Risk Assessment of E-Commerce Based on Credibility Theory

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Abstract—**The Chinese social informationization should start from the premise that the E-Commerce risk is scientifically assessed. Through introducing axiomatic credibility measure and classical analytic hierarchy process, we construct a multi-level risk assessment model based on credibility theory. For the complexity of multi-objective decision making in the process of E-commercial risk assessment, we have established the multi-level indicators system, and then have evaluated the E-Commerce risk by the risk assessment model proposed in this paper, which demonstrates the feasibility and effectiveness of the model. The multi-level risk assessment model based on credibility theory can effectively avoid subjective problem for selecting membership function in fuzzy evaluation, and thus the result of assessment is more scientific and objective.**

Keywords- credibility theory; analytic hierarchy process; E-commercial risk assessment

I. INTRODUCTION

E-Commerce involves the important area of the social informationization in China, and thus being a necessary measure of building a socialist harmonious society. As is promoted in the "2006 to 2020 National Development Strategy", the e-commerce community informatization is listed as one of the nine strategic priorities. [1]

With the rapid development of information technology, network brings tremendous changes to business activities. The development of e-commerce asks higher enterprise informatization and prompts more and more companies replace real paper with networks for information storage, transmission, switching and other activities. And the e-commerce risks, knowing as the possibility of losses during the e-commercial activities [2], draw more and more attention to its safety and other issues. So, analyze, evaluate various risks and then taking appropriate risk management and safety precautions is particularly important. [3]

Dai Weiming [4], Fushao Chuan and Zhang Wenjie [5] mainly discuss e-commerce risk factors, evaluation steps, and then put forward some suggestions to prevent risks. These studies enhance people's awareness of e-commerce risks, and provide some tips for prevention. However, enterprises can hardly use these findings to estimate the size of risks because of its lack of quantitative analysis. Zeng Xiaochun and Sun Ning [6] regard the e-commerce risks as objective risks and therefore use the risk assessment model to measure the ratio of the mean square error, which is between actual losses and forecast losses, and the mathematical expectation of the prediction losses. Song Jian[7] combines AHP and fuzzy comprehensive evaluation model, thus modifying the poor immunity of weighting coefficients and the lack of fuzzy information processing capabilities in AHP, giving qualitative and quantitative assessment of risk.

With the development of fuzzy mathematics, Liu [8] has founded the credibility of axiomatic theory, which could efficiently avoid the problem that choosing membership function is full of subjectivity in traditional fuzzy set theory. In view of this, we give up the traditional fuzzy comprehensive evaluation method, and adopt multi-level integrated assessment method based on credibility theory to judge the e-commerce risk so that the result of assessment is more scientific, objective and accurate.

II. INTRODUCTION OF CREDIBILITY THEORY

In 1965, Zadeh[9] proposed the fuzzy sets theory which has achieved considerable development under the joint efforts of numerous scholars, and accessed to practical applications in many fields. There are three important type measures in fuzzy mathematics: possibility measure, necessity measure and credibility measure. In the traditional view, possibility measure is parallel with the concept of probability measure. In fact, in the fuzzy set theory, only credibility measure can play the role of probability measure. Liu and Liu defined a self-dual credibility measure in 2002 [10], and then founded credibility theory based on an axiomatic foundation [8]. We shall briefly introduce definitions of these three measures and the concept of credibility space in the following.

Let ξ be a fuzzy variable with membership function μ, and h be an arbitrary real number. The possibility event, characterized by $\xi \le h$, is defined by

$$\mathrm{Pos}\{\xi \le h\} = \sup_{t \le h} \mu(t),$$

while the necessity of $\xi \le h$ is defined by the impossibility of its opposing event, that is

$$\mathrm{Nec}\{\xi \le h\} = 1 - \mathrm{Pos}\{\xi > h\} = 1 - \sup_{t > h} \mu(t).$$

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The credibility measure Cr is an average of possibility measure and necessity measure, namely,

$$\mathrm{Cr}\{\xi \le h\} = \left(\mathrm{Nec}\{\xi \le h\} + \mathrm{Pos}\{\xi \le h\}\right)/2 .$$

Let Θ be a nonempty set, and $P(\Theta)$ the power set of Θ. Each element in $P(\Theta)$ is called a fuzzy event. For any event A in $P(\Theta)$, it is necessary to assign to a real number $\mathrm{Cr}\{A\}$ which indicates the credibility that A will occur. $\mathrm{Cr}(\bullet)$ is a set function, and satisfies the following four axioms.

Axiom 1. (Normality) $\mathrm{Cr}(\Theta)=1$;

Axiom 2. (Monotonicity) $\mathrm{Cr}\{A\} \le \mathrm{Cr}\{B\}$ whenever $A \subset B$;

Axiom 3. (Self-Duality) $\mathrm{Cr}\{A\} + \mathrm{Cr}\{A^C\} = 1$ for any event $A \in P(\Theta)$;

Axiom 4. (Maximality) $\mathrm{Cr}\{\bigcup_i A_i\} = \sup_i \mathrm{Cr}\{A_i\}$ for any events $\{A_i\}$ with $\sup_i \mathrm{Cr}\{A_i\} < 0.5$.

Then ternary array $(\Theta, P(\Theta), \mathrm{Cr})$ is called credibility space. For the detailed introduction on credibility theory, the reader can refer to literature [8].

Definition [8] If ξ is a fuzzy variable defined in the credibility space, and t is a arbitrary real number, then membership function of ξ can be derived by following credibility measure

$$\mu(t) = \left(2\mathrm{Cr}\{\xi = t\}\right) \wedge 1 .$$

So we can obtain inversion theorem of credibility measure.

Theorem [8] If μ is the membership function of fuzzy variable ξ, then we have, for any real set A,

$$\mathrm{Cr}\{\xi \in A\} = \frac{1}{2}\left(\sup_{t\in A}\mu(t) + 1 - \sup_{t\in A^C}\mu(t)\right). \tag{1}$$

III. Multi-level Fuzzy Assessment Model Based on Credibility Measure

Here, according to the credibility theory defined by Liu, we provide the assessment model involving E-commerce, only including three levels factors, which is based on credibility measure. For the assessment model including more levels factors, it can be obtained in the similar way. Suppose that $U = \{u_1, u_2, \cdots, u_n\}$ is the main factor set of assessment, where $u_i = \{u_{i1}, u_{i2}, \cdots, u_{im}\}$ $(i = 1, 2, \cdots, n)$ is the sub factor set. Using analytic hierarchy process (AHP), we obtain weights of every level indicators, where $W = (w_1, w_2, \cdots, w_n)$ is the weight vector of main factor set $U = \{u_1, u_2, \cdots, u_n\}$ and $w_i = (w_{i1}, w_{i2}, \cdots, w_{im})$ $(i = 1, 2, \cdots, n)$ is the weight vector of sub factor set $u_i = \{u_{i1}, u_{i2}, \cdots, u_{im}\}$ $(i = 1, 2, \cdots, n)$. Weight vectors are fuzzy set in factor sets and review set $V = \{v_1, v_2, \cdots, v_k\}$ is a fuzzy set in credibility space $(\Theta, P(\Theta), \mathrm{Cr})$, where $\Theta = [0,1]$.

A. Single Factor Assessment Model

By applying Delphi method, we have membership g_{ijl} which responses the degree for indicator factor u_{ij} $(i = 1, 2, \cdots, n;\ j = 1, 2, \cdots, m)$ attaching to reviews level v_l $(l = 1, 2, \cdots, k)$, where g_{ijk} is equal to the ratio between number of experts who believe that indicator u_{ij} belongs to review level v_l and the total number of experts involving in the assessment. According to credibility inversion formula (1), we get

$$\mathrm{Cr}\{v_l = g_{ijl}\} = \frac{1}{2}\left(\mu_{ij}(t) + 1 - \sup_{t \ne g_{ijl}} \mu_{ij}(t)\right), \tag{2}$$

where $\mu_{ij}(t)$ is the membership for t attaching to review level v_l under indicator u_{ij}, and $r_{ijl} = \mathrm{Cr}\{v_l = g_{ijl}\}$ is credibility measure of fuzzy event $\{v_l = g_{ijl}\}$, that is, the credibility measure that property value g_{ijl} of assessment object belongs to review-level v_l under indicator u_{ij} $(i = 1, 2, \cdots, n;\ j = 1, 2, \cdots, m;\ l = 1, 2, \cdots, k)$. Hence, for single factor u_{ij}, we can get the credibility measure vector

$$r_{ij} = \{r_{ij1}, r_{ij2}, \cdots, r_{ijk}\}, \tag{3}$$

and it is also a fuzzy subset in the reviews level set.

B. Multivariate multilevel assessment model

The multivariate multilevel assessment process can be summarized as follows.

Step 1. Normalizing vector $r_{ij} = \{r_{ij1}, r_{ij2}, \cdots, r_{ijk}\}$, we have the normalized credibility assessment vector of factor u_{ij} as follows:

$$\overline{r}_{ij} = \{\overline{r}_{ij1}, \overline{r}_{ij2}, \cdots, \overline{r}_{ijk}\}, \tag{4}$$

where $\overline{r}_{ijl} = r_{ijl} \Big/ \sum_{l=1}^{k} r_{ijl}$ $(l = 1, 2, \cdots, k)$.

Step 2. Arrange normalized credibility measure vectors of m factors u_{ij} $(j = 1, 2, \cdots, m)$ in accordance with the ordinal, which form a credibility measure matrix for the upper level factor u_i,

$$R_i=\left(\overline{r}_{ijl}\right)_{m\times k}=\begin{bmatrix}\overline{r}_{i11} & \overline{r}_{i12} & \cdots & \overline{r}_{i1k}\\ \overline{r}_{i21} & \overline{r}_{i22} & \cdots & \overline{r}_{i2k}\\ \cdots & \cdots & \cdots & \cdots\\ \overline{r}_{im1} & \overline{r}_{im2} & \cdots & \overline{r}_{imk}\end{bmatrix}. \quad (5)$$

Step 3. Make a fuzzy linear transformation for matrix R_i, which results in the following fuzzy subset of factor u_i on reviews level set,

$$B_i=w_i*R_i=\left(b_{i1},b_{i2},\cdots,b_{ik}\right), \quad (6)$$

where operator $*$ denote multiplication of matrix ; b_{il} which is the comprehensive credibility measure of factor u_i for reviews level v_l ($l=1,2,\cdots,k$) can objectively reflect the extent of the pros and cons of factor u_i.

Step 4. Arrange $B_i=\left(b_{i1},b_{i2},\cdots,b_{ik}\right)$, credibility measure vectors of n factors u_i ($i=1,2,\cdots,n$), in accordance with the ordinal, which form a credibility measure matrix for main factor set U,

$$R=\left(b_{ij}\right)_{n\times k}=\begin{bmatrix}b_{11} & b_{12} & \cdots & b_{1k}\\ b_{21} & b_{22} & \cdots & b_{2k}\\ \cdots & \cdots & \cdots & \cdots\\ b_{n1} & b_{n2} & \cdots & b_{nk}\end{bmatrix}. \quad (7)$$

Step 5. Solve the assessment result of credibility measure vector for main factor $U=\left\{u_1,u_2,\cdots,u_n\right\}$. For this, making a fuzzy linear transformation for matrix R, we finally obtain credibility measure vector

$$B=W*R=\left(b_1,b_2,\cdots,b_k\right) \quad (8)$$

for main factor U on the reviews level set.

Step 6. According to the principle of maximum credibility measure, choose review level v_l that is corresponding to the maximum element of $B=\left(b_1,b_2,\cdots,b_k\right)$ as the final comprehensive assessment result.

IV. THE CREDIBILITY MEASURE ASSESSMENT OF CREDIT RISK IN COMMERCIAL BANKS

A. Constructing the indicators system of e-commerce risk assessment

We construct the e-commerce risk indicators system based on the following principles and standards: (1) scientificalness and objectivity; (2) comprehensiveness and representativeness; (3) correlation and dynamics; (4) practicability and comparability; (5) muti-layer. The concrete details of credit risk indicators system are shown in table I.

TABLE I. E-COMMERCIAL RISK INDICATORS SYSTEM AND EXPERTS REVIEWS TABLE

Risk types and weights	Risk projects and weights	Normal	Concern	Secondary	Suspicious	Loss
u_1 Planning risk(0.33)	u_{11} Value to the superior(0.69)	0.5	0.4	0	0.1	0
	u_{12} Completeness of planning (0.31)	0.5	0.2	0.2	0	0.1
u_2 Technology application risk(0.14)	u_{21} Technological level (0.40)	0.4	0.4	0.1	0	0.1
	u_{22} Business outsourcing risk (0.60)	0.5	0.4	0	0.1	0
u_3 Staff behaviour risk(0.18)	u_{31} Quality of staff (0.45)	0.7	0.1	0.1	0.1	0
	u_{32} Brain drain risk (0.21)	0.3	0.4	0.1	0.1	0.1
	u_{33} Moral hazard (0.34)	0.4	0.2	0.2	0.1	0.1
u_4 Management risk(0.25)	u_{41} Quality and experience of management(0.37)	0.2	0.4	0.2	0.1	0.1
	u_{42} Scientization of decision-making (0.19)	0.5	0.2	0.2	0	0.1
	u_{43} Management maturity (0.26)	0.5	0.3	0.1	0	0.1
	u_{44} Information unblocked reliability (0.18)	0.1	0.7	0.1	0.1	0
u_5 Environmental risk (0.10)	u_{51} Political risk (0.28)	0.6	0.2	0	0.1	0.1
	u_{52} Policy risk (0.18)	0.4	0.2	0.1	0.3	0
	u_{53} Economic risk (0.14)	0.3	0.4	0.2	0	0.1

	u_{54} Social and cultural risk (0.10)	0.4	0.1	0.2	0.2	0.1
	u_{55} Risk of Contingency (0.30)	0.3	0.1	0.5	0.1	0.1

B. Establishing reviews level set and factors set of credit risk

According to the analysis in the section *A*, we establish main factor set $U=(u_1,u_2,u_3,u_4,u_5)$ and sub factors sets $u_1=(u_{11},u_{12})$, $u_2=(u_{21},u_{22})$, $u_3=(u_{31},u_{32},u_{33})$, $u_4=(u_{41},u_{42},u_{43},u_{44})$, $u_5=(u_{51},u_{52},u_{53},u_{54},u_{55})$. The meaning of every factor is also shown in table I.

Considering the risk level of e-commercial companies, we establish reviews level set $V=\{v_1,v_2,v_3,v_4,v_5\}$ = {Normal, Concern, Secondary, Suspicious, Loss} which represents no risk, low risk, medium risk, high risk, sever risk, respectively.

C. Determining weights of credit risk indicators

It is noteworthy that the weight of each indicator should not the same since the importance of indicators is different obviously. Here we adopt analytic hierarchy process (AHP) to determine the weight of every indicator. AHP proposed by American operation research expert Saaty [11] is an efficient way to solve the problem of multi-attribute decision making. The general steps of AHP as follows: (1) divide the indicator of E-commercial risk into several categories according to property; (2) using pair-wise comparison matrix solve relative weights of both the third and the second level assessment indicators in the evaluation of comprehensive credit risk; (3) make single factor evaluation of every indicator under each given factor according to category, which form single factor assessment matrix; (4) apply comprehensive evaluation function to assess each factor by matrix operations. The detailed introduction for AHP, readers can refer to literature [11, 12].

AHP is quite mature in practical applications, which can be achieved by professional computer software. So we do not provide the process in detail, and only fill the ultimately derived results in table I. According to our results, weights of indicator factor U,u_1,u_2,u_3,u_4,u_5 are $w=(0.33,0.14,0.18,0.25,0.10)$, $w_1=(0.69,0.31)$, $w_2=(0.40,0.60)$, $w_3=(0.45,0.21,0.34)$, $w_4=(0.37,0.19,0.26,0.18)$ and $w_5=(0.28,0.18,0.14,0.10,0.30)$, respectively.

D. Comprehensive assessment of credit risk for loan companies

Employ ten experts to assess the lowest level indicator of e-commercial risk. For any one of the lowest level indictor, its membership for risk level $v_i(i=1,2,\cdots,5)$ is the rate between the number of experts choosing risk level $v_i(i=1,2,\cdots,5)$ and the total number of experts participating in the evaluation. We have filled the membership of each lowest indictor in table I. As is shown in table I, fuzzy evaluation vector of indictor u_{11} is

$$r_{11}^*=(0.5,0.4,0,0.1,0).$$

It follows from formula (2) that credibility measure vector of u_{11} is

$$r_{11}=(0.55,0.45,0.25,0.3,0.25).$$

Combining with (4), we have the normalized credibility measure vector of u_{11} as follows

$$\overline{r}_{11}=(0.3056,0.25,0.1389,0.1667,0.1389).$$

We can obtain normalized credibility measure vectors of u_{12},u_{13},u_{14} in the same method. After arranging these vectors by the manner in (5), we further get the following credibility measure evaluation matrix of factor set $u_1=\{u_{11},u_{12}\}$,

$$R_1=\begin{bmatrix}0.3056 & 0.25 & 0.1389 & 0.1667 & 0.1389\\ 0.3421 & 0.1842 & 0.1842 & 0.1316 & 0.1579\end{bmatrix}.$$

Matrix R_1 associated with (6) reduces to comprehensive evaluation vector of factor u_1 based on credibility measure as follows,

$$B_1=(0.3169\quad 0.2296\quad 0.1529\quad 0.1558\quad 0.1448)$$

Similarly, we respectively get the following comprehensive evaluation vectors of factor u_2,u_3,u_4 and u_5 based on credibility measure,

$$B_2=(0.2860\quad 0.2500\quad 0.1540\quad 0.1620\quad 0.1540);$$

$$B_3=(0.3756\quad 0.1789\quad 0.1586\quad 0.1507\quad 0.1363);$$

$$B_4=(0.2427\quad 0.2898\quad 0.1706\quad 0.1450\quad 0.1514);$$

$$B_5=(0.2863\quad 0.1860\quad 0.2049\quad 0.1676\quad 0.1555).$$

Arranging credibility measure vectors of u_1,u_2,u_3,u_4 and u_5 like the manner in (7), we further obtain credibility measure evaluation matrix of factor set $u=\{u_1,u_2,u_3,u_4,u_5\}$,

$$R = \begin{bmatrix} 0.3169 & 0.2296 & 0.1529 & 0.1558 & 0.1448 \\ 0.2860 & 0.2500 & 0.1540 & 0.1620 & 0.1540 \\ 0.3756 & 0.1789 & 0.1586 & 0.1507 & 0.1363 \\ 0.2427 & 0.2898 & 0.1706 & 0.1450 & 0.1514 \\ 0.2863 & 0.1860 & 0.2049 & 0.1676 & 0.1555 \end{bmatrix}.$$

Finally, it follows from (8) that credibility measure vector of main factor U in the reviews level set as follows,

$$B = (0.3015 \quad 0.2340 \quad 0.1637 \quad 0.1542 \quad 0.1473).$$

According to the principle of maximum credibility, we think that the state of E-commercial risk is normal in the company.

V. CONCLUSIONS

According to credibility theory, we construct a comprehensive evaluation model based on AHP and credibility measure. Taking into account complexity of evaluation object in E-commercial companies, we establish multilevel assessment indictors system. In the process of E-commercial risk evaluation for the company, we first determine weights of each risk indictor by AHP, and then comprehensively assess each level indictor by credibility measure. Finally, we obtain evaluation value of credit risk by the principle of maximum credibility. This example proves the feasibility and effectiveness of the model proposed in this paper. Moreover, the risk assessment model can be extended to more areas of fuzzy evaluation, and provides a new effective method for multi-objective decision making.

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