high-high and low-low agglomeration, which means there is significant positive correlation. The second quadrant and the fourth quadrant represent low-high and high-low agglomeration, which means there is significant negative correlation.

5. Spatial econometric analysis of the impact of informatization on the efficiency of green economy

There are a lot of researches on informatization to promote economic development, and informatization can reduce input and unexpected output. This part will study how informatization affects the spatial correlation of green economic efficiency.

5.1 Intermediate variable and control variable

In the process of selecting the influencing factors that affect the spatial correlation of green economy efficiency, following the principle of data availability, the following six variables are selected as the control variables.

Mediation variables mainly include the following two indexes:

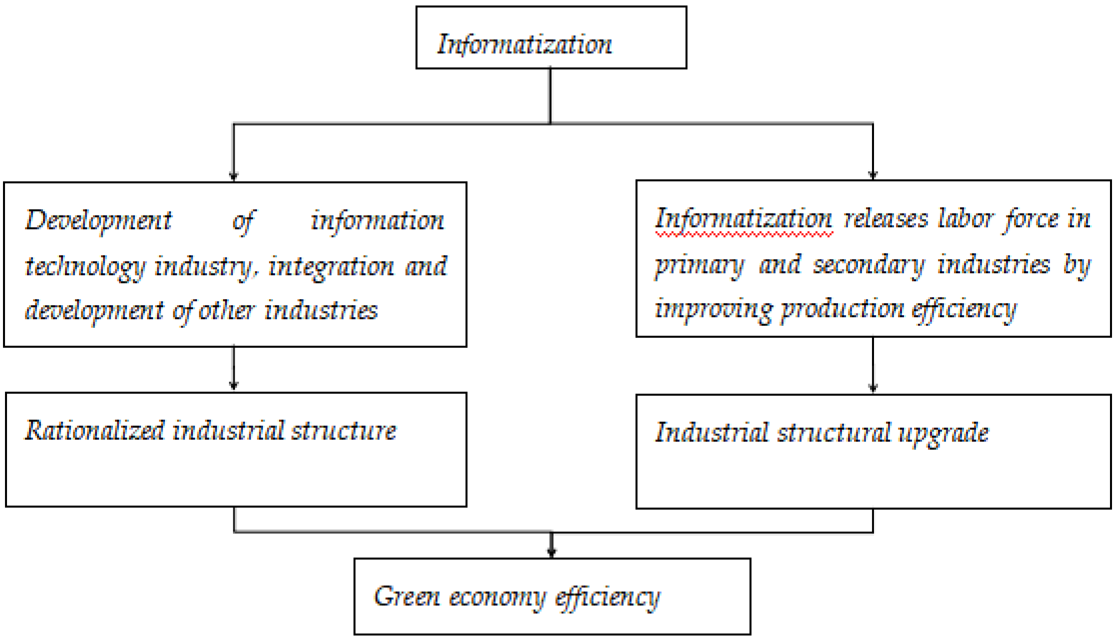
(i) Advanced indicator of industrial structure (Indushup). The index uses the ratio of the added value of the tertiary industry to the added value of the secondary industry, and the data comes from *the statistical yearbook*. The development of the tertiary industry promotes the development of green economy to some extent.

(ii) Rationalization index of industrial structure (Indushr). The index uses the reciprocal of the Theil index as a measure of industrial structure rationalization. *Y* indicates that the added value of each region's industry is divided into the first, second and third industries, and the data comes from *the statistical yearbook*. The rationalization of industrial structure represents the reasonable degree of industrial agglomeration[33]. The formula is as follows:

$$TL = \sum_{i=1}^{n} \left(\frac{Y_i}{Y}\right) \ln\left(\frac{Y_i}{L_i} / \frac{Y}{L}\right) \tag{8}$$

The mechanism of mediating variables is shown in Figure 11.

Figure 11. Mechanism of mediating variables



Control variable mainly include the following four indexes:

(i) Urbanization index(urban). The index is the ratio of the local urban population to the total population, and the data comes from *China statistical yearbook*. This indicator reflects the degree and process of population convergence in cities, which will expand the population scale and cause pollution problems [7].

(ii) Innovation investment index(rd). The index is the ratio of R&D investment to GDP in the region, and the data comes from *China Science and technology statistical yearbook*. Innovation is an important factor affecting regional economic growth.

(iii) Openness index(open). The index is the ratio of foreign direct investment to local GDP, and the data comes from *China statistical yearbook*. Foreign investment may bring technology spillover effect and pollution transfer.

(iv) Economic development index(led). The index is the logarithm of per capita GDP income, and the data comes from *China Statistical Yearbook*.

In order to verify the significance of the intermediary effect of the intermediary variables in the process of the impact of informatization on the industrial structure, the upgrading and rationalization of the industrial structure are taken as the explanatory variables, and the information technology and other control variables are taken as explanatory variables, and the least square regression method is used to estimate the parameters. It is used to judge whether there is intermediary effect in the path of the impact of informatization on the efficiency of green economy. The estimated results are shown in Table 5.

Table 5. Estimated results of the impact of informatization on industrial structure

	indushup	Indushr
Isi	5.276***	51.470***
Urban	0.628	49.246***
Rd	18.114***	123.265

Open	-2.518	30.436***
Led	-1.055***	-12.998***
Cons	9.580***	96.036***
N	290	290
R2	0.649	0.748

Note: *、**、*** significant at the 10%、5%、1% levels respectively

It can be seen from table 5 that the influence coefficients of informatization on the upgrading and rationalization of industrial structure of intermediary variables are all positive, indicating that the development of informatization will play a significant positive role in promoting industrial structure. The impact coefficient of informatization on the upgrading of industrial structure is 5.276, passing the significance test of 0.01 level; the impact coefficient of informatization on the rationalization of industrial structure is 51.470, passing the significance test of 0.01 level. The influence coefficient of informatization on the rationalization of industrial structure is greater than that of informatization on the advancement of industrial structure. It can be judged that informatization has a greater impact on the rationalization of industrial structure.

5.2 Selection and test of spatial econometric model

Because of the circulation of information, it is necessary to study the spatial spillover effect of informatization on the efficiency of green economy. There are three kinds of spatial econometric models: lag model (SLM), spatial error model (SEM) and spatial Doberman model (SDM). SLM model is used to study the influence of indicators in a certain area on the surrounding areas; SEM model is used to reflect the spatial dependence of disturbance items, and there is spatial dependence of missing variables that have influence on the interpreted variables, or there is spatial dependence of unobservable random shocks; SDM model is used to study the independent variables that the interpreted variables depend on the adjacent areas. SLM model, SEM model and SDM model are as follows:

$$\begin{aligned} gepi = {} & \beta_0 + \beta_1 isi_{it} + \beta_2 indushup_{it} + \beta_3 indushr_{it} + \beta_4 urban_{it} + \\ & \beta_5 rd_{it} + \beta_6 open_{it} + \beta_7 led_{it} + \rho \sum_{j=1}^{n} \omega_{ij} gepi_{ij} + \varepsilon_{it} \end{aligned} \tag{9}$$

Where ε_{it} is the random error term, $\rho \sum_{j=1}^{n} \omega_{ij} gepi_{ij}$ is the spatial lag variable, and ρ is the spatial autoregressive coefficient, which measures the influence level of the green economic efficiency of the adjacent region on the green economic efficiency of the central region.

$$\begin{aligned} gepi = {} & \beta_0 + \beta_1 isi_{it} + \beta_2 indushup_{it} + \beta_3 indushr_{it} + \\ & \beta_4 urban_{it} + \beta_5 rd_{it} + \beta_6 open_{it} + \beta_7 led_{it} + \lambda \sum_{j=1}^{n} \omega_{ij} u_{ij} + \varepsilon_{it} \end{aligned} \tag{10}$$

Where $\lambda \sum_{j=1}^{n} \omega_{ij} u_{ij}$ is the spatial error term, λ is the spatial error coefficient.

$$\begin{aligned} gepi = {} & \beta_0 + \beta_1 isi_{it} + \beta_2 indushup_{it} + \beta_3 indushr_{it} + \beta_4 urban_{it} + \\ & \beta_5 rd_{it} + \beta_6 open_{it} + \beta_7 led_{it} + \beta_8 w(isi_{ij}) + \rho \sum_{j=1}^{n} \omega_{ij} gepi_{ij} + \varepsilon_{it} \end{aligned} \tag{11}$$

Where $w(isi_{ij})$ is the spatial variable of informatization development level in each region. The test results of the three models are shown in table 6.

Table 6. Test results of the three models

Test methods	Test results

	LMLag	19.705***
LM Test	LMError	5.228**
	R-LMLag	19.005***
	R-LMError	4.527**
	Wald spatial lag	8.34***
Wald&LR Test	Wald spatial error	9.43***
	LR spatial lag	11.24***
	LR spatial error	5.72**
Hausman Test	Hausman	4.55***

Note: *、**、*** significant at the 10%、5%、1% levels respectively

It can be seen from table 6 that the LM index and R-LM index of SLM model pass the test of 0.01 level. The LM Test and r-lm test of SEM model only passed the test of 0.05 level, which shows that SLM model is better than SEM model. Then, Wald and LR are used to test whether SDM model can degenerate into SLM or SEM model. From the test results, it can be seen that Wald and LR test have passed the test of 0.05 level, indicating that SDM model can not degenerate into SLM or SEM model. Finally, Hausman test is used to determine whether fixed effect or random effect should be selected. Hausman's result is positive, indicating that fixed effect should be selected.

5.3 Analysis on the spatial effect of green economic efficiency

In this paper, stata15.0 software is used to analyze the influencing factors of green economic efficiency, and the results are shown in Table 7.

Table 7. Results of the spatial effect of green economic efficiency

Explanatory variable	SDM		SLM		SEM	
	Coefficient	Z	Coefficient	Z	Coefficient	Z
isi	.714***	4.23	.535***	3.27	.582***	3.42
indushup	.111***	4.65	.0953***	4.00	.0823***	3.54
indushr	.005***	3.04	.0054***	3.27	.006***	3.73
urban	-.996***	-4.38	-.940***	-4.05	-1.065***	-4.74
rd	8.931***	4.07	6.234***	2.98	7.301***	3.35
open	.959**	1.99	.528	1.11	.688	1.45
led	.109***	3.19	.099***	2.85	.106***	2.96
W*isi	-6.068***	-3.40				
rho	1.828*	1.79	-0.277	-0.33		
lambda					2.809**	2.48
sigma2_e	.003***	12.02	.003***	12.04	.003***	11.99
Log-likelihood	443.001		437.382		440.142	
R2	0.497		0.469		0.461	
N	290		290		290	

Note: *、**、*** significant at the 10%、5%、1% levels respectively

The coefficient value of the autoregressive coefficient *rho* of the explained variable in the spatial fixed effect model is 1828.692, which shows that the development of green economic efficiency in this region has a positive spillover effect on the green economic efficiency of adjacent regions. This shows that the development of green economic efficiency plays a leading role in the development of neighboring areas. The development of developed areas will drive the development of surrounding cities and form the dividend of surrounding areas. For the industrial upgrading or introduction of new technologies in developed areas, the surrounding regions will be more convenient to learn how to carry out industrial upgrading and new technologies. At the same time, the developed areas are subject to regional restrictions, sometimes forming a kind of spillover. For example, limited by housing prices and human resources, some enterprises will move out of the developed areas, thus bringing development to the surrounding areas.

The correlation coefficient of informatization *ISI* is 0.714, and it has passed the significance test of 0.01 level, which has a significant role in promoting the green economic efficiency of the region. The development of information technology has promoted the development of the tertiary industry, developed a large number of high-tech industries, and played a certain role in promoting the efficiency of green economy. In addition, the improvement of information technology can not only improve the efficiency of promotion, but also eliminate the information asymmetry and promote the supply side reform. The spillover effect of informatization is significantly negative at the significance level of 0.01, which shows that the development of information technology will have a certain "siphon" effect on the surrounding areas. The improvement of informatization level in the region will enhance the competitiveness of enterprises in the region, furthermore weaken the competitiveness of other regions. In addition, the improvement of the informatization level in the region will attract human resources, technology and various capital flows to the region, which will have a negative spillover effect on the neighboring regions.

The correlation coefficient between urbanization level *urban* and green economic efficiency is -0.996, passing the significance level test of 0.01. Urbanization is a process of population agglomeration. With the development of urbanization, it will not only bring scale welfare, but also bring more pollution. The correlation coefficient between innovation investment *rd* and green economic efficiency is 8.931, passing the significance level test of 0.01. The improvement of innovation level has brought a lot of new technologies, among which cleaner production technology, pollution control technology and production efficiency have effectively improved the input-output rate. The correlation coefficient between openness *open* and green economic efficiency was 0.959, which passed the significance level test of 0.05. Foreign direct investment not only brings capital but also technology to the region, provides advanced technology for the development of the region, and promotes the efficiency of green economy. The correlation coefficient between economic development level *led* and green economic efficiency is 0.109, passing the significance level test of 0.01. The local government has more funds for environmental governance, which is conducive to the improvement of the environment and the development of green economic efficiency. In general, the level of innovation has the greatest impact on the efficiency of green economy. At present, the development of China is in the era of rapid development of technology. The improvement of innovation level can directly and effectively improve production efficiency, reduce input and increase expected output. At the same time, the rapid development of clean energy technology has promoted the emission reduction of unexpected output.

Because of the great regional differences in China, this paper further discusses the spatial effect of green economic efficiency in different regions. The results are shown in table 8.

Table 8. Different regions' results of the spatial effect of green economic efficiency

Explanatory variable	Eastern(SDM)		Central(SDM)		Western(SDM)	
	Coefficient	Z	Coefficient	Z	Coefficient	Z
isi	0.763**	2.21	0.770***	3.66	0.007	0.06
indushup	0.085	1.23	0.057	1.34	0.030	1.25
indushr	0.006***	2.59	-0.137**	-2.35	0.012**	2.38
urban	-1.165*	-1.89	-0.885***	-3.84	0.203	0.53

rd	3.438	0.72	0.359	0.10	6.476***	2.84
open	0.522	0.61	0.701	0.43	-0.031	-0.04
led	0.037	0.105	0.074*	1.85	-0.023	-0.59
W*isi	1.159	0.27	-3.875	-0.53	13.213***	3.76
rho	0.708	0.40	17.029***	5.32	1.947	0.53
sigma2_e	0.006***	7.41	0.001***	6.07	0.000***	7.07
Log-likelihood	128.606		166.033		253.958	
R2	0.380		0.108		0.416	
N	110		80		100	

Note: *、**、*** significant at the 10%、5%、1% levels respectively

It can be seen that the influence coefficient of informatization in eastern and central regions on local green economic efficiency is significantly positive, while that in western regions is not significant. This may be due to the high level of information development in the eastern and central regions, the low cost and high efficiency of further development, and the construction of information technology has had a positive impact on the efficiency of the green economy. Due to the backward development level and poor informatization foundation in the western region, the impact of informatization on the efficiency of green economy is not significant. From the perspective of spatial spillover effect, the information spillover effect in the eastern central region is not obvious, and the information spatial spillover effect in the western region is significantly positive, because the western region is in the stage of information development and transformation, and the construction of information infrastructure can promote the efficiency of green economy by the coordinated development of all provinces.

On the whole, the development of industrial rationalization has a significant role in promoting the eastern and western regions. However, the level of urbanization in the eastern and central regions has a significant negative impact on green economic efficiency, while the impact of urbanization in the western region on green economic efficiency is not significant. This is because the level of urbanization in the western region is low and has not yet produced the effect of agglomeration.

6. Conclusions and Suggestions

This study makes an empirical study on the spatial effect of informatization on the efficiency of green economy in 29 provinces of China by using the method of Dubin model. The empirical study yields the following three conclusions.

(i) The spatial distribution of the green economy efficiency and informatization are unbalanced. The spatial distribution of green economy and informatization shows that the eastern region is higher than the central region, and the central region is higher than the western region. From the perspective of time dimension, the efficiency of green economy and informatization are on the rise in general, and only some regions may have slight fluctuations. This shows that there are still problems of unbalanced development in China's regional development, but the regional differences are getting closer and higher with time.

(ii) There is a significant spatial spillover effect in the efficiency of green economy. From the perspective of overall autocorrelation, Moran's I index is significantly positive, indicating that there is spatial agglomeration. From the perspective of local autocorrelation, most regions have high-high and low-low agglomeration. From the perspective of overall autocorrelation, there is also a significant spatial agglomeration of informatization.

(iii) The development of informatization plays an important impact on the efficiency of green economy. The development of informatization has a significant positive role in promoting the efficiency of local green economy, and has a "siphon" effect on the development of adjacent areas, which is consistent with the reality. The development of information technology plays a more reasonable role in the allocation of local resources, improving the utilization rate of resources, and also plays an important role in the development of local economy. In addition, the industrial structure, the degree of openness, the level of innovation investment and other factors of the region also have a positive effect on the efficiency of green economy.

The following suggestions can be obtained based on the above conclusions:

(i) Developing green economy according to different conditions of different places. Because of the great regional differences in China, we should give full play to the advantageous industries in different regions. The northeast and the West have the characteristics of vast area, rare population and unique culture. We should develop the primary industry and give full play to the tertiary industry. At the same time of green development concept, we should effectively develop regional economy.

(ii) Establishing regional coordination mechanism of green economic development. Form a regional coordinated development mechanism guided by the government, and give full play to the coordinated advantages of complementary advantages among regions. The eastern region has technological advantages, while the central region has the advantages of land and human resources. During the process of introducing advanced technology, we should mainly introduce some industries and technologies to promote the development of green economy. In this process, it may be necessary for the local government to play the role in introducing some preferential policies, which will bring certain employment opportunities and economic development opportunities for the local development

(iii) Using informatization to promote the development of green economy. First of all, it is very important to develop the local information level by seizing the new round of informatization development opportunities, such as innovative cloud computing, big data, artificial intelligence, etc. At the same time, vigorously develop the integration of informatization and other industries, such as the development of agricultural informatization, industrial informatization, logistics informatization, etc., and integrate and optimize resources. Although the development of informatization will bring significant development to the local region, it will introduce the inflow of human resources and other resources from the surrounding areas, leading to the weakening of the competitiveness of the surrounding areas. In order to achieve comprehensive development, it is necessary to establish the fair competition mechanism, while avoiding the unbalanced development situation and the malicious competition mechanism.

Our research also has some limitations. First and most notably, our results are based on data for China. We reason that the results are correct based on the empirical test above and are in line with China's national condition. However, they are not widely applicable to other regions because of the different situation of each region. The impact mechanism of informatization on the efficiency of green economy is mainly discussed by the influence process of intermediary variables. However, there are some other ways may have effects are not taken into account. In future study, these ways should be considered more comprehensively in order to explain the spatial effect of informatization on the efficiency of green economy more scientifically.

Acronym：gepi：green economy performance index

Isi： Index system of information

Declarations

- Ethics approval and consent to participate

Not applicable

- Consent for publication

Not applicable

- Availability of data and materials

Not applicable

- Competing interests

Not applicable

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- Authors' contributions

X.T. wrote the paper; C.Y. contributed the collection of data and idea.

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- Authors' information (optional)

School of economics and management, Shanxi University, Taiyuan 030006, China.

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Figures

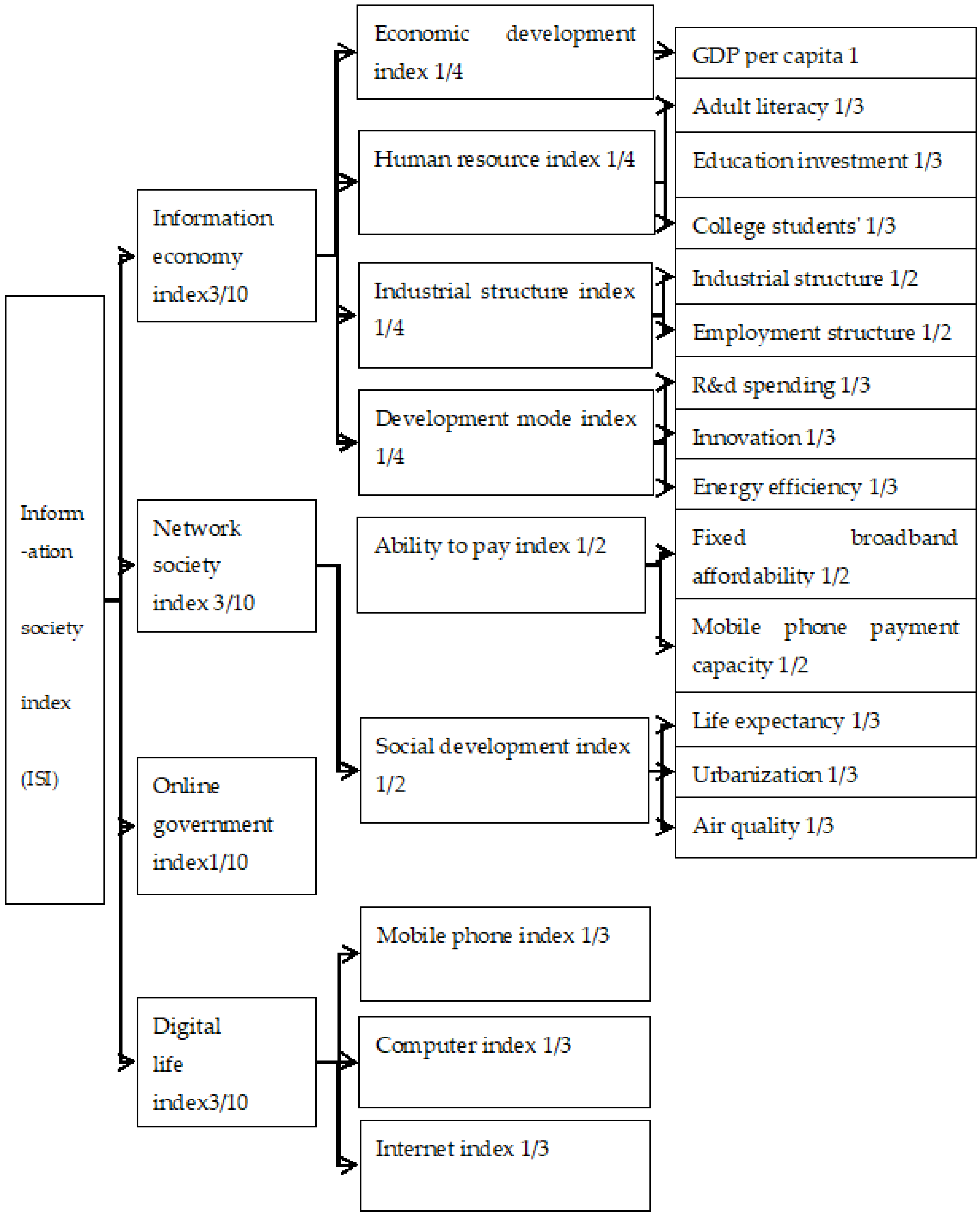

Figure 1

Index system of information society

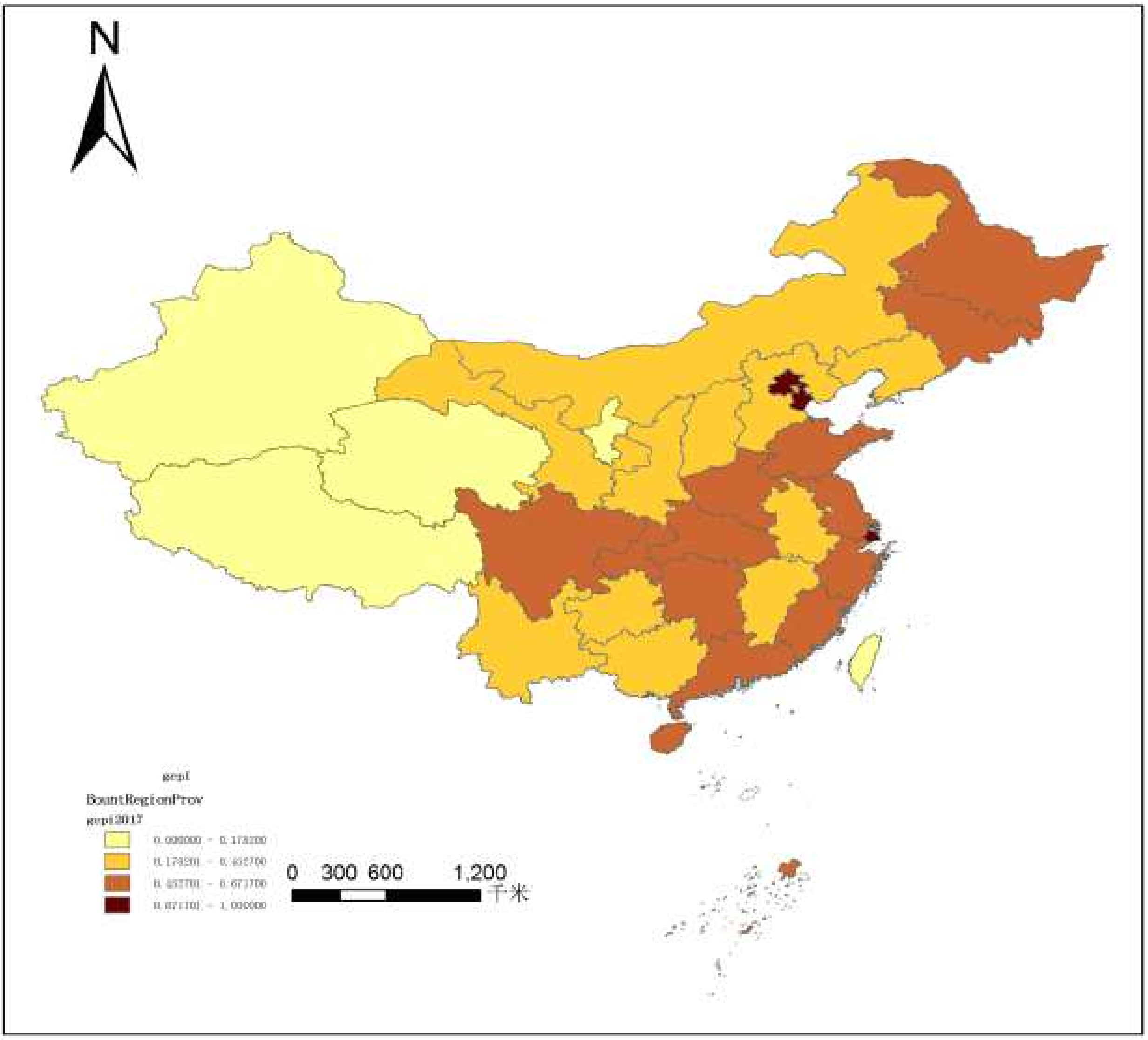

Figure 2

Gepi distribution map in 2017 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

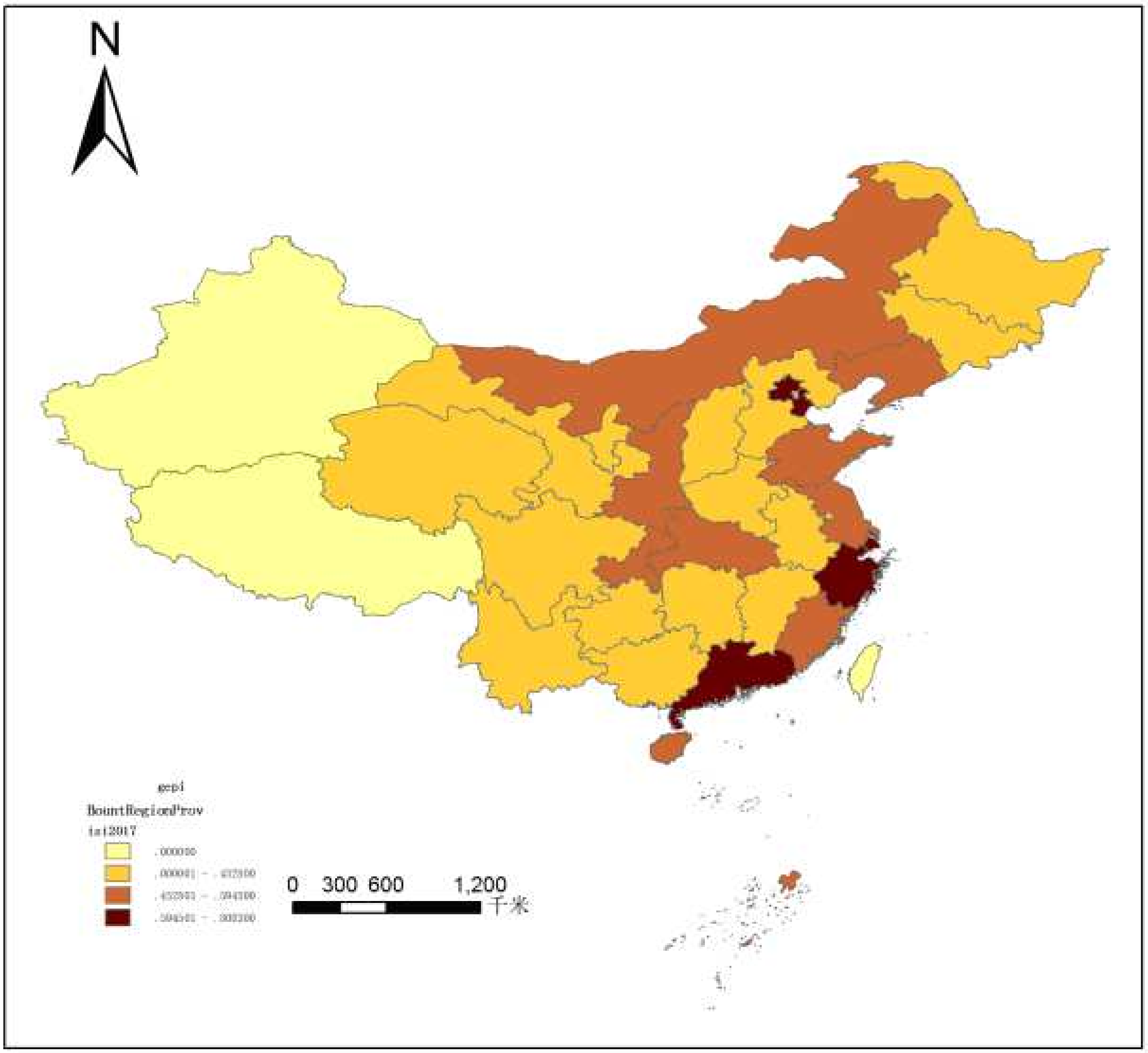

Figure 3

Isi distribution map in 2017 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

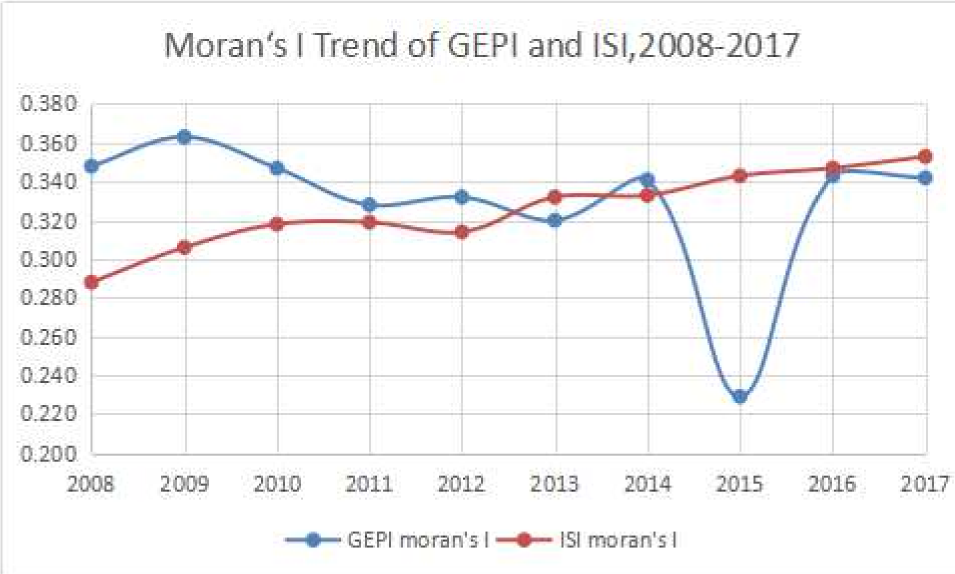

Figure 4

Overall Moran's Index of GEPI and ISI from 2008 to 2017

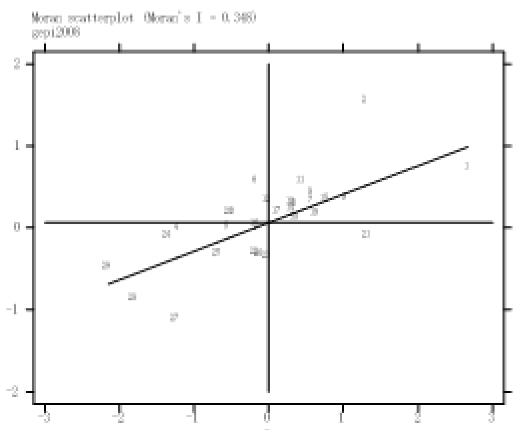

Figure 5

GEPI Local scatter plot in 2008

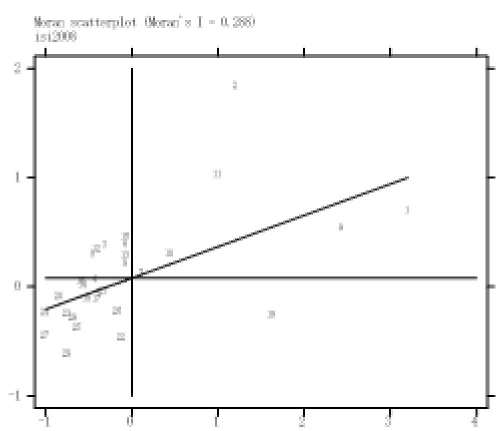

Figure 6

Isi Local scatter plot in 2008

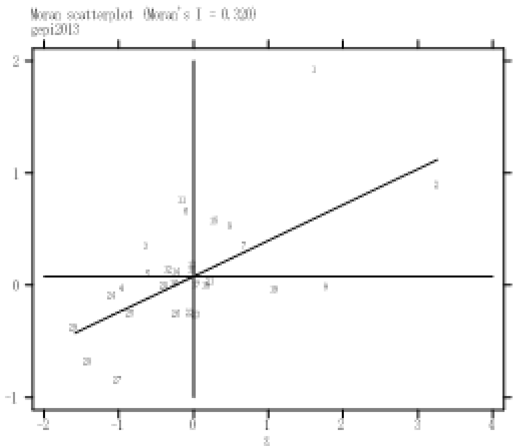

Figure 7

GEPI Local scatter plot in 2013

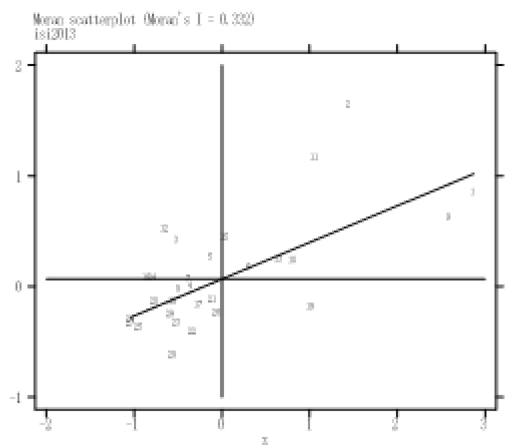

Figure 8

Isi Local scatter plot in 2013

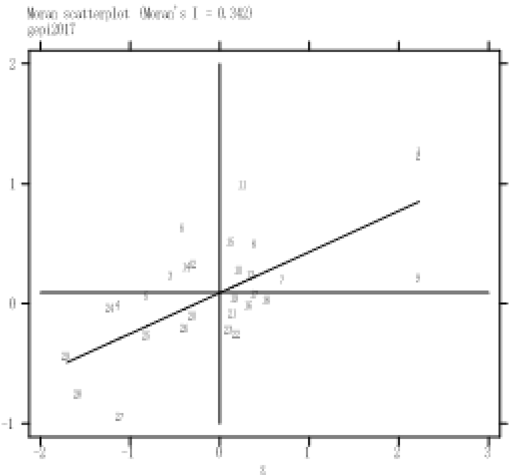

Figure 9

GEPI Local scatter plot in 2017

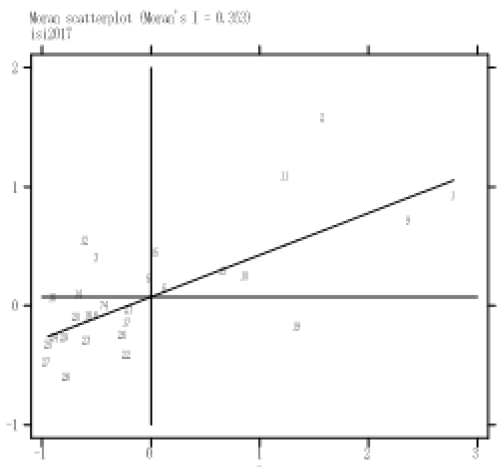

Figure 10

Isi Local scatter plot in 2017

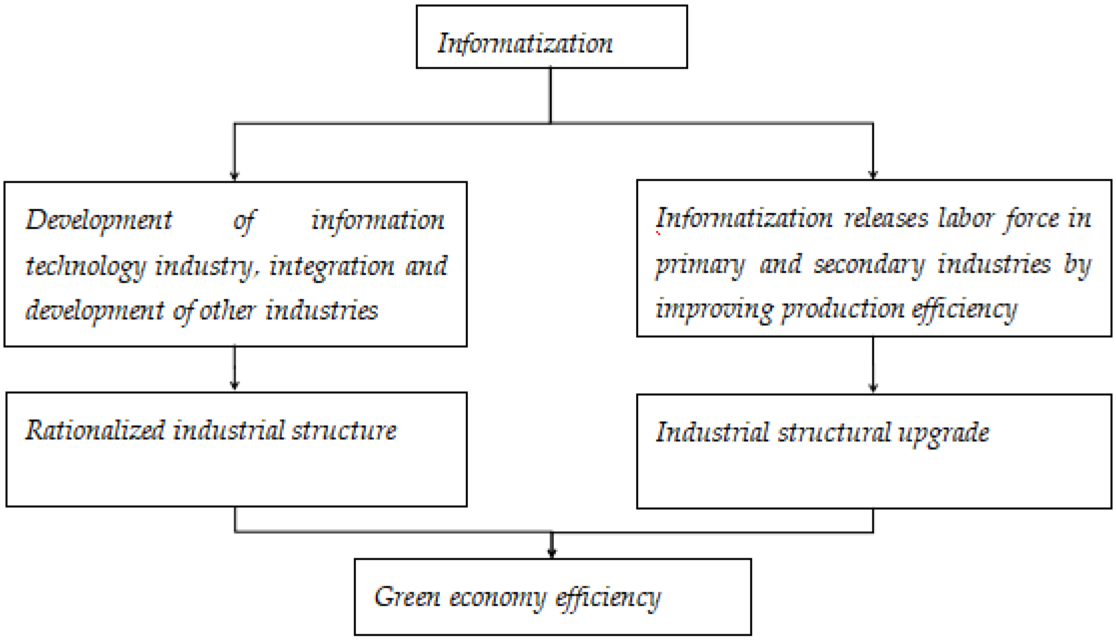

Figure 11

Mechanism of mediating variables