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ORIGINAL ARTICLE

Study on the Factors Affecting China's Green Transformation

Guoshun Ma[A], Chen Han[1A]

[A]**College of Mathematics and Statistics, Northwest Normal University, Lanzhou730000, China**

Corresponding Author: Guoshun Ma

Abstract:

This study assessed the degree of green transformation in Chinese cities and its affecting variables using pan el data from 2011 to 2020. According to the study's findings, urban green transformation is generally improv ing in Chinese cities; its primary influencing factors are innovation and entrepreneurial vitality, science and innovation investment intensity, economic development level, and advanced industrial structure; the relation ship between advanced industrial structure and green transformation level is an inverted "U" shape, and the r elationship between advanced industrial structure and green transformation level is an inverse "U." An inver ted "U" shape represents the link between advanced industrial structure and the degree of the green transfor mation, while a "M" shape represents the relationship between the intensity of research and innovation inves tment and the level of the green transformation. Finally, pertinent recommendations are made in light of the findings above.

Keywords: Green Transformation; Carbon neutrality; Innovation and entrepreneurial vitality; Machine Learning; SHAP interpretation framework

1. Introduction

To address the climate problem, the world urgently needs a green and low-carbon transition. China has been investigating the route of eco-friendly and low-carbon development, summarizing historical experiences and accomplishments, and exhibiting real-world outcomes and experiences. China has been promoting sustainable development in recent years by reducing energy use (Jiang et al., 2020), and the growth rate of overall urban green transition performance has fluctuated in a "W" pattern (Wang et al., 2022). Due to low returns on science and innovation, the Northeast area lacks the incentives for long-term transformation (Fu et al., 2020). Unsurprisingly, the importance of innovation in fostering transformation is also diminished by the southern region's slow growth of green institutional innovation capability (Chongming, W. 2016). In general, socioeconomic factors must be taken into account when choosing the direction of regional green transformation (Cheba et al., 2022).

The majority of studies on the influencing elements of urban greening renovation now conducted by academics use linear regression techniques; nevertheless, these conventional techniques have many drawbacks, including numerous restrictions on regression models and a dearth of complicated data linkages. Methods for machine learning overcome these restrictions. To measure the degree of urban green transformation, this paper first uses the entropy method of panel data. Next, it uses the machine learning method to thoroughly explore the factors that influence urban green transformation and to visualize and analyze the relative importance of each factor and its mode of action.

2. Comprehensive evaluation of the level of green transformation of cities

2.1. Green transformation level comprehensive evaluation model construction

The goal of the green transformation is to convert the country's economy into a cutting-edge, environmentally friendly economic system, however due to the complexity of the metropolitan system, there cannot be a single paradigm for the green transformation across all regions. This research breaks out the urban green transformation measuring method into four tiers from a broad perspective. In Table 1, the specific index layer is displayed.

Table 1 Evaluation index system of green transformation level of cities.

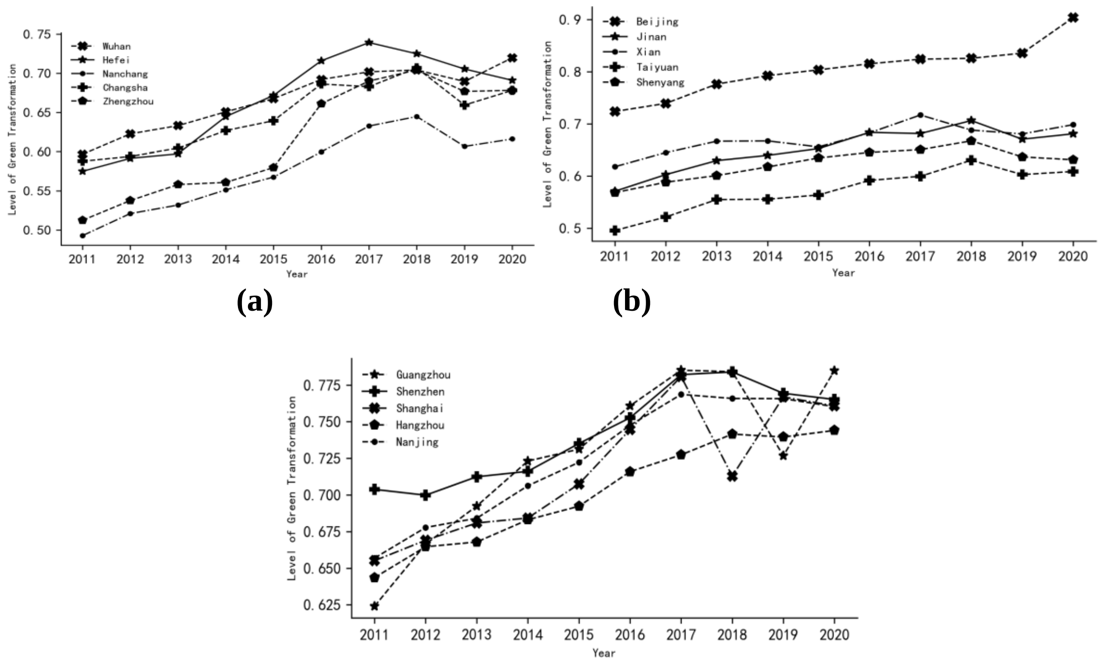
Green transformation of the city	Support Mechanism	Green Total Factor Productivity
	Motivation Mechanism	Number of Green Patent Acquisitions
	Governance Mechanism	Urban domestic sewage treatment rate Harmless treatment rate of urban domestic waste General industrial solid waste comprehensive disposal utilization rate
	Protection mechanism	Greening coverage rate of urban built-up areas Parkland area per capita

Among these, this work uses Stata17.0 software to implement the SBM-GML index measurement method for the measurement of green total factor productivity.

2.2. Analysis of the level of green transformation

In order to calculate the weights of the indicators of urban green transformation, this study uses the entropy weighting method of panel data. Due to space constraints, the complete score data will not be shown.

In addition, this article chooses five sample cities from the central, northern, and southern regions to illustrate the dynamic evolution of the green transformation level in order to elucidate the development trend and regional profile of Chinese cities.

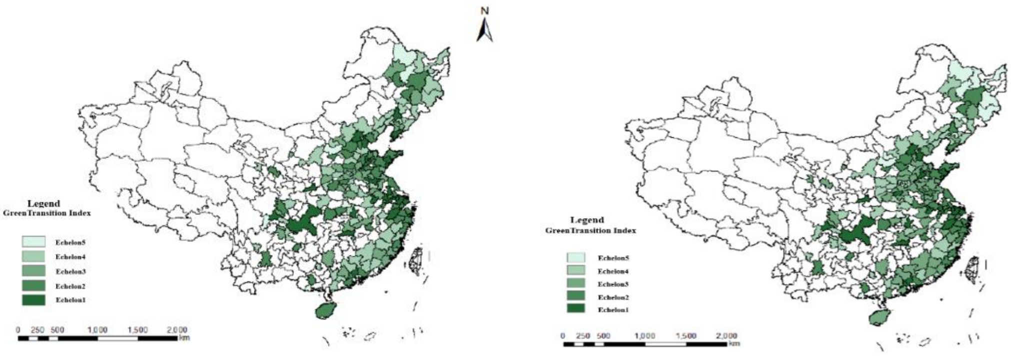


(a) (b)

(c)

Figure 1. (a) Evolution of green transition level in northern cities of China; (b) Evolution of green transformation level in central cities of China; (c) Evolution of green transition level in southern cities of China.

This article maps the entire green transition level of cities in China in 2011 and 2020, respectively, to further illustrate the regional disparities. According to the degree of green transformation, the map separates 197 cities in China into five echelons, with the first echelon having the highest degree of green transformation and the darkest hue, and the others following in decreasing order. White represents the area without data (see Fig. 2).



(a) (b)

Figure 2. (a) Level of green transformation in China's cities in 2011; (b) Level of green transformation in China's cities in 2020.

The overall degree of green transformation of Chinese cities continued to advance between 2011 and 2020, with the capital Beijing taking the absolute lead, according to the results of the overall comprehensive evaluation. The top spots are held by southern cities. The foundation for the green transformation of the southern cities has been set by an active economy, great ability for innovation, and high entrepreneurial vigor; the northern cities are lagging somewhat. The growth of high-tech businesses in the north has long lagged behind that of the south, and the transition to a low-carbon economy is more difficult. Central cities, though, are doing well. The economic and social green revolution in the central region has accelerated due to a number of initiatives the State Council of the Central Committee of the Communist Party of China (CPC) enacted.

3. Analysis of factors influencing the level of green transformation in cities

Table 2 Green Transformation Impact Factor Indicator Description[1]

Socioeconomic	Advanced industrial structure (Indus)	Tertiary industry value added / Secondary industry value added
	Tertiary industry development level (TI)	Tertiary industry value added /GDP
	Secondary industry development level (SI)	Secondary industry value added /GDP
	Use of foreign investment (FI)	Total actual utilization of foreign capital /GDP
	Regional economic development level	Per capita GDP (AGDP)
Quality of life	People's living standard	Consumer Price Index (CPI)
	Urbanization rate (UR)	Urban population / Total population
	People Employment (UE)	Urban unemployment rate
Improvement of people's livelihood	Urban-rural income gap (URIP)	The difference in per capita disposable income between urban and rural residents
	Environmental protection intensity (EPI)	Energy saving and environmental protection expenditure / Local general public budget

[1] The indicator's abbreviation is in parentheses and will be used later in the image.

		expenditure
	Social security investment intensity (SSI)	Social Security and Employment Expenditures / Total local general public budget expenditure
Education Development	Investment intensity in education (EI)	Education Expenses / Local general public budget expenditure
	Human Capital Level (HCM)	General undergraduate population or above / Area population (resident)
Technology Innovation	Technology education input intensity (TEI)	Science and technology expenditures / Local general public budget expenditure
	Innovation and entrepreneurial vitality	China Regional Innovation and Entrepreneurship Index (RIEC)

This article further examines the influencing elements and their involvement mechanisms in order to vigorously advance the path toward the green transformation of China's cities. This paper uses the comprehensive evaluation system created in the previous paper as a guide when choosing indicators. It first takes into account the influencing factors of each sub-mechanism, then combines the components that have a cross-influence on each sub-mechanism to create the five levels of the green transformation influencing factors system that are displayed in Table 2.

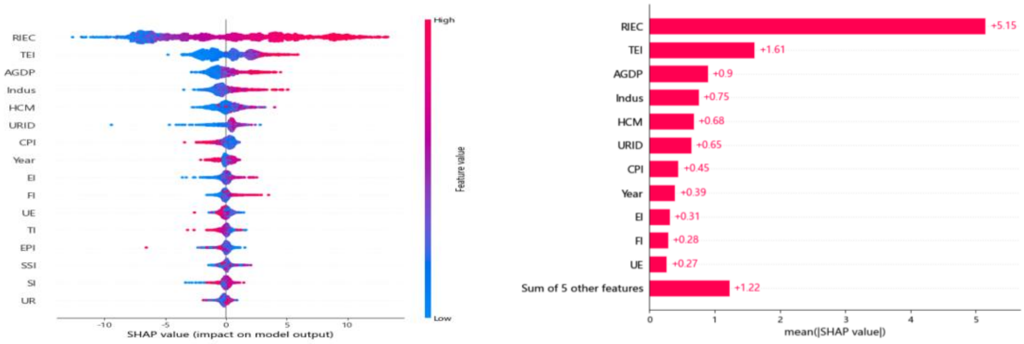
The impact variables of urban green transformation are modeled using a variety of techniques in this study, and the model-fitting effect is measured using R2 and MSE, as shown in Table 3. The XGBoost algorithm will be used for the remainder of this paper's investigation because testing has shown it to have the best effect.

Table 3 Machine Learning Algorithm Fitting Optimization Statistics

MachineLearning Algorithms	R^2	MSE
Ridge Return	0.791	23.881
Lasso Returns	0.804	20.374
SVM	0.813	19.032
RF	0.871	15.782
KNN	0.859	15.650
XGBoost	0.890	10.237

3.1. Overall analysis of green transition impact factors

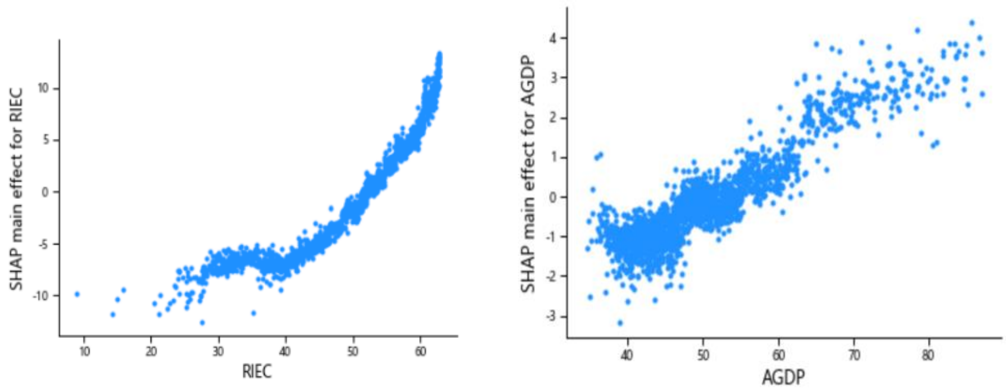
In this study, which is based on the XGBoost algorithm, the comprehensive evaluation index of green transformation level and its influencing factors for 197 Chinese cities over the ten-year period of 2011–2020 were modelled using regression analysis. The influence of each indicator was evaluated from two angles, the first of which was to rank each indicator in descending order according to its SHAP value. Second, the average of each characteristic's absolute SHAP value was used to determine how important that feature was.



(a) (b)

Figure 3. (a) SHAP values of green transition impact factors; (b) Ranking the contribution of green transformation impact factors.

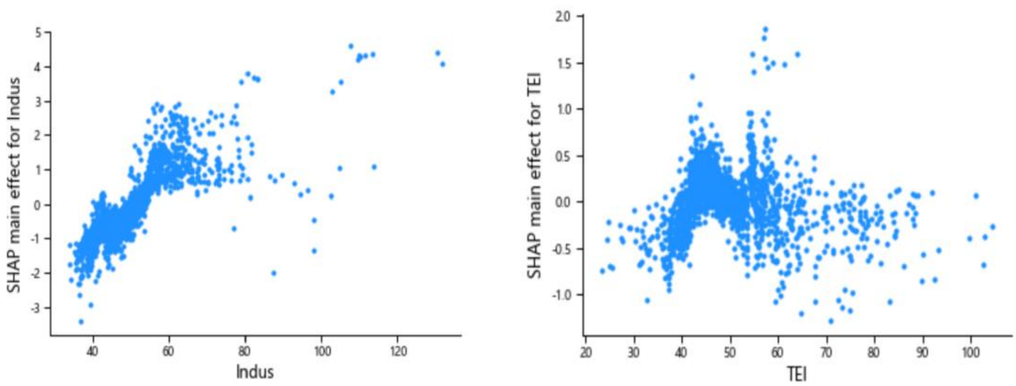
In this study, which is based on the XGBoost algorithm, the comprehensive evaluation index of green transformation level and its influencing factors for 197 Chinese cities over the ten-year period of 2011–2020 were modelled using regression analysis. The influence of each indicator was evaluated from two angles, the first of which was to rank each indicator in descending order according to its SHAP value. Second, the average of each characteristic's absolute SHAP value was used to determine how important that feature was.



(a) (b)

Figure 4. Evolution of RIEC and AGDP contribution rates: (a) Evolution of RIEC contribution rate; (b) Evolution of AGDP contribution ratio.

Thirdly, it is clear from Fig. 5 that the link between the level of green transformation and the advanced industrial structure is an inverted "U" type, while the relationship between the level of green transformation and the intensity of research and innovation input is a "M" type. The XGBoost algorithm comes to the conclusion that the industrial structure's impact on green transformation is more than that of the conventional linear method, which finds that it has little effect.



(a) (b)

Figure 5. (a) **Evolution of Indu's contribution rate;(b) Evolution of TEI contribution rate.**

3.2. Exploring the Interaction of Green Transformation Influencing Factors

This research divides the total study into two samples with higher and lower innovation dynamics and graphs the specifics of the contribution rate of each indicator in the two samples because regional innovation and entrepreneurial dynamics play a crucial role in the process of the green transformation. Human capital has a limited impact in places with little innovation and entrepreneurship.

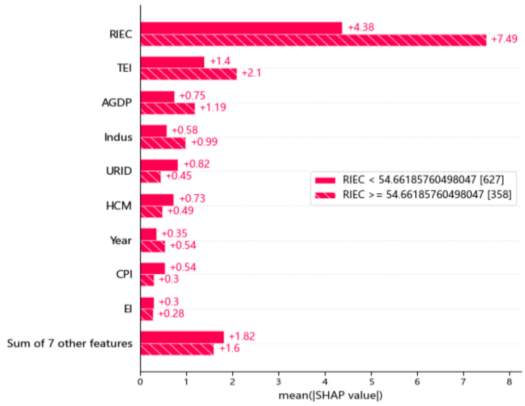


Figure 6. Sub-sample green impact factor contribution statistics.

4. Conclusions and Recommendations

4.1. Conclusions

In order to arrive at the following research conclusions, this paper evaluated and analyzed the current state of the green transformation level in Chinese cities using the entropy weight method of panel data and the XGBoost algorithm to regression model the green transformation index and its influencing factors: The vitality and level of regional science and innovation development, the degree and structure of socioeconomic development, and the contribution of indicators like science and innovation to green transformation are the main influencing factors of urban green transformation in Chinese cities. The contribution of human capital to green transformation is relatively large in regions with relatively low innovation and entrepreneurial vitality.

4.2. Recommendations

The following suggestions are offered in response to the aforementioned research findings: Build a market-driven green innovation technology system first, then encourage synergy in innovation and determine the course of local innovation mechanisms. This can be achieved specifically by boosting market promotion, creating a platform for the exchange of green technologies, etc.; second, supporting and directing economic structure innovation; third, improving the system for managing urban pollution; and fourth, mobilizing the public, businesses, and the government to work together to build a comfortable and livable green city.

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