Investment Risk Evaluation Model of Energy Project with Intuitionistic Fuzzy Information

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Abstract

Global economy growing demands the energy development. For traditional energy sources are depleted and the increased new energy demand, the new energy has become an important part of future energy strategy. As a high-tech, high investment and high risk industry, the investment risk of new energy industry is a major obstacle to the healthy development of China's new energy and, therefore, analyzing the related risk factors to predict and warning to the overall investment of the new energy industry has an important practical and theoretical significance. In this paper, we investigate the intuitionistic fuzzy multiple attribute decision making problems for investment risk evaluation model of energy project. We utilize the intuitionistic fuzzy weighted averaging (IFWA) operator to aggregate the intuitionistic fuzzy information corresponding to each alternative, and then rank the alternatives and select the most desirable one(s) according to the score function and accuracy function. Finally, an illustrative example for investment risk evaluation model of energy project is given to verify the developed approach and to demonstrate its practicality and effectiveness.

Keywords

Multiple Attribute Decision Making; Intuitionistic Fuzzy Number; Intuitionistic Fuzzy Weighted Averaging (IFWA) Operator; Entropy; investment risk evaluation; energy project.

1. Introduction

High technology is now becoming the main productive force. The blossom of high technology industrial lies in the foundation of the new investment and financing system, and the employment of modern finance instruments by high-tech corporations. As a new investment mode for high-tech corporations, venture investment becomes more and more important in economy.Nowadays, lots of environment problems emerge. Facing this serious situation, the whole world continuously makes efforts for energy saving and emission reduction. Low-carbon economy has now brought about a new revolution. After 30 years' extensive growth of our economy, the sustainability of our environment has reached its utmost. Seeking for new energy and changing the way of economy growth call for new technology. And venture investment will play a pivotal role.Though starting late, our new energy venture investment develops very fast. Considering the high risk, many investment institutions made their decision with discretion. Only few companies can get the investment. How to scientifically judge the value of a new energy venture investment project, how to decrease the risk for investment and how to increase the probability of success are what one should consider before investment.To estimate a new energy project, a series of estimation system and estimation standard should be built. And that can help one to get rid of the blindness for estimation. One can determine whether the project should be invested in or not.As a long-term equity investment, new energy venture investment has irreversibility and flexibility comparing with common energy venture investment. Theory and method of real options will be used for analyzing both the value and the risk of a certain project, and consummating new energy venture investment project estimation system. The real option is a kind of option that considers non-finance as underlying assets. And this kind of option has a wide range of application, for example, all kinds of project investment decision-making, corporation value assessment, tech and intangible assets value assessment, etc. Real option greatly breaks the traditional way of decision-making and well adapt to new energy projects with uncertainty and risk.

Atanassov [1,2] introduced the concept of intuitionistic fuzzy set(IFS), which is a generalization of the concept of fuzzy set [3]. The intuitionistic fuzzy set has received more and more attention since its appearance. Gau and Buehrer [4] introduced the concept of vague set. But Bustince and Burillo [5] showed that vague sets are intuitionistic fuzzy sets. In [6], Xu developed some geometric aggregation operators, such as the intuitionistic fuzzy weighted geometric (IFWG) operator, the intuitionistic fuzzy ordered weighted geometric (IFOWG) operator, and the intuitionistic fuzzy hybrid geometric (IFHG) operator and gave an application of the IFHG operator to multiple attribute group decision making with intuitionistic fuzzy information. In [7], Xu developed some arithmetic aggregation operators, such as the intuitionistic fuzzy weighted averaging (IFWA) operator, the intuitionistic fuzzy ordered weighted averaging (IFOWA) operator, and the intuitionistic fuzzy hybrid aggregation (IFHA) operator. Xu [8] investigated the intuitionistic fuzzy MADM with the information about attribute weights is completely unknown or completely unknown, a method based on the ideal solution was proposed.

Global economy growing demand for energy development. For traditional energy sources are depleted and the increased new energy demand, the new energy has become an important part of future energy strategy. As a high-tech, high investment and high risk industry, the investment risk of new energy industry is a major obstacle to the healthy development of China's new energy and, therefore, analyzing the related risk factors to predict and warning to the overall investment of the new energy industry has an important practical and theoretical significance. In this paper, we investigate the intuitionistic fuzzy multiple attribute decision making problems for investment risk evaluation model of energy project. We utilize the intuitionistic fuzzy weighted averaging (IFWA) operator to aggregate the intuitionistic fuzzy information corresponding to each alternative, and then rank the alternatives and select the most desirable one(s) according to the score function and accuracy function. Finally, an illustrative example for investment risk evaluation model of energy project is given to verify the developed approach and to demonstrate its practicality and effectiveness.

2. Preliminaries

In the following, we introduce some basic concepts related to intuitionistic fuzzy sets.

Definition 1. Let X be a universe of discourse, then a fuzzy set is defined as:

$$A=\left\{\left\langle x,\mu_A(x)\right\rangle \middle| x\in X\right\} \tag{1}$$

Which is characterized by a membership function $\mu_A : X \to [0,1]$, where $\mu_A(x)$ denotes the degree of membership of the element x to the set A [3].

Atanassov extended the fuzzy set to the IFS, shown as follows:

Definition 2. An IFS A in X is given by

$$A=\left\{\left\langle x,\mu_A(x),\nu_A(x)\right\rangle \middle| x\in X\right\} \tag{2}$$

Where $\mu_A : X \to [0,1]$ and $\nu_A : X \to [0,1]$, with the condition

$$0\le \mu_A(x)+\nu_A(x)\le 1,\ \forall\, x\in X$$

The numbers $\mu_A(x)$ and $\nu_A(x)$ represent, respectively, the membership degree and non-membership degree of the element x to the set A [1,2].

Definition 3. For each IFS A in X, if

$$\pi_A(x)=1-\mu_A(x)-\nu_A(x),\ \forall\, x\in X . \tag{3}$$

Then $\pi_A(x)$ is called the degree of indeterminacy of x to A [1,2].

Definition 4. Let $\tilde{a}=(\mu,\nu)$ be an intuitionistic fuzzy number, a score function S of an intuitionistic fuzzy value can be represented as follows [9]:

$$S(\tilde{a})=\mu-\nu\,,\quad S(\tilde{a})\in[-1,1]. \tag{4}$$

Definition 5. Let $\tilde{a}=(\mu,\nu)$ be an intuitionistic fuzzy number, a accuracy function H of an intuitionistic fuzzy value can be represented as follows [10]:

$$H(\tilde{a})=\mu+\nu\,,\quad H(\tilde{a})\in[0,1]\,. \tag{5}$$

to evaluate the degree of accuracy of the intuitionistic fuzzy value $\tilde{a}=(\mu,\nu)$, where $H(\tilde{a})\in[0,1]$. The larger the value of $H(\tilde{a})$, the more the degree of accuracy of the intuitionistic fuzzy value $\tilde{a}$.

As presented above, the score function S and the accuracy function H are, respectively, defined as the difference and the sum of the membership function $\tilde{\mu}_A(x)$ and the non-membership function $\tilde{\nu}_A(x)$. Xu [6] showed that the relation between the score function S and the accuracy function H is similar to the relation between mean and variance in statistics. Based on the score function S and the accuracy function H, in the following, Xu give an order relation between two intuitionistic fuzzy values, which is defined as follows:

Definition 6. Let $\tilde{a}_1=(\mu_1,\nu_1)$ and $\tilde{a}_2=(\mu_2,\nu_2)$ be two intuitionistic fuzzy values, $s(\tilde{a}_1)=\mu_1-\nu_1$ and $s(\tilde{a}_2)=\mu_2-\nu_2$ be the scores of $\tilde{a}$ and $\tilde{b}$, respectively, and let $H(\tilde{a}_1)=\mu_1+\nu_1$ and $H(\tilde{a}_2)=\mu_2+\nu_2$ be the accuracy degrees of $\tilde{a}$ and $\tilde{b}$, respectively, then if $S(\tilde{a})<S(\tilde{b})$, then $\tilde{a}$ is smaller than $\tilde{b}$, denoted by $\tilde{a}<\tilde{b}$; if $S(\tilde{a})=S(\tilde{b})$, then

if $H(\tilde{a})=H(\tilde{b})$, then $\tilde{a}$ and $\tilde{b}$ represent the same information, denoted by $\tilde{a}=\tilde{b}$; (2) if $H(\tilde{a})<H(\tilde{b})$, $\tilde{a}$ is smaller than $\tilde{b}$, denoted by $\tilde{a}<\tilde{b}$ [6].

Definition 7. Let $a_j=(\mu_j,\nu_j)(j=1,2,\cdots,n)$ be a collection of intuitionistic fuzzy values, and let IFWA: $Q^n\to Q$, if

$$\text{IFWG}_{\omega}(\tilde{a}_1,\tilde{a}_2,\cdots,\tilde{a}_n)=\bigotimes_{j=1}^{n}(\tilde{a}_j)^{\omega_j}=\left(\prod_{j=1}^{n}\mu_j^{\omega_j},1-\prod_{j=1}^{n}(1-\nu_j)^{\omega_j}\right) \tag{6}$$

where $\omega=(\omega_1,\omega_2,\cdots,\omega_n)^T$ be the weight vector of $\tilde{a}_j\,(j=1,2,\cdots,n)$, and $\omega_j>0$, $\sum_{j=1}^{n}\omega_j=1$, then IFWG is called the intuitionistic fuzzy weighted geometric (IFWG) operator [7].

3. Model for Intuitionistic Fuzzy Multiple Attribute Decision Making Problems

The following assumptions or notations are used to represent the intuitionistic fuzzy MADM problems with entropy weight information:

(1) The alternatives are known. Let $A=\{A_1,A_2,\cdots,A_m\}$ be a discrete set of alternatives;

(2) The attributes are known. Let $G=\{G_1,G_2,\cdots,G_n\}$ be a set of attributes;

(3)The information about attribute weights is incompletely known. Let $w=(w_1,w_2,\cdots,w_n)\in H$ be the weight vector of attributes, where $w_j\geq 0$, $j=1,2,\cdots,n$, $\sum_{j=1}^{n} w_j=1$.

Suppose that $\tilde{R}=(\tilde{r}_{ij})_{m\times n}=(\mu_{ij},\nu_{ij})_{m\times n}$ is the intuitionistic fuzzy decision matrix, where μ_{ij} indicates the degree that the alternative A_i satisfies the attribute G_j given by the decision maker, ν_{ij} indicates the degree that the alternative A_i doesn't satisfy the attribute G_j given by the decision maker, $\mu_{ij}\subset[0,1]$, $\nu_{ij}\subset[0,1]$, $\mu_{ij}+\nu_{ij}\leq 1$, $i=1,2,\cdots,m$, $j=1,2,\cdots,n$.

Definition 8. Let $\tilde{R}=(\tilde{r}_{ij})_{m\times n}=(\mu_{ij},\nu_{ij})_{m\times n}$ be an intuitionistic fuzzy decision matrix, $\tilde{r}_i=(\tilde{r}_{i1},\tilde{r}_{i2},\cdots,\tilde{r}_{in})$ be the vector of attribute values corresponding to the alternative A_i, $i=1,2,\cdots,m$, then we call

$$\tilde{r}_i=(\mu_{ij},\nu_{ij})=\mathrm{IFWG}_w(\tilde{r}_{i1},\tilde{r}_{i2},\cdots,\tilde{r}_{in})$$
$$=\left(\prod_{j=1}^{n}\mu_{ij}^{\;w_j},1-\prod_{j=1}^{n}(1-\nu_{ij})^{w_j}\right),\quad i=1,2,\cdots,m. \tag{7}$$

the overall value of the alternative A_i, where $w=(w_1,w_2,\cdots,w_n)^T$ is the weight vector of attributes.

In the situation where the information about attribute weights is completely known, i.e., each attribute weight can be provided by the expert with crisp numerical value, we can weight each attribute value and aggregate all the weighted attribute values corresponding to each alternative into an overall one by using Eq. (7). Based on the overall attribute values $\tilde{r}_i$ of the alternatives $A_i\,(i=1,2,\cdots,m)$, we can rank all these alternatives and then select the most desirable one(s). The greater $\tilde{r}_i$, the better the alternative A_i will be.

Entropy[11] was one of the concepts in thermodynamics originally and then Shannon first introduced the concept of information entropy in connection with communication theory. He considered entropy was an equivalent to uncertainty. It made a pervasive impact to many other disciplines in extending his work to other fields, ranging from management science, engineering technology and the sociological economic field. In these disciplines entropy is applied as a measure of disorder, unevenness of distribution and the degree of dependency or complexity of a system. Information entropy is an ideal measure of uncertainty and it can measure the quality of effective information. In the intuitionistic fuzzy MADM problems which have m alternatives and n attributes, the jth attribute's entropy is defined as follows:

$$H_j=-k\sum_{i=1}^{m} f_{ij}\ln f_{ij},\; i=1,2,\cdots,m,\; j=1,2,\cdots,n.$$

where

$$f_{ij}=\frac{H(\tilde{r}_{ij})}{\sum_{i=1}^{m}H(\tilde{r}_{ij})},\quad k=\frac{1}{\ln m}. \tag{8}$$

Assume that if $f_{ij}=0$, then $f_{ij}\ln f_{ij}=0$.

Then, the jth attribute's entropy is defined as follows:

$$w_j=\frac{1-H_j}{n-\sum_{j=1}^{n}H_j}. \tag{9}$$

Based on the above models, we develop a practical method for solving the MADM problems, in which the information about attribute weights is completely unknown, and the attribute values take the form of intuitionistic fuzzy information. The method involves the following steps:

Step 1. Let $\tilde{R}=\left(\tilde{r}_{ij}\right)_{m\times n}$ be the intuitionistic fuzzy decision matrix, where $\tilde{r}_{ij}=\left(\mu_{ij},\nu_{ij}\right)$, which is an attribute value, given by an expert, for the alternative $A_i\in A$ with respect to the attribute $G_j\in G$, $w=\left(w_1,w_2,\cdots,w_n\right)$ be the weight vector of attributes, where $w_j\in[0,1]$, $j=1,2,\cdots,n$, $\sum_{j=1}^{n}w_j=1$.

Step 2. Determine the entropy weight of each attribute according to equations (8) and (9).

Step 3. Utilize the weight vector $w=\left(w_1,w_2,\cdots,w_n\right)$ and by Eq. (7), we obtain the overall values $\tilde{r}_i$ of the alternative $A_i\left(i=1,2,\cdots,m\right)$.

Step 4. calculate the scores $S\left(\tilde{r}_i\right)$ of the overall intuitionistic fuzzy preference value $\tilde{r}_i\left(i=1,2,\cdots,m\right)$ to rank all the alternatives $A_i\left(i=1,2,\cdots,m\right)$ and then to select the best one(s) (if there is no difference between two scores $S\left(\tilde{r}_i\right)$ and $S\left(\tilde{r}_j\right)$, then we need to calculate the accuracy degrees $H\left(\tilde{r}_i\right)$ and $H\left(\tilde{r}_j\right)$ of the overall intuitionistic fuzzy preference value $\tilde{r}_i$ and $\tilde{r}_j$, respectively, and then rank the alternatives A_i and A_j in accordance with the accuracy degrees $H\left(\tilde{r}_i\right)$ and $H\left(\tilde{r}_j\right)$.

Step 5. Rank all the alternatives $A_i\left(i=1,2,\cdots,m\right)$ and select the best one(s) in accordance with $S\left(\tilde{r}_i\right)$ and $H\left(\tilde{r}_i\right)\left(i=1,2,\cdots,m\right)$.

Step 6. End.

4. Numerical example

Since reform and opening up, our country's economy has achieved continuous and rapid growth. Meantime, extensive economic growth with the characteristics of highly investing, highly-polluting, toughly-cycling and inefficiency is not changed fundamentally. Contradiction between economic growth depending on energy and energy shortage becomes bigger and bigger. Under the circumstance of conventional energy in emergency and environment-friendly concept identified, how to increase energy amount by developing new energy industry, and then maintain sustainable economic growth on base of perfecting energy structure has been a center problem on accelerating transportation of way of economic development.Comparatively, funding input in new energy regions in our China is severely insufficient, even less than small and medium developing countries, can not meet the need. Being lack of funding input, indispensible infrastructure and technical equipment are in short supply which result in slow pace of development and low level of the industrializations, commercialization and internationalization. It can not meet the requirement of coordinated development of the economy and society. By which means to make up for the fund shortage in new energy industry development and then boost its healthy development has become a currently prominent problem. The key solution, taking examples by other countries'general practice, is to establish a special fund for new energy industry.U.S. is a nation with the most full-order systems in fund collection, management mechanism and exit mechanism, which have remarkably contributed for American economic growth. 80 percent of American companies survived and developed in the support of venture capital investment fund. American successful development mechanism in venture capital investment fund has set up a good example for us. We should bring those mature experiences in channels of fund-raising, types of organization and exit mechanism. Drawing on American successful experience of developing venture investment fund to develop new energy industry development fund with Chinese characteristics has become a significant point cut of solving the bottleneck of new energy industry.New energy industry fund model is divided into three parts which are management model, fund-raising model and operation model. To set up new energy industry development fund is in accordance with the three models to establish respectively.Management model of new energy industry fund:Our previous other industry funds were all contractual type funds, which had insurmountable defects in"free-riding"and"fund spokesperson absent". Corporate type fund, combines corporate system with fund feature to establish industry fund management organization in charge of fund management, operation and fund-raising can overcome the shortcomings above thanks to board of directors and independent management from director. Fund-raising model of new energy industry:Out of considerations that the required huge volume of new energy industry fund and long-time operation, most of countries adopt way of fund-raising by private placement. In aspect of fund capital sources, pension insurance is the principle capital source of American venture capital investment fund, which accounts for 50% of fund sources. It, on the one hand, solves the problem of difficulty of capital sources and also makes pension insurance profitable. Our conventional capital sources are from government fund, bank credit, venture capital and foreign businessmen's capital. Social insurance funds and insurance companies can be only allowed to invest in low-risk regions such as bank account, government bond and financial bond. This section presents a numerical example to illustrate the method proposed in this paper. Suppose a province plans to evaluate the investment risk of energy project. There is a panel with five possible energy projects $A_i\left(i=1,2,3,4,5\right)$ to select. The expert group selects four attribute to evaluate the five possible energy projects: ①G_1 is the teaching contents; ②G_2 is the teaching method; ③G_3 is the teaching atmosphere; ④G_4 is the teacher quality. The five possible energy projects $A_i\left(i=1,2,3,4,5\right)$ are to be evaluated using the intuitionistic fuzzy information by the decision maker under the above four attributes, as listed in the following matrix.

$$\tilde{R}=\begin{bmatrix}(0.5,0.4) & (0.6,0.3) & (0.3,0.6) & (0.2,0.7)\\(0.7,0.3) & (0.7,0.2) & (0.7,0.2) & (0.4,0.5)\\(0.6,0.4) & (0.5,0.4) & (0.5,0.3) & (0.6,0.3)\\(0.8,0.1) & (0.6,0.3) & (0.3,0.4) & (0.2,0.6)\\(0.6,0.2) & (0.4,0.3) & (0.7,0.1) & (0.5,0.3)\end{bmatrix}$$

Procedure for evaluating the investment risk of energy project contains the following steps.

Step 1 According to equations (8) and (9), we get the weight vector of attributes:

$$w=\left(0.3016\ \ 0.1202\ \ 0.2411\ \ 0.3331\right)^T$$

Step 2 Utilize the weight vector $w=\left(w_1,w_2,\cdots,w_n\right)$ and by Eq. (7), we obtain the overall values $\tilde{r}_i$ of the energy projects $A_i\left(i=1,2,\cdots,m\right)$.

$$\tilde{r}_1=\left(0.3703,0.5254\right),\tilde{r}_2=\left(0.6181,0.2973\right),\tilde{r}_3=\left(0.5567,0.3316\right)$$
$$\tilde{r}_4=\left(0.4714,0.3379\right),\tilde{r}_5=\left(0.5777,0.1989\right)$$

Step 3 Calculate the scores $S\left(\tilde{r}_i\right)$ of the overall intuitionistic fuzzy preference values $\tilde{r}_i\left(i=1,2,\cdots,m\right)$

$$S\left(\tilde{r}_1\right)=-0.1551,S\left(\tilde{r}_2\right)=0.3207,S\left(\tilde{r}_3\right)=0.2251$$
$$S\left(\tilde{r}_4\right)=0.1335,S\left(\tilde{r}_5\right)=0.3788$$

Step 4 Rank all the energy projects $A_i\left(i=1,2,3,4,5\right)$ in accordance with the scores $S\left(\tilde{r}_i\right)$ $\left(i=1,2,\cdots,5\right)$of the overall intuitionistic fuzzy preference values $\tilde{r}_i\left(i=1,2,\cdots,m\right)$: $A_5\succ A_2\succ A_3\succ A_4\succ A_1$, and thus the most desirable energy projects is A_5.

5. Conclusion

Since having joined the WTO, in order to solve the passive situations of the shortage of domestic energy and growing demand for energy, China has positively expanded the direct investment of overseas energy in greater scope and depth and opened up wider energy supply channels. Energy companies represented by the China National Offshore Oil Corporation (CNOOC) and Petro China Company Limited., etc. have made direct investment actively in high-grade areas all over the world, complied with the requirements of Chinese enterprises "Go Out" Strategy and good results have been obtained. Although peace and development continue to remain as the main theme of the current time, conflicts still exist in some areas and become increasingly intense. Overseas direct investment of our energy companies are always in these turbulent districts, such as the Middle East and Latin America, etc. and these companies often meet with all kinds of political risks alongside of the state acts of host countries or some accident factors. In this paper, we investigate the intuitionistic fuzzy multiple attribute decision making problems for investment risk evaluation model of energy project. We utilize the intuitionistic fuzzy weighted averaging (IFWA) operator to aggregate the intuitionistic fuzzy information corresponding to each alternative, and then rank the alternatives and select the most desirable one(s) according to the score function and accuracy function. Finally, an illustrative example for investment risk evaluation model of energy project is given to verify the developed approach and to demonstrate its practicality and effectiveness. In the future, we shall continue working in the application of the intuitionistic fuzzy multiple attribute decision-making to other domains [12-36].

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