Ecological Indicators 85 (2018) 841–852

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original Articles

Green competitiveness evaluation of provinces in China based on correlation analysis and fuzzy rough set

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ARTICLE INFO

Keywords:
Green competitiveness
Fuzzy rough set
Regional competitiveness
Indicator
Evaluation system
China

ABSTRACT

The meaning of regional competitiveness has been changed recently to better fit the new development theme of "green" and "sustainable". Correspondingly, the traditional regional competitiveness evaluation system, which pays too much attention to economic indicators, has not been able to fully evaluate regional green competitiveness. Based on the meaning of regional green competitiveness, we used correlation analysis, fuzzy rough set and entropy weight methods to select and analyze 21 indicators and develop a regional green competitiveness index. Indicators included measures of natural resources competitiveness, ecological environment competitiveness, energy consumption and energy saving competitiveness, economic and social sustainable competitiveness as well as human health competitiveness. Based on the green competitiveness index, we divided the green competitiveness spectrum into three levels (light green, medium green and dark green) to explore changes of the index in 30 provinces of China during the period 2004–2014. Results showed that ecological environment competitiveness and sustainable competitiveness of economy and society are two key factors that influence the green competitiveness of provinces in China. Green competitiveness also showed spatial differences, varying from high to low in a westerly direction from the eastern region, central region, northeast region and western region. Notably, the green competitiveness level of more than half of the provinces changed markedly, proving that the green competitiveness of the provinces can develop through leap-style changes.

1. Introduction

With the increasingly serious situation of environmental pollution and resource shortage, as well as the growing emphasis on green development, regional green competitiveness has become an important element of the comprehensive competitiveness of a country or region. How to define the regional green competitiveness, how to evaluate regional green competitiveness, and how to maximize regional green competitiveness are critical challenges for scholars and government in the context of environmental and resource management. Based on an accurate definition of regional green competitiveness, it is of great significance to establish a scientific, objective and operable evaluation system to adjust green development strategies and realize sustainable development of a region.

In the 1990s, Porter (1990) showed that enterprises can take advantage of environmental strategies to improve market competitiveness. He proposed the concept of green competitiveness for the first time, and defined it as the ability to obtain market competitive advantage based on the green economic model of environmental protection, healthy ecosystems and sustainable development (Porter, 1991). Since then, research has been conducted to study green competitiveness from a variety of perspectives. Generally speaking, green competitiveness can be defined from two viewpoints. One view holds that green competitiveness is a systematic concept. Chiang et al. (2011) believed that green competitiveness included a number of aspects that are specific to the green competitiveness of enterprises; these include raw materials acquisition, manufacturing, product use and waste treatment. Another view is that green competitiveness is a relative competitive advantage. For example, Bowen and Fankhauser (2011) stated that green competitiveness provided more attractive products and services than competitors under the premise of protecting the environment.

Against this background, we hold in this paper that the concept of regional green competitiveness includes three components. The first is greenness of regional competitiveness. That is to say, regional competitive advantage is based on efficient use of natural resources, ecological environment protection and energy saving. From this viewpoint, green competitiveness is fundamental to regional competitiveness. Furthermore, natural resources, ecological environment and energy saving must be taken into account when evaluating regional green competitiveness. The second component refers to sustainable

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https://doi.org/10.1016/j.ecolind.2017.11.045
Received 17 May 2017; Received in revised form 8 September 2017; Accepted 21 November 2017
Available online 08 December 2017
1470-160X/

competitiveness. Obviously, a region that exhibits high green competitiveness must embrace sustainable development; consequently, its economic and social development is bound to be advanced and superior to other regions. In this respect, the sustainability of the economy and society is a key indicator for assessing regional green competitiveness. The third component is people-oriented competitiveness. The subject and object of regional development are humans. The foremost purpose of regional development is to enhance people's health and life. Based on the above discussion, we define regional green competitiveness as follows: under the premise of protecting the ecological environment as well as changing the utilization pattern of resources through innovation, a region must have a comprehensive ability to provide more resource saving and environmentally friendly technology, innovative products and services compared to other competitors in order to achieve a sustainable development of economy and society, as well as a healthy life for its people.

Although there is little literature about the evaluation of regional green competitiveness, lessons can be drawn from regional competitiveness, of which the national competitiveness model developed by the Lausanne International Institute for Management Development (IMD), the international competitiveness model established by the World Economic Forum and the diamond model constructed by Porter are most representative. The IMD model considers productivity to be one of the performance indicators of competitiveness, and evaluates national competitiveness from four aspects: economic performance, business efficiency, government efficiency and infrastructure. The index system contains 20 elements and more than 300 indicators (IMD, 2017). The World Economic Forum attached great importance to international competitiveness and considered lower-cost products and better service to be two key factors affecting competitiveness (World Economic Forum, 2016). Porter proposed a diamond model (Porter, 1991), which included production factors, demand conditions, corporate strategy structure and peer competition to evaluate national competitiveness from the perspective of the value chain and industrial chain, pointing out that domestic competition has a positive influence on national competitiveness (Porter, 2010). Though the above models have played a vitally important role in evaluating regional competitiveness, the evaluation systems are more for national competitiveness than regional competitiveness, and have index systems that are complex and difficult to operate. Besides, some weights for indicators were determined by experts based on experience, introducing human bias into the evaluation (Cho and Moon, 2000; Kaplan, 2003). In addition, from a decision-making perspective, Fernandez et al. (2013) developed a decision-making system based on the structural equation model and evaluated the competitiveness of the Mexican region using the final evaluation indicators. Other scholars have taken different factors into account when evaluating regional competitiveness, such as Guo et al. (2015) who evaluated city competitiveness from environmental conditions, the extent to which the economy had been opened, economic development and people's quality of life. Taking several factors (including economy, firms, government, infrastructure and people) into consideration, Charles and Zegarra (2014) constructed an indicator system to measure and rank regional competitiveness in Portugal.

Notably, some scholars are involved in research about enterprise green competitiveness. Hart (1997) pointed out that when environmental protection becomes a part of an overarching strategy, enterprises can open the door to green competitiveness. Using ecology principles for business studies, Shireman and Tachi (2002) suggested that enterprises can enhance green competitiveness beyond environmental restrictions through innovation, replication and improvement in the cycle of operational mechanisms. Analyzing 110 manufacturing sectors in eight countries, Fankhauser et al. (2013) identified three success factors for green competitiveness at the sector level: the speed at which sectors convert to green products, the ability to gain and maintain market share and a favorable starting point. Using a structural equation model to analyze a survey of 124 companies in eight industries in Taiwan, Chiou et al. (2011) found that it is necessary to encourage enterprises to implement a green supply chain and green innovation to improve environmental performance, so as to enhance the competitive advantage in the global economy.

In research on the evaluation of the enterprise green competitiveness, it is easy to find that the methods used in constructing evaluation systems mainly focus on the combination of fuzzy evaluation, analytic hierarchy process, factor analysis and principal component analysis. Taking 144 listed companies in the Yangtze River Delta region and the Bohai region as examples, Wang et al. (2008) evaluated their green competitiveness by constructing an entropy weight fuzzy evaluation model. In other research, principal component analysis was used to evaluate the importance of factors in a manufacturing enterprise (Azadeh et al., 2007). At present, there is little research on green competitiveness from a macroscopic perspective. Using the Delphi method and the analytic hierarchy process, Chen et al. (2016) constructed a green competitiveness evaluation system that included environmental protection, ecological environment quality, low-carbon achievements, recycling, sustainability and human health. However, the evaluation method was rather subjective, and the selection of evaluation indicators lacked sufficient objectivity.

Although previous research is instructive, it is not difficult to see that there are two limitations. (a) Although there are many studies on green competitiveness of enterprises at the micro perspective, there are few studies at the macro perspective. (b) Although some evaluation index systems are related to the green competitiveness of provinces from the macro perspective, it is difficult to avoid the influence of human bias in these systems due to their reliance on the Delphi method and the analytic hierarchy process. Thus, the scientific basis and objectivity of existing index systems cannot be guaranteed. Therefore, it is very important to establish a scientific and objective evaluation system for assessing provincial green competitiveness.

From the definition of regional green competitiveness explained previously, it can be inferred that an acceptable evaluation of regional green competitiveness must (a) take natural resources as the starting point, focus on ecological environment, energy consumption and energy saving, (b) regard sustainable development of economy and society, as well as residents' healthy life as a foothold, and (c) represent every aspect of "greenness" in natural resources, ecological environment, energy consumption, and people's lives. Last but not least, both the scientific validity and objectivity of the system must be ensured. Unfortunately, required information or prior knowledge of indicators often is not readily available when constructing a green competitiveness evaluation system. However, the fuzzy rough set method can be a good solution to this problem. It can effectively analyze imprecise, inconsistent and incomplete information, and uncover the hidden knowledge in large data sets that are influenced by a large number of uncertain factors (Abu-Donia, 2012; Feng et al., 2010). Without the requirement for prior information, the fuzzy rough set method can accommodate the uncertainty problem objectively and ignore redundant information to a great extent according to the approximate quality of classification reduction. Attribute reduction is a common use of fuzzy rough sets (Song and Jin, 2015), and its effectiveness and superiority have been proved by many studies (Tsang et al., 2008; Zhao et al., 2009). At last, the variable precision fuzzy rough set was used in our paper to simply attribute to overcome the classification problem due to human error or noise data (Zhao et al., 2009). Using this method, an evaluation system of green competitiveness can be obtained scientifically and objectively.

In this paper, we describe research in which we used a literature analysis to construct a conceptual framework for a green competitiveness evaluation system that included five aspects: natural resources, ecological environment, energy consumption and energy saving, economic and social sustainability, and human health. Based on this conceptual framework, an objective reduction method-correlation analysis and fuzzy rough set method were applied to reduce the number of