Exploring the Application of Green Innovation Risk Measurement Model in China's Manufacturing Industry

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Abstract: With the increasingly serious global environmental problems and the demand for sustainable development in society, green innovation has become an important direction for the development of China's manufacturing industry, but it faces numerous risks and challenges. Therefore, establishing a scientifically effective green innovation risk measurement model is of great significance for assessing and managing risks and improving investment returns. This article elaborates on the concept and principles of the current green innovation risk measurement model, and analyzes its applicability, advantages and disadvantages. On this basis, the specific application of the model in China's manufacturing industry is explored. Finally, the effectiveness of the model application is elaborated, and future research directions and suggestions are proposed. Through the research in this article, it is expected to enhance China's manufacturing industry's understanding and management capabilities of green innovation risks, promote the transformation of enterprises towards sustainable development, and make positive contributions to achieving a win-win situation of economic and environmental benefits.

Keywords: manufacturing industry; Green innovation; Risk measurement; Model application

1 Introduction

With the increasingly serious global environmental problems and the urgent demand for sustainable development in society, green innovation has become an important direction for the development of China's manufacturing industry. However, green innovation in the manufacturing industry faces numerous risk challenges. In the field of risk management research, it is not only necessary to identify risks, but also to quantitatively estimate or measure the possible consequences of risks. Only in this way can effective prevention and control of risks be implemented[1]. Therefore, measuring the risk of green innovation is a complex and challenging task. Green innovation risk measurement refers to the use of certain methods to analyze the likelihood of risk occurrence and estimate and measure the magnitude of losses caused by risks. In recent years, risk measurement has become an important research field for scholars both domestically and internationally. The selection of risk measurement methods mainly depends on the scale, type, nature, and availability and reliability of information of the project[2]. However, green innovation is different from traditional innovation. The risks of green innovation have characteristics such as complexity, systematicity, dual externalities, duality, foresight, and uncertainty. Therefore, on the basis of

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identifying green innovation risks, a comprehensive analysis of the factors affecting green innovation risks is conducted. Based on the inherent characteristics of green innovation risks, methods suitable for measuring green innovation risks are identified, Effectively and accurately measuring green innovation risks is of great significance for the development of green innovation activities in enterprises.

2 The Importance of Green Innovation Risk Measurement Models

The green innovation risk measurement model is an important tool for evaluating and managing the risks of green innovation projects. With the rapid development of the green economy and the increasing call for environmental protection, green innovation has become the focus of more and more enterprises' attention[3].However, due to the high technological content, long development cycle, and market uncertainty of green innovation, the relationship between investment return and risk is complex and difficult to measure [4]. The green innovation risk measurement model can help enterprises quantify and manage risks during the evaluation, selection, design, and implementation stages of green innovation projects, helping them better grasp risks and improve investment returns. The green innovation risk measurement model can not only help enterprises obtain better business opportunities and market competitiveness in the field of green innovation, but also promote sustainable development of enterprises and better meet the needs of society and the environment. Therefore, the green innovation risk measurement model is of great significance for the sustainable development of enterprises and the entire society.

3 Analysis of Current Green Innovation Risk Assessment Methods

Currently, there are many methods for measuring green innovation risk. Domestic and foreign scholars have roughly divided risk measurement methods into three categories when conducting risk measurement research, namely: methods based on mathematical theory, methods based on statistical analysis, and methods based on computer simulation. See Table 1:

Table 1. Classification of Green Innovation Risk Measurement Methods

A method based on mathematical theory	Probability analysis method Sensitivity analysis method Fuzzy comprehensive evaluation method Grey correlation analysis Set pair analysis method
Statistical analysis based method	Analytic Hierarchy Process principal component analysis
Computer simulation based method	Artificial neural network method Extension matter element analysis method Rough network Support Vector Machine

3.1 Risk measurement method based on mathematical theory

(1) Probability analysis method

Probability analysis method, also known as risk analysis method, is a quantitative analysis method that uses probability prediction to analyze the impact of uncertain factors and risk factors on the economic effectiveness of a project. Its essence is to study and calculate the range of changes in various influencing factors, as well as the probability and expected values that occur within this range[5]. The difference between actual value and estimated or expected value caused by probability is usually referred to as risk, so probability analysis can also be referred to as risk analysis. The probability used in the project measurement process refers to the frequency of various basic variables (such as investment, cost, return, etc.) appearing. The reliability of its analysis results largely depends on the accuracy of the probability value judgment for each variable. When using probability analysis for risk measurement, there are three main methods, namely: expected value method, utility function method, and simulation analysis method. However, the probability analysis method does not analyze the specific number of risk factors and the weight of their impact when conducting risk measurement, but only provides an overall analysis of the impact and consequences caused by the risk. Therefore, the probability analysis method has little significance in the application of risk measurement in green innovation.

(2) Sensitivity analysis method

Sensitivity analysis method is an uncertainty analysis method that identifies sensitive factors that have a significant impact on the economic benefits indicators of investment projects from many uncertain factors, and analyzes and measures their impact and sensitivity on the economic benefits indicators of the project, in order to determine the risk tolerance of the project [6]. Sensitivity analysis method can be divided into single factor sensitivity analysis method and multi factor sensitivity analysis method based on the changes in the number of influencing factors. Unlike probability analysis method, sensitivity analysis method considers the number of influencing factors and the impact of each influencing factor on the risk measurement results. It further analyzes innovation risk, but fundamentally, sensitivity analysis can only identify the factors that are more sensitive to changes in risk factors, However, there was no specific analysis of the likelihood of changes in these risk factors and the ability of the action subject to withstand these changes. So the results obtained from sensitivity analysis cannot directly reflect the level of risk faced.

(3) Fuzzy comprehensive evaluation method

The fuzzy comprehensive evaluation method is a comprehensive evaluation method that uses the membership theory in fuzzy mathematics to transform qualitative analysis into quantitative analysis. The fuzzy comprehensive evaluation method is highly systematic and suitable for the analysis of uncertain problems, and it can clearly evaluate problems that are difficult to quantify due to fuzziness [7]. Fuzzy mathematics is applicable to risk measurement with a large amount of fuzzy information, and has been widely applied, especially in the risks involved in innovation activities. Most of its risk factors are fuzzy, uncertain, and difficult to express with specific numbers, making this type of risk measurement particularly applicable. Fuzzy mathematics provides a quantitative representation method for qualitative risk indicators, especially for some fuzzy and uncertain risk factors, which can be well expressed by fuzzy mathematics. It is a measurement method that combines qualitative and quantitative methods. However, its disadvantage is that when there are too many risk indicators, it cannot solve the problem of duplicate information for each influencing factor, so its practicality is not strong.

(4) Grey correlation analysis

Grey correlation analysis is based on the approximate degree of the curve shape of each factor sequence to analyze its development trend and provide some suggestions for decision-makers. The grey correlation degree can be divided into two categories: local grey correlation degree and overall grey correlation degree. Grey correlation degree is suitable for measuring dynamic development trends. It is a multi factor statistical analysis method. If the trend of changes between these two factors is basically the same, it can be considered that their correlation degree is very high; If the trend of changes between these two factors is basically different, it can be considered that the correlation between them is very small. Grey correlation analysis is widely used in risk measurement research. The advantage of this method is that it has clear ideas and is easy to understand. It can especially solve problems such as incomplete information, information asymmetry, and difficulty in quantification. It also has low data requirements and simple calculations, with only a small number of samples; Its main drawback is that it is too subjective, difficult to fully express the relationship between things, and unable to effectively solve the problem of information duplication between risk indicators.

(5) Set pair analysis method

In 1989, Chinese scholar Zhao Keqin proposed set pair analysis. Set pair analysis is a mathematical theory that deals with the interaction between system certainty and uncertainty. Its basic principle is to study certainty and uncertainty in a system, and to conduct a systematic and mathematical analysis of the determinacy and uncertainty of two sets in a set pair, as well as the interaction between certainty and uncertainty, in a certain problem context. As a combination of qualitative and quantitative methods, set pair analysis has been widely applied, which can be used for both simple and complex system analysis. Its advantages are: comprehensive analysis of the content, high accuracy, and intuitive results; The disadvantage is that the weight of risk indicators cannot be calculated, and the problem of information duplication between risk indicators has not been solved.

3.2 Risk measurement methods based on statistical analysis

(1) Analytic Hierarchy Process

In the early 1970s, American operations researcher T L. Professor Satty proposed the Analytic Hierarchy Process (AHP), which is a hierarchical weight decision-making analysis method based on subjective judgment. AHP is a decision-making method that decomposes elements related to decision-making into levels such as goals, criteria, and plans, and conducts qualitative and quantitative analysis on this basis. In real life, we often encounter decision-making problems by dividing each factor into different levels, determining the relative weights of each level based on a hierarchical structure model, and finally determining the order of risk size through calculation. The Analytic Hierarchy Process (AHP) has strong practicality, clear logic, and is widely used in the calculation of risk indicator weights. However, the use of AHP cannot calculate the probability of risk occurrence and the consequences caused by risk. It is a result obtained through pairwise comparison, and can only calculate the relative risk of each factor. It is necessary to judge the consistency of the matrix, and can only choose from alternative solutions and cannot provide new solutions, When experts score the weight of indicators, their subjectivity is too strong, with a majority of qualitative components, which are not convincing and can easily lead to distorted results.

(2) Principal Component Analysis

In 1901, K. Pearson first proposed principal component analysis, which was later extended by H. Hotelling. Principal component analysis is a multivariate statistical analysis method that selects fewer important variables from multiple variables through linear transformation. When analyzing multiple indicators in statistics, having too many variables can increase the complexity of the research. Principal component analysis is the process of deleting redundant and repetitive indicators, and establishing new indicators with a small number that can maintain the original meaning of the indicators. Principal component analysis is a multivariate statistical analysis method that involves the correlation between multiple variables. Its purpose is to derive several principal components from numerous indicators and study the internal structure of multiple indicators through these components. These indicators represent a linear combination of the original indicators and are independent of each other. At the same time, they reflect the original information to ensure the accuracy of the results.

3.3 Risk measurement method based on computer simulation

(1) Artificial neural network method

In the 1980s, the field of artificial intelligence emerged as a research hotspot in the field of artificial neural networks. Artificial neural networks are a mathematical operation model characterized by imitating animal neural behavior, where a large number of neurons use structures similar to synaptic connections in the brain to process information. Each connection between two neurons represents a weight, which can continuously modify the indicator weights that satisfy researchers. The difference between it and other measurement methods is that it overcomes the disadvantage of subjective evaluation of indicator weights, and it also requires more sample data to complete training. Artificial neural networks are divided into two categories: learning strategy based and network architecture based. Both have self-learning and adaptive abilities, but they cannot answer practical problems such as "why" and "how". However, they can find optimized solutions to complex problems, and they have both associative and storage functions. However, they have not yet been well solved in terms of network structure and neuron selection. The advantages of artificial neural networks are: rigorous derivation process, wide universality, and applicability in various fields; The disadvantage is that the convergence speed of the learning algorithm is slow and there are errors, which are not sensitive to full-time changes.

(2) Extension matter element analysis method

The concept of matter elements in extenics provides a new way to solve the problem of innovation risk measurement, which is the most basic cell that organically combines quality and quantity. Applying the idea of extension theory, based on the indicators of innovation risk factors, a multidimensional extension matter-element model for innovation risk measurement is constructed, which unifies quality and quantity. Then, the established risk extension measurement method is used to measure innovation risk. In the process of establishing the extension matter-element model for innovation risk measurement, firstly, the main feature matter-element matrix is established. Secondly, the classical domain matter-element matrix and nodal domain matter-element matrix for risk measurement are established. Thirdly, the enterprise matter-element matrix to be evaluated is constructed. Finally, the risk extension metric method established is used to determine the magnitude of innovation project risk. When dealing with problems, people often consider things, features, and corresponding quantities together, which can more accurately describe the changing process of objective things. Matter element is a very important concept, breaking through conventions, grasping key strategies, and unifying things, properties, and quantities. When dealing with problems, people should consider both quantity and quality. Matter element is also a basic tool for describing the variability of things, and it is a favorable means to solve major contradictions and key problems.

(3) Rough Networks (Rough Sets and Artificial Networks)

In the 1980s, Professor Z. pawlak of the Polish Polytechnic University proposed the theory of rough sets, which is a quantitative analysis method used to study imprecise, inconsistent, and incomplete information and knowledge as a mathematical tool. Its characteristic is that it does not require additional information and can analyze facts hidden in the data. Rough set theory has been widely applied in machine learning, knowledge discovery from databases, decision analysis, and other fields. With the maturity and improvement of artificial neural network technology, a measurement method integrating rough sets and artificial neural networks has been proposed. These two methods process information differently but have strong complementarity. Rough sets mainly simulate human abstract logical thinking, while artificial neural networks mainly simulate intuitive thinking, Combining the advantages of the two to establish a rough network model for innovation risk measurement can effectively solve the problem of too many influencing factors.

(4) Support Vector Machine

In 1995, Corinna Cortes and Vapnik et al. proposed a new machine learning method called support vector machine, which has many advantages in small sample size and nonlinear recognition. The so-called support vector refers to the training sample points at the edge of the interval. The term 'machine' here refers to 'machine' and refers to an algorithm. Support vector machines, like artificial neural networks, are both learning mechanisms. Support vector machines are a binary classification model with the basic idea of separating data by constructing segmentation surfaces. Its purpose is to find a hyperplane for sample segmentation, with the principle of maximizing the interval and ultimately transforming it into a convex quadratic programming problem to solve. Support vector machines are basically the best supervised learning algorithms, utilizing statistical learning theory and structural risk minimization principles. They have low requirements for data distribution and do not make any assumptions about the distribution of the original data, so their applicability will naturally be more extensive.

4 Advantages and disadvantages of evaluation measurement methods

Through the comparison and analysis of current measurement methods, it can be seen that the commonly used risk measurement methods by many scholars have approached maturity, but there are still certain limitations when using these methods for green innovation risk measurement. For example, probability analysis method and sensitivity analysis method are suitable for risk measurement methods with single risk indicators and without calculating the number and size of influencing factors, and sensitivity analysis method cannot deeply analyze the possibility of changes in risk factors and the ability of the action subject to bear these changes [8,9]; Both fuzzy evaluation method and grey comprehensive evaluation method cannot solve the problem of consistency in expert judgment, but grey comprehensive evaluation method can solve the problem of information loss that fuzzy evaluation method cannot solve; The principal component analysis method contains too many subjective factors when measuring the dividing line [10], therefore, the accuracy of the results obtained is relatively low; The number of factors analyzed by the Analytic Hierarchy Process should not be too large. When the number of factors exceeds the limit, it will result in inaccurate analysis results and indistinguishable importance levels; The application of artificial neural network method in risk assessment of technological innovation projects is relatively objective and fair. The measurement process solves the problem of containing too many subjective factors. Through self-learning simulation systems, in the case of incomplete risk factor information, an objective and fair measurement model can be obtained. However, the artificial neural network method has high calculation accuracy and weak practical operability [11,12]. As is evident, the main characteristics of green innovation risk measurement in the manufacturing industry are: limited research data, single measurement methods, and multiple risk influencing factors. At the same time, green innovation risks also have characteristics such as complexity, systematicity, dual externalities, duality, foresight, and uncertainty, which further increases the difficulty of measuring green innovation risks in the manufacturing industry under the global value chain [13].

5 Conclusions

In summary, with the complex changes and uncertainties in green innovation risks, risk measurement models are constantly developing and improving [14]. Up to now, various models have emerged, but each has its own advantages and disadvantages, making it difficult to adapt to the complexity of green innovation risks in the manufacturing industry. At the same time, the selection of risk measurement methods for green innovation in the manufacturing industry mainly depends on the scale, type, nature, and completeness of available data. However, for high risks such as green innovation, the selection of risk measurement methods is definitely not simple. Therefore, in selecting models, multiple methods should be used to consider each other, leveraging strengths and avoiding weaknesses to find complementarity between models and methods, as well as considering the interaction between factors influencing green innovation risks, in order to construct a manufacturing green innovation risk measurement model suitable for China's current situation.

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