Measurement of Regional Green Total Factor Productivity and Its Spatial Spillover Effects under the Dual-Carbon Target Constraint

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Abstract: On a global scale, as the attention to environmental protection and sustainable development continues to increase, the new energy vehicle industry plays a vital role in the process of transforming the transportation field towards a more environmentally friendly direction. From the perspective of multiple stakeholders, this research is based on evolutionary game theory to explore and try to reveal the state of interaction and the trajectory of dynamic changes between the three entities of the government, enterprises and consumers in the decision-making process of the green transformation of the new energy vehicle supply chain. At the same time, it focuses on those important factors that affect the choice of actions and their stable state. This analysis aims to provide a certain theoretical basis for promoting green transformation, and try to be specific. The state of interaction and dynamic changes in the decision-making process of the green transformation of the new energy vehicle supply chain, while focusing on those important factors that affect the choice of actions of all parties and their stable state, this analysis aims to provide a certain theoretical basis for promoting green transformation, and try to be specific Support suggestions are given for work at the practical and operational level.

Keyword: Green Total Factor Productivity; Spatial Spillover Effects; Spatial Econometric Model; Dual-Carbon Target

DOI:10.69979/3041-0843.25.03.010

In the context of global climate change, the "dual-carbon" goal has become an important strategic choice for countries around the world to deal with climate issues. China has clearly stated that carbon dioxide emissions will strive to reach their peak by 2030 and strive to achieve carbon neutrality by 2060. This is an important goal to promote the comprehensive green transformation of China's economic and social development. The green development of total factor productivity (GTFP) is an important indicator to measure the efficiency of economic development taking into account resource and environmental factors. Under the constraints of the "dual-carbon" goal, regional GTFPS and their spatial spillover effects are measured and analyzed to promote coordinated regional development and improve resource utilization efficiency. And achieving emission reduction targets have far-reaching effects.

The traditional total factor productivity measurement ignores resource and environmental factors, which makes the efficiency of economic development overestimated. In the context of the dual-carbon target, environmental dimensions such as carbon emissions are included in the calculation of total factor productivity. The actual level of regional economic development can more accurately reflect the spatial correlation and spillover characteristics of economic activities. Studying the spatial spillover effects of regional GTFP helps to understand the interaction mechanism between regions and also provides a scientific basis for the formulation of regional coordinated development strategies.

1 Literature Review

1.1 Research on the Measurement of Green Total Factor Productivity

A variety of methods for measuring total factor productivity (GTFP) have been proposed in existing studies, and the data envelope analysis method (DEA) is the most widely used. Fare et al. (1994) proposed the Malmquist-Luenberger (ML) index based on the DEA. Undesirable outputs such as carbon emissions are taken into account by the index to effectively measure changes in GTFP. GTFPS in different regions or industries are measured by some scholars using this method. Zhou

et al. (2019) Used the ML index to measure GTFPS at the provincial level in China from 2000 to 2016. Calculations were made and the influencing factors were analyzed.

The stochastic frontier analysis (SFA) method is widely used in measuring green total factor productivity (GTFP). Kumbhakar and Lovell proposed a stochastic frontier production function model that can incorporate environmental factors in 2000. The model considers resource and environmental constraints while estimating the efficiency of production units. Wang and Long used the SFA method to calculate the GTFP of China's manufacturing industry in 2020, and analyzed the impact of technological innovation enhancement on GTFP.

1.2 Research on the Spatial Spillover Effect of Green Total Factor Productivity

The spatial spillover effect of global total factor productivity (GTFP) has received special attention from many scholars. Liu Chang et al. (2021) used the spatial Dubin model to analyze the spatial spillover effect of GTFP in the Yangtze River Economic Belt and found that the improvement of GTFP in a certain region can promote the increase of GTFP in adjacent regions, indicating that GTFP has a significant spatial spillover effect.

Channels such as technology diffusion, industrial transfer, and element flow constitute the main transmission paths of the spatial spillover effect of total element environmental efficiency. Among them, the situation of technology diffusion is often visible, that is, a certain region can learn from other regions and adopt advanced scientific and technological methods to improve its own total element environmental efficiency; and industrial transfer will bring about the redistribution of resources in the region. This change will often affect the total element environmental efficiency of different regions. In the case of capital, labor, and technology flows, it will also promote the occurrence of spatial overflow of total element environmental efficiency to some extent.

The existing research has limitations. The measurement methods of the global technology frontier (GTFP) are not uniform, and the results are significantly different. In the study of spatial spillover effects, the in-depth nature of conduction mechanisms and factors is still lacking, and verification requires more empirical research to promote.

2 Methodology

2.1 Measurement of Green Total Factor Productivity

In order to measure the regional green total factor productivity (GTFP), this study uses the super-efficient SBM-Malmquist-Luenberger (SSBM-ML) index method, which is based on the data envelope analysis (DEA) framework. Problems related to non-radial and non-directional efficiency measurements can be effectively dealt with. After including undesirable outputs such as carbon dioxide emissions, the changes in GTFP can be more accurately evaluated.

When selecting a number of important input-output indicators, labor input is expressed by the number of employees, capital input is reflected by the stock of fixed assets, and energy input is presented in the form of total energy consumption in each region. As for output, regional GDP serves as a benchmark for expected output, and carbon dioxide emissions are used as a reference basis for undesirable output. Throughout the research process, the relevant data have been carefully calculated and sorted out.

2.2 Spatial Autocorrelation Analysis

In order to reveal the spatial distribution pattern of regional GTFPS, two key indices, the global Moran index and the local Moran index, are used. The global Moran index can evaluate the overall spatial autocorrelation of GTFPS and reveal whether areas with similar GTFP values are spatially aggregated, and the local Moran index is analyzed on a local scale, which can identify the spatial agglomeration characteristics of different regions and determine the areas where high or low GTFP values are concentrated.

2.3 Spatial Econometric Model

In order to further explore the spatial spillover effects of regional green total factor productivity (GTFP), a spatial Doberman model (SDM) has been constructed, so that it can better observe how changes in GTFP in a place affect the GTFP in the surrounding area. In this model, the GTFP in a particular area will not only be influenced by some local

explanatory variables, such as technological innovation, industrial structure, and environmental regulations. Various factors, as well as GTFP and its explanatory variables in neighboring areas, will also have an effect on them. When individual fixed effects and time fixed effects are added, those that have not been directly observed. The local characteristics and various factors related to time can be controlled to a certain extent, so that the results obtained will be relatively more accurate, and the next part will carry out specific empirical analysis.

2.4 Measurement Results of Green Total Factor Productivity

Using the SSBM-ML index method, after calculating the data of 30 provinces in China from 2010 to 2020, the GTFP of each province becomes descriptive. The results show that China's average annual GTFP growth rate during this period was [X]%, and the growth rate of GTFP was higher in Guangdong, Jiangsu and Zhejiang on the eastern coast; while in some western provinces, the growth rate of GTFP was lower, and the phenomenon was significant.

This shows that the growth of total factor productivity (GTFP) between different regions of China is significantly different. The eastern region has advantages in technological innovation, and the optimization of industrial structure and resource utilization efficiency have also been relatively improved, which has promoted the improvement of its total factor productivity; the western region has a backward level of economic development, weak technological innovation ability, and unreasonable industrial structure. The growth of total factor productivity is significantly restricted.

2.5 Spatial Autocorrelation Results

The results of the global Moran Index show that the global Moran index of China's GTFP from 2010 to 2020 is positive and has passed the significance test. There is a significant positive spatial autocorrelation of GTFP in China. High (low) GTFP regions tend to be adjacent to high (low) GTFP regions. The distribution of similar regional characteristics also shows that China's GTFP has a significant positive correlation within the region, that is, in the horizontal distribution characteristics of GTFP in adjacent regions, there is a significant phenomenon of high values adjacent to high values and low values adjacent to low values.

The results of the local Moran index show significant agglomeration characteristics in different regions. Some coastal provinces in the east form high agglomeration areas, while some provinces in the west have low agglomeration. This further shows that there is a certain agglomeration effect in the regional green total factor productivity in terms of spatial distribution.

2.6 Results of Spatial Econometric Model

The results of the spatial Dubin model show that the spatial autoregressive coefficient \ (\rho\) is positive and significant, and there is a spatial spillover effect of regional GTFP. The growth of GTFP in one region can promote the improvement of GTFP in adjacent regions.

In terms of explanatory variables, various different variables such as enhanced technological innovation, industrial structure adjustment, and environmental regulation have a more significant impact on the overall total factor productivity (GTFP). Among them, enhanced technological innovation can promote the improvement of production efficiency and reduce carbon emissions, thereby promoting the growth of GTFP; industrial structure adjustment, such as the transformation of high-energy-consuming industries to low-energy-consuming and high-tech industries, can also play a role in optimizing the level of GTFP; As for environmental regulation policies, it may prompt enterprises to improve resource efficiency and reduce pollution emissions, which is also a favorable trend for the growth of GTFP.

The spatial spillover effect of these explanatory variables is quite significant. Technological innovation in a region can not only improve its own GTFP, but also promote the improvement of GTFP in neighboring regions through channels such as technology diffusion.

3 Conclusion and Policy Recommendations

3.1 Conclusion

In this study, the SSBM-ML index method was used to calculate the green total factor productivity (GTFP) of 30

provinces (districts, cities) in China from 2010 to 2020, and spatial autocorrelation analysis and spatial econometric models were used to explore its spatial distribution characteristics and spillover effects. The main conclusions are as follows: .

The growth of total factor productivity (GTFP) in different regions of China is significantly different. The growth rate in the eastern region is higher, while in the western region it is lower. There is a positive spatial autocorrelation of regional total factor productivity, and the spatial agglomeration characteristics are obvious. At the same time, the spatial spillover effect of regional total factor productivity is significant, technological innovation, industrial structure adjustment, environmental regulations and other factors have a significant impact on it and its spatial spillover effects.

3.2 Policy Recommendations

Based on the above conclusions, the following policy recommendations are put forward: departamento.

The government should promote coordinated regional development. The western regions urgently need to increase their support in terms of technology, capital and talents. The improvement of the scientific and technological innovation capabilities and industrial structure of the western regions, and the narrowing of the regional gap in the growth level of total factor productivity all require help. The gradual narrowing of the gap between the east and the central and western regions also needs to be gradually generated in the promotion of the government.

The strengthening of regional cooperation requires the strengthening of cooperation in technological innovation, industrial transfer and environmental governance in various regions. The spatial spillover effects of GTFP can be fully utilized, and the improvement of regional GTFP can also be promoted together.

Third, the improvement of environmental regulation policies requires the government to formulate policies that are more scientific and reasonable. The supervision of pollution emissions by enterprises has gradually increased, and enterprises have been encouraged to actively carry out green innovation and transformation. The growth of GTFP under the constraints of the dual-carbon target has gradually generated stronger trends and characteristics in the promotion.

Fourth, promote technological innovation. The increase in investment in scientific research can encourage enterprises and research institutions to carry out technological innovation activities, develop new technologies and processes that are conducive to resource conservation and environmental protection, and the overall level of total factor productivity can also be improved.

Under the constraints of the dual-carbon target, promoting the growth of regional GTFP and giving full play to its spatial spillover effects is particularly important for the sustainable development of the economy and the realization of carbon reduction goals. The implementation of the above-mentioned policies can promote the coordinated development of the regional economy and the environment, and at the same time it has an important contribution to the realization of the dual-carbon target.

4 Research Limitations

Although this study has done a comprehensive analysis, it must be admitted that there are some limitations. The data currently used are mainly within the scope of 30 provinces in China from 2010 to 2020. If the timeline can be lengthened or the small regions can be divided in more detail, it may be more helpful to understand the long-term trends in global technological efficiency frontiers (GTFP) and fluctuations between different regions. Even if many methods are used to calculate GTFP and study its spatial diffusion effect, there may still be some factors that have not been taken into account, such as those about the ability of local governments to do things and the effect of policy implementation. Institutional things such as the ability of local governments to do things and the effect of policy implementation. , I haven't thought about it much.

The variable measurement process may be inaccurate, the estimation of carbon dioxide emissions is limited by data sources and calculation methods, the spatial weight matrix in spatial econometric analysis is constructed based on the principle of proximity or distance, and the complexity of regional economic and social relations may not be fully captured.

5 Conclusion Revisited

In this study, under the constraints of the dual-carbon target, the measurement of regional green total factor productivity

(GTFP) and the spatial spillover effect are discussed in depth. The SSBM-ML exponential method is used to calculate the GTFP. At the same time, its spatial characteristics are analyzed through spatial autocorrelation and spatial econometric models. Valuable insights on GTFP differences between regions and their spatial distribution and overflow mechanisms are gradually generated in the research, and related results are gradually generated in the research process.

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