The Spatial Correlation Effect of Hunan Green Finance Efficiency and the Green and Low-consumption Development of Tobacco Industry Based on Social Network Analysis

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Abstract:The efficiency of green finance for promoting the upgrading of regional industrial structure shows a correlation effect. In this paper, 14 cities and prefectures in Hunan, China, are taken as regional cases, and relevant data from 2010 to 2017 are analyzed. The three-stage DEA model, modified gravity model, and social network analysis are employed to measure the efficiency of Hunan green finance in promoting the energy saving and emission reduction of tobacco industry, industrial upgrading and its spatial network relationship. The results show that Changsha, Hengyang, Zhangjiajie, Loudi, and other cities and prefectures have high efficiency, while other cities and prefectures have relatively low efficiency. Clear spatial agglomerations exist between cities and states, depicting a complex spatial network structure. Their spatial network connections have increased, and agglomerations are closely linked, forming four major sections: "two-way overflow", "net overflow", "net income", and "broker". Cities and states with these four major sectors have played different roles in the spatial network, demonstrating their respective roles and orientations. This suggests that when inter-regional governments formulate green finance policies for promoting the upgrading of the industrial structure, they are supposed to not only concentrate on coordinated advancement, but they should also adjust measures to local conditions. Tobacco industry should also actively implement the concept of green development, pay close attention to equipment energy-saving technological transformation, and improve energy management through lean management.

Key words: green finance; industrial upgrading; financial efficiency; social network analysis; tobacco industry

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QUESTION FORMULATION

China's reform and opening up has not only created an economic development miracle for more than 40 years, it also induced unprecedented ecological and environmental pressures. Transforming the green development path and striving for the goal of "carbon neutrality" have become key to achieving a harmonious development of humans and nature. This also requires the optimization and upgrading of the industrial structure and the energy saving and emission reduction of tobacco industry of the whole country or a specific region. Under the market economy, market-oriented operation and policy-oriented means are used to both guide and restrain enterprises in efforts of upgrading national or regional industrial structures and reducing energy consumption of tobacco industry. This is where the green financial policy becomes important. It provides specialized financial services for project investment and financing, project support, and risk management and green and low-consumption development of tobacco industry in terms of environmental protection, energy conservation, clean energy, green transportation, and green building.[1] Moreover, it also guides the transformation and upgrading of enterprises through credit guidelines, which effectively provides an interface between the market and the government. The current assertion which green finance motivates the upgrading of regional industrial structures and the energy saving and emission reduction of tobacco industry has been studied initially. Green finance development has the ability to promote industrial structure upgrading[2–4] and induce clear competitive and strategic interactions in the use of green financial instruments among local governments and promote the upgrading of tobacco industry to low-carbon development.[5,6] This makes it necessary to study green finance issues not only by focusing on their economic effects on industrial upgrading, but also by focusing on relevant inter-regional policy linkages and their coordination and the cooperation of tobacco industry. Therefore, it is centrally important to investigate the efficiency of interregional green finance development and the spatial correlation relationship generated. This information is very important for local governments to formulate green finance policies, efficiently use green finance tools for promoting industrial structure upgrading and the energy conservation and emission cutback of tobacco industry, and realize the promotion of interregional synergistic development.

Green finance is a financial innovation for solving the contradictions between economy and environment. It bridges the financial industry and environmental industry,[7] and its innovative tools can effectively serve the real economy, provide financial support for the development of green economy, and promote the sustainable development of society.[8] Current research on how green finance manages to upgrade the industrial structure is the mainstream direction of academic research. In terms of research on the underlying mechanism, green credit motivates industrial structure optimization and escalation by mechanisms such as fund formation, fund supply, signal transmission, and credit catalysis.[2,5] It can also achieve industrial structure upgrading by promoting technological progress and improving the energy utilization structure of enterprises.[4,9] In terms of empirical findings, Han (2020) concluded that green finance can significantly enhance the efficiency of green technological innovation,[10] which in turn promotes the optimization rate of the industrial structure, improves resource utilization of tobacco companies and activates high-quality development.[11] Furthermore, as empirical studies deepen, scholars found significant distinctions in the influence of green finance on promoting industrial structure upgrading between eastern, central and western regions of China from a heterogeneity perspective.[5] Green credit policy is beneficial to regional industrial structure upgrading and secondary industry development, but less favorable to tertiary industry development, showing certain spatial correlation.[6]

Clearly, the above literature has confirmed the role of green finance in motivating industrial structure upgrading and the energy saving and emission reduction of tobacco industry. However, how efficient the input-output efficiency of inter-regional green finance is on industrial structure upgrading remains unclear. Although existing spatial association studies are only based on the perspective of geographical proximity, they identify a small amount of spatial association of green finance between regions. Therefore, it remains to be explored whether spatial transmission mechanisms exist in the spatial association and what role each region plays in this. To address these questions, this paper assesses 14 cities in Hunan Province as regional cases, using data related to green finance and industrial structure upgrading in Hunan. With these data, the interregional green finance efficiency is assessed. The efficiency value is used as data base and network analysis is applied to overcome the limitation of traditional spatial measurement of only analyzing the proximity relationship to also identify the overall, community, and node individual characteristics of green finance efficiency in this spatial association.[12,13] Thus, the results enable a systematic grasp of the spatial association pattern of green finance among regions and its evolution.

ANALYSIS OF THE EFFICIENCY OF GREEN FINANCE FOR INDUSTRIAL UPGRADING IN HUNAN

Research Methodology and Data Sources

For the efficiency measurement of green finance for industrial upgrading in Hunan, this essay uses the three-stage data envelopment analysis (DEA) method. The three-stage DEA is the result of Fried's improvement of the traditional DEA model,[14] which mainly corrects environmental dimensions and random errors in the classical DEA model and separates management inefficiencies. In this paper, lessons are drawn from Liu's (2014) approach to deal with panel three-stage DEA.[15] In the first stage, this approach uses the traditional DEA model to derive primary efficiency values. In the second stage, it then uses stochastic frontier analysis (SFA) regression to remove both environmental dimensions and random errors from the first stage to obtain adjusted decision unit input values. In the third stage, the final efficiency value is obtained by using the classical DEA model again.

This paper takes Hunan Province as a regional case and uses data related to 14 cities in Hunan from 2010–2017. Relevant data are obtained from Juchao.com, the Statistical Bulletin of National Economic and Social Development of Hunan Municipalities and Counties, and the Hunan Statistical Yearbook. Because of the problem of data availability, this paper draws on the selection method of green credit data of Zhang et al. (2018).[16] The environmental protection companies listed in the securities A-share and New Third Board markets in each city and state of Hunan are taken as samples. The sum of medium- and long-term loans of these enterprises are used as the overall amount of green credit, while the rest of the qualitative index data are manually collated through government websites.

Determination of Input-output Indicators

This paper studies the efficiency of green finance in promoting industrial upgrading. Therefore, green finance indicators are served as input indicators in the input-output system, and corresponding indicators are used as output indicators measuring industrial upgrading.

Among input indicators, existing studies on the green finance measurement system mainly use quantitative indicators like green credit, green stocks, green bonds, and green funds,[16, 17–19] and also qualitative indicators.[20] Considering the current problem of availability of green finance data and combined with existing research results, six indicators such as green credit are selected as input indicators from three levels (see Table 1 for details).

Among output indicators, industrial structure optimization and upgrading refers to the reallocation of production elements in diverse sectors of the economy and distinct industries as well as changes in the proportion of performance.[21]The current academic measurement of industrial structure upgrading is divided into three parts: industrial structure rationalization (*ia*), industrial structure heightening (*ib*), and industrial structure greening (*ic*). In this paper, drawing on Han et al.,[22] the reciprocal of the Thayer index is used as a measure of industrial structure rationalization, as shown in Eq. (1).

$$ia = \frac{1}{\sum_{i=1}^{n}(Y_i / Y)\left|(Y_i / L_i)/(Y/L) - 1\right|} \quad (1)$$

In this index formula, *ia* is the index of industrial structure rationalization, Y is the output amount, L is the number of employees, Yi/Y is the output structure, and Y/L is the productivity. The value of *ia* indicates the rationalization coefficient of the industrial structure, and a high or low value of *ia* indicates the rational degree of industrial structure.

The height of the industrial structure is reflected by the proportional relationship between industries. For example, according to Clark's law,[23] the proportion (abbreviated as *ib* in this paper) of the output value of secondary to tertiary industries is taken as a measure of industrial structure height, as shown in Eq. (2).

$$ib = \frac{Y_3}{Y_2} \quad (2)$$

In this indicator equation, Y_3 denotes the tertiary industry and Y_2 denotes the secondary industry. The *ib* value indicates the heightened coefficient of the industrial structure, and the high or low *ib* value indicates the level of heightened industrial structure.

Greening of the industrial structure is measured by the decreasing rate of energy consumption per 0.1 million GDP in industrial production.[24]This approach determines the degree of greening of industrial structure by the amount of energy consumed in industrial unit production.

Analysis of Environmental Variables

The selection of environmental variables follows the "separation hypothesis" proposed by Simar et al. (2007).[25] External environmental variables are selected that significantly impact the input-output efficiency of green finance for industrial upgrading, and that are not easily influenced by each individual decision unit. Therefore, combined with existing literature, four variables (added value of high-tech industry, fixed asset investment, fiscal expenditure, and environmental protection industry income) are used as environmental variables in the second stage SFA model regression. Their effects on the slack value are studied. The added value of high-tech industry indicates the increase of regional high-tech production over the year. This represents the rate of technological progress which in turn yields technological support for industrial structure upgrading. Therefore, the added value of the high-tech industry can be used as a variable to measure technological environmental factors. Fixed asset investment indicates the social investment in industrial upgrading, which provides funds, and can be used as a variable to measure the economic environmental factors. Fiscal expenditure indicates the government's investment in financial subsidies in industrial upgrading to stimulate enterprises to realize industrial upgrading. This can be used as a variable to measure the government environmental factor. Environmental protection industry income indicates the income of green industry in the industry, which can be used to measure the prospect of industrial structure upgrading.

Table 1
Green Finance for the Industrial Upgrading Efficiency Quantitative Index System in Hunan

Types	Level 1 indicator layer	Level 2 indicator layer	Units	Characteristic
Input indicators (level of green finance)	Green credits	Green credit amounts	%	Quantitative
		Green credit volumes as a percentage of total regional credit	%	Quantitative
	Green stocks	Numbers of listed environmental companies in cities	Individual	Quantitative
		Availability of green resource asset securitization products	—	Qualitative
	Green investments	Proportion of energy-saving and environmental protection expenditure in fiscal expenditure	—	Quantitative
		Proportion of investment in science and technology in fiscal expenditure	%	Quantitative

Output indicators (level of industrial upgrading)	Rationalization of industrial upgrading	Formula (1)	—	Quantitative
	Heightening of industrial upgrading	Formula (2)	—	Quantitative
	Greening of industrial upgrading	Energy consumption reduction rate of 10,000 Yuan GDP	%	Quantitative
Environmental factors	Technology	High-tech industry added value	0.1 billion Yuan	Quantitative
	Economy	Fixed assets investment	0.1 billion Yuan	Quantitative
	Government	Financial expenditures	0.1 billion Yuan	Quantitative
	Green benefits	Environmental industry revenue	0.1 billion Yuan	Quantitative

EFFICIENCY VALUE OUTCOME MEASURE

Stage 1: Empirical Results Based on Traditional DEA

Using DEAP2.1 software, the efficiency levels of green finance were analyzed in 14 cities and states in Hunan Province from 2010 to 2017, and the outcomes are presented in Table 2. Without considering environmental and consequential factors, Table 2 shows that the average values of integrated technical efficiency, pure technical efficiency, and scale technical efficiency of 14 cities in Hunan Province were 0.538, 0.647, and 0.812 in 2010, respectively. In 2017, these increased slightly to 0.724, 0.794, and 0.913, respectively. The calculation results also show that the cities at the forefront of green financial efficiency in Hunan during 2010–2017 are Shaoyang (2010–2017), Yongzhou (2010–2017), and Xiangxi (2010–2017). Hengyang (2012–2017), Huaihua (2010–2012 and 2014–2017), and Loudi (2012, 2017) are at the forefront of green financial development in Hunan in terms of efficiency in the corresponding years.

However, as indicated from the steps of the three-stage DEA method explained in the previous section, the efficiency measurement in the first stage does not exclude the influence of statistical noise generated by environmental elements, management inefficiency terms, and random error terms. To obtain the true green finance efficiency level, further data adjustment is needed.

Table 2
Green Finance First Stage Efficiency Values of 14 Cities in Hunan

Cities	2010				2017			
	Comprehensive Technical Efficiency	Pure Technical Efficiency	Scale Technical Efficiency	Scale Efficiency Characteristic	Comprehensive Technical Efficiency	Pure Technical Efficiency	Scale Technical Efficiency	Scale Efficiency Characteristic
Changsha	0.043	1	0.043	drs	0.458	1	0.458	drs
Zhuzhou	0.101	0.19	0.53	drs	0.566	0.779	0.726	drs
Xiangtan	0.041	0.047	0.874	irs	0.298	0.299	0.996	irs
Hengyang	0.746	1	0.746	drs	1	1	1	-
Shaoyang	1	1	1	-	1	1	1	-
Yueyang	0.032	0.043	0.734	drs	0.351	0.382	0.918	irs
Changde	0.13	0.145	0.895	drs	0.459	0.527	0.871	irs
Zhangjiajie	1	1	1	-	1	1	1	-
Yiyang	0.41	0.419	0.977	irs	0.45	0.482	0.932	irs
Chenzhou	0.144	0.211	0.685	drs	0.623	0.7	0.89	irs
Yongzhou	1	1	1	-	0.935	0.951	0.984	drs
Huaihua	1	1	1	-	1	1	1	-

Loudi	0.888	1	0.888	irs	1	1	1	-
Xiangxi	1	1	1	-	1	1	1	-
Averages	0.538	0.647	0.812		0.724	0.794	0.913	

Note:
Because of space limitations, only data for 2010 and 2017 are presented; the scale efficiency characteristics in this table indicate constant scale payoffs, *drs*represents diminishing returns to scale, and *irs*represents increasing returns to scale.

Stage 2: SFA Regression Results

The second stage mainly regresses the slack variables gained from the first stage. In this paper, the explained variables in the regression analysis include the amount of green credit, the ratio of green credit to total regional credit, the number of listed environmental protection enterprises, the presence of green resource asset securitization products, the proportion of energy conservation and environmental protection expenditure to fiscal expenditure, and the proportion of science and technology R&D investment to fiscal expenditure in input indicators. The explaining variables include the high-tech industry added value, fixed asset investment, fiscal expenditure, and environmental protection industry income. Then, the SFA model is established. Frontier 4.1 software is used to measure regression results, and the specific regression results are shown in Table 3.

The results presented in Table 3 denote that the δ^2 and γ values passed the significance test. The γ values are greater than 0.9 and most of the values are close to 1, indicating that the internal management inefficiency has a very large impact on the overall efficiency, making it necessary to eliminate environmental variables and other noise variables before measuring them.

Table 3
SFA Parameter Estimation of External Environmental Variables for Green Financial Efficiency in Hunan

	Green Credit Amount	Proportion of Green Credit Amount to Total Regional Credit	Number of Listed Environmental Companies	Presence of Green Resource Asset Securitization Products	Proportion of Energy Conservation and Environmental Protection Expenditure to Fiscal Expenditure	Proportion of Science and Technology R&D Investment to Fiscal Expenditure
Constant Term	33.627*** (33.627)	63.752*** (72.543)	134.561*** (145.651)	421.32*** (497.721)	1884.984*** (2045.543)	38.504*** (45.431)
Added Values of High-tech Industries	0.141 (0.141)	-2.171** (-2.978)	-0.068 (-0.075)	-0.520 (-0.576)	0.727** (1.754)	0.021** (1.975)
Fixed Asset Investment	0.086 (0.086)	-2.254*** (3.423)	0.046*** (2.654)	-0.059 (-0.523)	-1.118*** (-2.321)	0.002 (0.032)
Fiscal Expenditure	-2.984*** (-2.984)	0.510 (0.754)	-0.212** (-1.765)	0.111 (0.864)	2.787*** (3.876)	-0.087 (-0.135)
Environmental Protection Industry Income	-2.135** (-2.135)	1.096 (1.754)	-0.026 (-0.231)	0.260** (0.187)	1.055* (1.654)	0.013 (0.843)
δ^2	0.742** (1.754)	0.861*** (3.654)	1.515*** (7.864)	0.032 (0.542)	70.926 (134.454)	0.199** (1.876)
γ	0.994*** (1118.211)	0.975*** (432.514)	0.891*** (11.986)	0.972*** (164.866)	0.996*** (16.865)	0.991*** (32.865)
logL	68.970	79.760	377.290	243.330	140.652	450.057
LR	23.690	26.870	22.598	45.650	23.033	42.426

Note:
*, **, and *** express significance levels of 10%, 5%, and 1%, respectively, and t-values are shown in parentheses.

Stage 3: DEA Efficiency Analysis after Adjusting Inputs Indicators

After the adjustment of second-stage input indicators, the classical DEA model is served again to measure the green financial efficiency of cities in Hunan. The outcomes are listed in Table 4, indicating changes in two aspects. Firstly, adjusting efficiency values have changed. The changes of adjusting efficiency values from 2010 to 2017 show that the average values of comprehensive technical efficiency, pure technical efficiency, and scale efficiency in 2010 were 0.785, 0.983, and 0.796, respectively, while they reached 0.916, 1, and 0.916, respectively, in 2017. This shows that the adjusting efficiency values generally follow a rising trend. The pure technical efficiency values of Xiangtan City increased significantly except for a slight decrease in 2017 compared with 2010. The changes in efficiency of each city and each year before and after adjustment, show that in the first stage, the mean value of comprehensive technical efficiency, the mean value of pure technical efficiency, and the mean value of scale efficiency in 2017 are 0.724, 0.794, and 0.913, separately, while in the third stage, values are 0.916, 1, and 0.916, respectively. Each mean value has changed significantly. Thus, it can be concluded that the green financial efficiency of Hunan is influenced by both the external environment and random dimensions, and it is also affected to a greater extent. In addition, the comparison between the efficiency values of each city before and after the adjustment shows that most cities either significantly increases or retained the same efficiency values after the adjustment, while certain cities have experienced a decline in efficiency values. For example, in 2017, except for Shaoyang, Huaihua, and Xiangxi (which showed a decline after adjustment), the values of all other cities showed either increased or remained unchanged. This indicates that the efficiency values of Shaoyang, Huaihua, and Xiangxi are overestimated.

Secondly, the spatial relationship of the efficiency of the cities after adjustment has also changed. The adjusted efficiency values shows that in 2017, Changsha, Zhuzhou, and Xiangtan in the Changzhutan region have higher efficiency values; Yueyang, Changde, and Yiyang in the north of Hunan have lower values, Hengyang, Chenzhou, and Yongzhou in the south of Hunan have higher values, while Huaihua and Xiangxi in the west of Hunan have lower values.

The underestimated or overestimated combined efficiency corroborates the correctness of using the three-stage DEA model for removing the follow-on disturbance term. However, the adjusted efficiency values show regional clustering characteristics, and the problem needs to be analyzed from a spatial correlation perspective. Therefore, based on both the efficiency values and spatial agglomeration, this paper further investigates whether spatial correlation occurs in the green financial development of each city and state to promote industrial upgrading. Furthermore, what kind of distribution and degree of correlation closeness the correlation network presents is also analyzed. By answering these questions, corresponding suggestions and strategies for Hunan green financial development planning can be provided.

Table 4
Green Financial Efficiency Values of Cities in Hunan in the Third Stage

Cities	2010				2017			
	Comprehensive Technical Efficiency	Pure Technical Efficiency	Scale Technical Efficiency	Scale Efficiency Characteristic	Comprehensive Technical Efficiency	Pure Technical Efficiency	Scale Technical Efficiency	Scale Efficiency Characteristic

Changsha	1	1	1	-	1	1	1	-
Zhuzhou	0.66	0.973	0.678	irs	0.881	0.999	0.882	irs
Xiangtan	0.576	1	0.576	irs	0.953	0.999	0.954	irs
Hengyang	1	1	1	-	1	1	1	-
Shaoyang	1	1	1	-	0.969	1	0.969	irs
Yueyang	0.537	0.952	0.564	irs	0.9	0.999	0.901	irs
Changde	0.551	0.958	0.575	irs	0.825	1	0.825	irs
Zhangjiajie	1	1	1	-	1	1	1	-
Yiyang	0.813	0.982	0.828	irs	0.864	1	0.864	irs
Chenzhou	0.833	0.982	0.848	irs	0.849	1	0.85	irs
Yongzhou	1	1	1	-	0.966	1	0.966	irs
Huaihua	0.607	0.958	0.633	irs	0.723	1	0.723	irs
Loudi	0.842	0.982	0.857	irs	1	1	1	-
Xiangxi	0.575	0.975	0.589	irs	0.887	1	0.887	irs
Averages	0.785	0.983	0.796		0.916	1	0.916	

Note:
Because of space limitations, only the adjusted efficiency values for 2010 and 2017 are shown.

ANALYSIS OF THE SPATIAL CORRELATION CHARACTERISTICS OF HUNAN GREEN FINANCE FOR INDUSTRIAL UPGRADING

Based on the efficiency values obtained above, the spatial correlations in Hunan's green finance for industrial upgrading are investigated next. Compared with the popular spatial econometrics analysis (EDSA), SNA is better capable to portray the characteristics of network structure presented by resources across regions.[12–13] Therefore, this paper adopts SNA for the next step of analysis.

SNA is based on "relational data", which reveals the spatially linked structural patterns and spatial clustering of networks and can demonstrate the influence of spatially linked "relationships"[26]. In reference to the gravitational model of Liu et al. (2015),[12] a modified gravitational model is established according to the research content, as shown in Eq. (3).

$$x_{ij} = k_{ij} \frac{\sqrt[3]{P_i G_i L_i}\,\sqrt[3]{P_j G_j L_j}}{[D_{ij}/(g_i - g_j)]^2}, k_{ij} = \frac{L_i}{L_i + L_j} \tag{3}$$

Where, i and j represent each city, x_{ij} is the spatial correlation between i and j; P_i and P_j are the overall number of people in i and j, respectively; G_i and G_j are the total value of GDP in i and j, separately; L_i and L_j are the efficiency values of green finance for industrial upgrading in i and j, respectively; k_{ij} is the contribution margin of i to the efficiency of i and j. Considering the impact of economic and geographic distance between municipalities and states on the spatial relationship of regional industrial upgrading, geographic distance and economic distance are introduced into the modified gravity model; D_{ij} is the shortest traveling distance via highways between municipalities and states i and j, as calculated by Gaode map; g_i and g_j are the GDP per capita of i and j, respectively.

Overall Network Structure Characteristics

In this thesis, the modified gravity model is used to obtain the spatial correlation gravitational matrix of green finance for industrial upgrading. This draws on the practice of Wu et al. (2016) to establish the critical value of spatial correlation between cities.[26]If the gravitational value is less than the critical value, it is recorded as 0, suggesting that there is no spatial relationship between the two cities. If the gravitational value is greater than the critical value, it is recorded as 1, showing that a vital spatial relationship presences between the two cities.

According to the green financial efficiency spatial correlation gravitational matrix, the green financial efficiency spatial correlation network maps in 2011 and 2017 are drawn with the help of the UCINET tool (Figure 1). Figure 1 shows that in 2011, the spatial linkage of Hunan green finance for industrial upgrading was relatively solitary, mostly between the provincial capital of Changsha and other cities. Changsha acted as the "leader" of green finance development in Hunan region in that period.

By 2017, the network map of spatial linkage changed significantly. Not only did the number of network linkage increase significantly, the linkage among cities became closer. Changsha, Zhuzhou, and Xiangtan are closely linked with other cities and gradually became the center of the network.

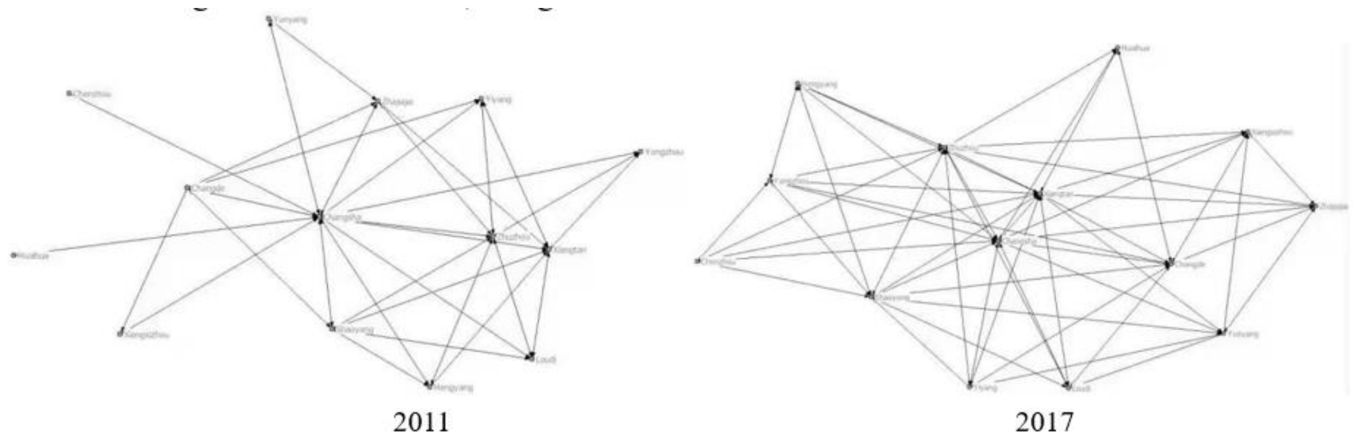

Figure 1 Spatial correlation network of Hunan green finance for industrial upgrading efficiency

To study the density and stability of the spatial relationship network, this paper analyzes the overall network density and network correlation (The overall network characteristics mainly include the number of network linkage relationships, network efficiency, and network rank degree. Network density reflects the sparsity of green financial efficiency relationships among cities in the network. The higher this density, the more closely it connects units. The efficiency of the network reflects the connection efficiencythe among the members. The lower the efficiency, the more connected and denser the connections are among the members and the more stable the associated network.). Figure 2 shows that the spatial density has increased from 0.2967 in 2011 to 0.5604 in 2017. The corresponding number of network relations has augmented from 54 in 2011 to 102 in 2017, while the network efficiency has evolved from 0.8077 in 2011 to 0.4744 in 2017. These three indicators show that with the economic, transportation, and social developments, the network connection among cities in the process of green finance for industrial upgrading has increased and become more closely connected. However, in terms of network density, the density value is still relatively low, and room to improve the network space connection still exists. Therefore, it is necessary to continue improving the green financial development connection relationship in Hunan.

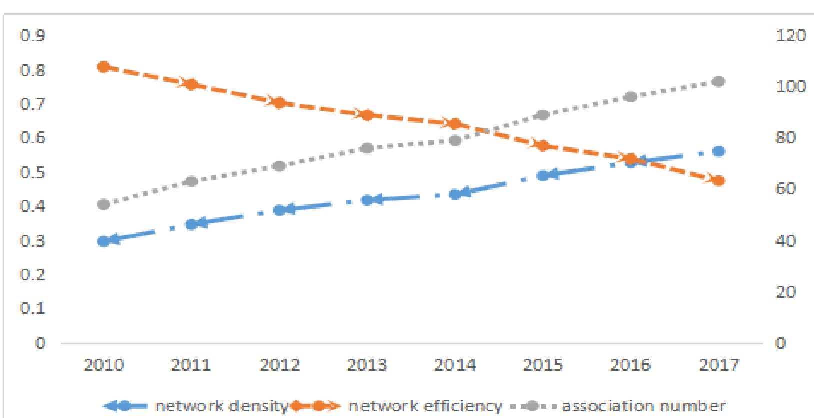

Figure 2 Spatial network density, network efficiency, and corresponding number of network relations

Individual Network Structure Characteristics

Then the individual network centrality of each city is examined (Individual network characteristics refer to three dimensions: point centrality, intermediary centrality, and proximity centrality. In a directed network, point centrality is a measure of the position of an individual city-state in the network. A higher value implies that the city-state is more central to the network. Intermediation centrality is an indicator of the degree of influence a city-state exerts on the green financial efficiency of other cities and states. The higher the node degree of the city-state, the more it can control the connection of other cities, and the more it is in the relative central position, thus fulfilling the role of a bridge in the whole network. Proximity to the center reflects the degree to which a city-state is "not controlled by other nodes" in the overall network. The higher the value is, the more direct the connections the city-state has with other cities and states, and the stronger the degree of control over other cities.), and Table 5 shows the network centrality of each city and state in Hunan in 2017 (Due to the length restrictions, only 2017 results are shown.). Based on point degree centrality analysis, the average point degree centrality index is 56.04, and five cities are exceeding the average of point degree: Changsha, Xiangtan, Zhuzhou, Shaoyang, and Changde. These are closely connected with other cities in the process of green finance for industrial upgrading in Hunan. Furthermore, the point-in degree is greater than the point-out degree, showing more benefit than spillover, including Zhuzhou, Shaoyang, Yongzhou, Loudi, and Xiangxi. The point-out degree is higher than the point-in degree, showing more spillover than benefit, including Yueyang, Changde, Chenzhou, and other cities. This indicates that in promoting industrial upgrading, the development of green finance (such as Zhuzhou, Shaoyang, and other cities) attracts relevant resources from other cities to realize their own industrial upgrading and transformation.

According to the analysis of intermediary centrality, the average value of intermediary centrality is 5.71, and five cities are above the average value (i.e., Changsha, Zhuzhou, Xiangtan, Shaoyang, and Changde). These form the center of the spatial network and have the ability to control other cities. In contrast, Loudi, Xiangxi, Huaihua, Chenzhou, and Hengyang, which have a lower intermediary centrality index, are vulnerable to the impact of cities with a higher intermediary centrality index. Finally, from the perspective of proximity centrality, the average value of proximity centrality is 60.36, and five cities are above the mean value (i.e., Changsha, Zhuzhou, Xiangtan, Shaoyang, and Zhangjiajie). The higher the proximity centrality index, the stronger the degree of control the city exerts over other low-index cities. High-index cities are in the network center of the spatial network.

Summing up the centrality results, Changsha, Zhuzhou, and Xiangtan have higher three centrality indices, which means that Changsha, Zhuzhou, and Xiangtan play a key part in the spatial network of Hunan green finance for industrial upgrading. This is also intimately tied to the economy and financial strength of these three cities, and is a direct manifestation of the construction of two types of society in Changsha, Zhuzhou, and Xiangtan.

Table 5
Spatial Network Centrality Analysis

Cities	Point Degree Center Degree				Intermediary Center Degree		Proximity Center Degree	
	Point-out Degree	Point-in Degree	Center Degree	Ranking	Center Degree	Ranking	Center Degree	Ranking
Changsha	13	13	100.00	1	22.69	1	100.00	1
Zhuzhou	10	11	76.92	3	13.50	3	65.00	2
Xiangtan	13	13	100.00	2	22.69	2	65.00	3

Hengyang	5	5	38.46	13	0.00	14	59.09	6
Shaoyang	9	10	69.23	4	8.41	4	61.91	4
Yueyang	7	4	53.85	6	1.20	8	52.00	13
Changde	9	8	69.23	5	7.05	5	56.52	8
Zhangjiajie	6	6	46.15	8	1.36	6	61.91	5
Yiyang	5	5	38.46	9	0.52	9	59.09	7
Chenzhou	5	4	38.46	12	0.00	13	52.00	10
Yongzhou	6	7	46.15	7	1.31	7	52.00	11
Huaihua	4	4	30.77	14	0.24	12	52.00	12
Loudi	5	6	38.46	10	0.52	10	56.52	9
Xiangxi	5	6	38.46	11	0.52	11	52.00	14
Averages	7.29	7.29	56.04	-	5.71	-	60.36	-

Block Model

The block model is further used for spatial clustering analysis (The block model is divided into four main segments, namely the "two-way spillover" segment, the "net income" segment, the "net spillover" segment, and the "broker" segment. If the expected internal relationship proportion is less than the actual ratio, the board belongs to the "two-way spillover" segment or the "net benefit" segment. If the number of beneficiary relationships is small compared with these two, the board behaves as a "two-way spillover"; otherwise, the segment is a "net benefit". If the proportion of desired internal relationships is greater than the proportion of actual internal relationships, the board is a "broker" or a "net spillover". If there are more spillover relationships, the segment is a "net spillover". If there are less spillover relationships, the segment is a "broker".). Based on the role position in the spatial network of Hunan green finance for industrial upgrading, the CONCOR method is used to identify spatial network plate association relations, choosing a maximum segmentation depth of 2 and a convergence criterion of 0.2. These 14 cities are divided into four blocks of two-way spillover segment, net benefit segment, broker segment, and net spillover segment (Table 6). Table 6 shows that there are 103 correlations in the overall network association, among which 14 are inter-relations and 89 are intra-relations. This implies that apparent correlations and spillover effects exist between blocks.

Table 6 shows that Block I has 26 overflowing relations, 24 receiving block relations, and 2 internal block relations, and the proportion of expected internal relations equals the proportion of actual internal relations, both of which are 7.69%. However, because the corresponding cities in this block have more relations in and outside the block, Block I can be judged as a “two-way overflowing” block. The cities in this block are Changsha and Xiangtan, whose comprehensive strength is at the top of Hunan, exerting a two-way “leading” role between blocks. There are 26 spillover relationships, 23 receiving relationships, and 0 internal relationships in Block II. The expected internal relationship ratio and the actual internal relationship ratio are 15.38% and 0. This implies that the number of spillovers in this block is much larger than the number of benefits. According to the previous definition, this identifies Block II as a “net spillover” block. There are cases of green financial resources spillover from this sector to other cities, including Zhuzhou, Changde, and Yueyang, whose comprehensive strengths are in the second level of Hunan. There are 25 spillover relations, 26 acceptance relations, and 10 sectoral internal relations in Block III. The proportion of expected internal relations and actual internal relations are

23.08% and 40%, respectively. Because the proportion of expected internal relations is lower than the proportion of actual internal relations, and the number of beneficiary relations is higher than in Block I, Block III is identified as a "net benefit" block. The cities in this block include Shaoyang, Hengyang, Chenzhou, and Yongzhou, which are in the third level of Hunan's comprehensive strength. Block IV has 26 spillover relationships, 27 receiving block relationships, and 2 intra-plate relationships. The proportion of desired internal relations in this block is greater than the proportion of actual internal relations, and the number of spillover relations is higher. According to the previous definition, this identifies Block IV as a "broker" block, which includes cities with low comprehensive strength, such as Yiyang, Zhangjiajie, Huaihua, Loudi, and Xiangxi. These cities exert the role of "intermediary" and "bridge" in the spatial network structure and geographical location.

Table 6
Stock Structure of the Spatial Relationship Network

Blocks	Beneficiary Relationship		Spillover Relationship		Expected Internal Relationship Ratio	Actual Internal Relationship Ratio	Judgment
	Inside the Block	Outside the Block	Inside the Block	Outside the Block			
Block I	2	24	2	24	7.69%	7.69%	Two-way Overflowing Block
Block II	0	23	0	26	15.38%	0	Net Spillover Block
Block III	10	16	10	15	23.08%	40%	Net Benefit Block
Block IV	2	25	2	24	30.77%	7.69%	Broker Block

Note:
The expected internal relationship ratio is calculated by (number of cities in the block - 1) / (number of all cities in the network - 1), and the actual internal relationship ratio is calculated by number of internal relationships in the block / total number of overflow relationships in the block.

To identify the spatial relationship between blocks more clearly, this paper uses clustering calculation (UCINET software) to obtain the density matrix between each block. Compared with the overall network density (0.5604), if the block density value exceeds 0.5604, it is recorded as 1 in the image matrix; conversely, if it is less than 0.5604, it is recorded as 0. The corresponding image matrix table is presented in Table 7. The two-way spillover block and the net benefit blocks exert stronger spillover effects on themselves, while the net spillover and broker blocks have weaker effects. This indicates that the two-way spillover block and the net benefit block have stronger linkage effects in the overall network in Changsha, Xiangtan, Shaoyang, Hengyang, Chenzhou, and Yongzhou, while other cities are weaker. The net spillover block, net benefit block, and broker block all spillover to the two-way spillover block. This indicates that Changsha and Xiangtan (in the two-way spillover block) not only spillover to themselves, they also receive the inflow of green financial resources from other cities. Thus, they become the main beneficiaries in the spatially linked network of Hunan green finance for industrial upgrading.

Table 7
Spatial Correlation Network Density Matrix and Image Matrix

	Density Matrix				Image Matrix			
	Two-way Overflowing	Net Spillover	Net Benefit	Broker Block	Two-way Overflowing	Net Spillover	Net Benefit	Broker Block

	Block	Block	Block		Block	Block	Block	
Two-way Overflowing Block	1	1	1	1	1	1	1	1
Net Spillover Block	1	0	0.5	0.933	1	0	0	1
Net Benefit Block	1	0.5	0.833	0.05	1	0	1	0
Broker Block	1	0.733	0.1	0.1	1	1	0	0

CONCLUSIONS AND INSIGHTS

To study the spatial correlation of green finance efficiency among regions, this paper establishes an input-output index system based on the data of green finance for industrial upgrading in Hunan, China, from 2008 to 2017. The efficiency values of inputs and outputs are measured with the three-stage DEA model, and the efficiency values are calculated using the modified gravity model and social network analysis. Finally, relevant spatial network correlation structure characteristics are obtained. The specific research findings are summarized in the following.

(1) The three-stage DEA model is effective in eliminating both environmental factors and random interference. The results show that Changsha, Hengyang, Shaoyang, Zhangjiajie, and Loudi are more efficient, while other cities are comparatively less efficient. Efficiency values of 14 cities indicate agglomeration. (2) From the overall network structure, with the development of economy, transportation, and society, the network association of each city in the process of green finance for industrial upgrading has increased, the connection has tightened, and the associated network has stabilized. However, the overall density value remains relatively low, and there is still space for improving the network spatial connection. (3) From the perspective of the individual network structure, the results of the centrality of spatial network show that Changsha, Xiangtan, Zhuzhou, Shaoyang, and Changde are in the core of the spatial network, while other cities are at its edge. (4) The results of the block model indicate that Changsha and Xiangtan belong to the two-way spillover block, exerting a two-way “leading” role both within and outside network plates. Zhuzhou, Changde, and Yueyang belong to the net spillover block, which show spillover of green financial resources to other cities. Shaoyang, Hengyang, Chenzhou, and Yongzhou are net beneficiaries, benefiting more than spilling over in their interactions. Yiyang, Zhangjiajie, Huaihua, Loudi, and Xiangxi belong to the broker block, exerting the role of “intermediaries” and “bridges” not only in the spatial network structure, but also geographically.

The spatial association network characteristics during the procedure of green finance for industrial upgrading in Hunan are complex. These characteristics provide a new factual foundation and basis for motivating the development of green finance and the energy saving and emission reduction of tobacco industry in Hunan and throughout China. Based on this, to better realize green financial services for industrial upgrading and transformation and the energy saving and emission reduction of tobacco industry in Hunan, the government should follow the spatially related network characteristics of green finance in each city when formulating policy. Moreover, the concept of synergistic development should be established, and a gradient development strategy should be implemented according to differences between cities. The concept of green development should be implemented, technological transformation should be strengthened, and energy management should be improved in the development of tobacco industry.

Firstly, the policy should focus on synergistic development. On the one hand, the emergence of spatially linked network characteristics has overcome the prior situation of independent development of green finance in each city and has provided a new factual basis for overall synergistic development. However, the spatial network characteristics also induce serious challenges for strategy formulation. At present, both disparities and differences exist among cities in Hunan in terms of their economic foundation, financial strength, and industrial structure. How macro-control and market mechanism can be used to realize cross-regional flow of green financial resources, optimal spatial allocation and the promotion of tobacco industry's energy saving and emission reduction has become a key policy-making goal towards synergistic development. On the other hand, the "attribute data" of green finance for industrial promotion in each city should be compared with the "correlation data" of the spatial correlation network. For cities with high intermediary centrality and proximity to the center in the spatial network, it is not only necessary to study the reasons for their high efficiency in green finance, but attention should also be directed to the central and leading roles these cities exert. By using "attribute data" and "correlation data", these cities should be fully utilized to control the macroeconomic reality of other cities. Consequently, the synergistic development of policies from "point" to "surface" and from "local" to "overall" can be promoted.

Secondly, policy needs to be tailored to local conditions and the implementation of differentiated strategies among cities. The characteristics of green finance for industrial upgrading of spatially linked network segments provide a basis for formulating differentiated development strategies for green finance in cities and for implementing spatial classification management. (1) For cities in the "two-way spillover" and "net spillover" blocks (with high green financial efficiency), the threshold of green credit should be raised. For example, in the "three high" industries, financial institutions must strictly control the granting of green credit to enterprises, to force them out of the market. At the same time, strict macro-control policies should be implemented for these sectors, to fully utilize the role of these sectors as a "guide" for promoting the quality of green financial development in other sectors. (2) For the "broker" block, according to its role as a "bridge" between segments, the policy should focus on its function in the overall network transmission. (3) Regarding cities in the "net beneficiary" block, these should actively absorb the experience of cities in the "two-way spillover" block and the "net spillover" block in the development of high-quality green finance. These measures can achieve steady upgrading of their own industries.

In conclusion, inter-regional governments should make the most of the spatial network effect already existing in green finance for industrial structure upgrading and the promotion of tobacco industry's energy saving and emission reduction. In doing do, inter-regional synergistic linkage can be strengthened and localized policies implemented, towards realizing the mutual circulation of capital and technology. Consequently, good green finance policies for industrial structure upgrading can be jointly guided. Tobacco industry also apply advanced energy-saving technologies in an all-round way, reduce energy consumption, make lean improvements, optimize and upgrade energy management and control technologies, and adhere to green development to contribute to energy saving, emission reduction, and low-carbon life.

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