Hindawi
Discrete Dynamics in Nature and Society
Volume 2023, Article ID 3744725, 11 pages
https://doi.org/10.1155/2023/3744725

Research Article

Risk Assessment of Scientific and Technological Cooperation among RCEP Countries Based on Cloud Model

Lijuan Long and Yuanchang Wang

School of Mathematics, Yunnan Normal University, Kunming 650500, China

Correspondence should be addressed to Yuanchang Wang; wangyuanchang@ynnu.edu.cn

Received 3 May 2022; Revised 15 December 2022; Accepted 30 December 2022; Published 3 May 2023

Academic Editor: Rodica Luca

Accurate risk assessment of international scientific and technological (S&T) cooperation is significant to international cooperation. In this paper, 5 risk dimensions with respect to the political, economic, social, cultural as well as technological of the regional comprehensive economic partnership countries (RCEP) are selected to establish a proper S&T cooperation index system for risk assessment. To calculate the weight of each index, a cross-entropy combination weighting method is proposed based on the combination weighting method of game theory. Furthermore, the standard cloud model is constructed by using the golden ratio, and the risk of S&T cooperation among the RCEP countries is analyzed by the cloud model. The results show that the combination weighting method proposed in this paper is effective, and its calculation is simpler than that of the game theory combination weighting method. Besides, compared with political, social, cultural, and technological indicators, economic indicators have a greater impact on S&T cooperation risk. Furthermore, it is also obtained from the results that the risk of S&T cooperation with China and the Philippines is at a lower to low level and medium to higher level, respectively, and the risk of S&T cooperation with other countries is all at a lower to medium level.

1. Introduction

One of the key initiatives to address global risks and challenges is international science and technology cooperation, and it is crucial and difficult to reasonably assess the risks of such cooperation. With the formal implementation of the regional comprehensive economic partnership (RCEP), the agreement is more applicable to today's rapidly developing world of science and technology as its treaties on intellectual property rights and science and technology cooperation have been further developed compared to other free trade agreements. In recent years, the topic of choosing low-risk partner countries has gotten more and more attention.

In the literature of international risk studies, Andric et al. used fuzzy logic to study the infrastructure risk profile of Belt and Road countries [1]. Wu et al. found that political risks, economic risks, and resource risks occupy the main determinant position during the overseas renewable energy investment while Chinese factors have certain effects on investment behaviors [2]. Yuan et al. pointed out that among the Belt and Road countries, Singapore has the lowest risk for China's CFPP investment, followed by New Zealand and Thailand [3]. Li et al. identify and evaluate the risk of countries along the "Belt and Road Initiative" [4]. Sun et al. identified 10 core low carbon financial risk factors that could derail Green Belt and Road PPP projects [5].

For the usage of qualitative concepts, some scholars focus on the transformation between evaluation results and linguistic variables, such as 2-dimension linguistic variable [6], interval-valued triangular fuzzy numbers [7], intuitionistic fuzzy sets [8], GCLEs [9] as well as HFLTs [10, 11]. These methods all reflect the problem that failing to account for the stochastic nature of expert information. Li et al. suggested the idea of a cloud model based on fuzzy mathematics and probability theory to express both fuzziness and stochasticity. The cloud model uses three numerical features with natural language as the entry point to realize the uncertainty transformation between qualitative concepts and quantitative values. The quantitative value of the cloud model can reflect both the fuzziness of the concept and the stochasticity of the evaluation [12]. Wu et al. used the ANP-cloud model to study the risks of renewable energy investments in 54 countries along the Belt and Road [2]. Xiong et al. used a cloud model and found that the main factors influencing the occurrence of roof accidents were roof pitch, counterweight strength, and rib spalling, followed by coal stress concentrations, initial support forces, and geological conditions [13]. Wang et al. used a cloud model to evaluate the water quality of each spring in Jinan [14]. Yu et al. used a cloud model to assess rainfall risk in Changzhou City and found that areas with high rainfall risk levels included most of the Jintan and Xinbei districts and parts of Wujin and Zhonglou districts [15].

Obviously, the relative importance of each indicator is different in the process of risk evaluation, so weight is introduced to reflect this characteristic. There are many methods for calculating weights, and the common ones are entropy method [16], CRITIC method [17], the coefficient of variation method [18], and analytic hierarchy process [19]. However, a single weight calculation method has some disadvantages, so combination assignment methods such as the game theory combination assignment method, deviation minimization assignment method, and distance function minimization assignment method are proposed to combine the benefits of each combination assignment method [20–23]. However, these combination assignment methods all have the limitations of large computation and not considering the correlation into account.

In this paper, we first analyzed the factors affecting international S&T cooperation and classified the risks of international S&T cooperation, and the S&T cooperation index system for risk assessment is built on this basis. Second, the combination weighting method based on cross-entropy is introduced, and we use the proposed cross-entropy combination weighting method to combine the weights obtained from the entropy method, CRITIC method, and the coefficient of variation method to obtain the combination weight. Finally, the golden section ratio is used to build a standard cloud model, the digital characteristics of the secondary indicator cloud model are obtained through the reverse cloud model, combining the digital characteristics of the cloud model with the weights of indicators at all levels, and the total weights of countries are obtained. Then, a comprehensive cloud map is drawn by MATLAB software and compared with the standard cloud map to obtain the risk level of S&T cooperation among countries as well as reasonably evaluated the risks of countries.

The contributions of this article are twofold. First, a system for evaluating the risks of international S&T cooperation has been established. This system considers five different factors to evaluate the risks of such cooperation: economics, politics, culture, society, and technology. Second, a new combination weighting method called the cross-entropy combination weighting method that is distinct from the traditional combination weighting method is proposed. The method proposed addresses the problems of the current combination weighting method that involves numerous calculations and does not take the correlation among indicators into account. As far as we know, we are the first to propose the international S&T cooperation's risk indicator system and use cross-entropy for combination weighting.

The rest of this article is organized as follows. Section 2 introduces the cross-entropy combination weighting method and cloud model. Section 3 takes the member countries of RCEP as examples to apply the risk assessment model of S&T cooperation. Section 4 draws the conclusion.

2. Methodology

2.1. Determination of Index Weight. This paper first calculates each index weight using the entropy method, CRITIC method, and coefficient of variation method, respectively, to ensure the accuracy of each index weight. The final weight of each index is then calculated by combining the weights acquired in the three ways mentioned above in accordance with a new weighting approach (named the cross-entropy combination weighting method) that is proposed in this paper. Among them, the cross-entropy combination weighting method's fundamental idea is as follows.

Assuming that the weight vectors obtained under k methods are $W_1, W_2, W_3, \ldots, W_k$, the combined comprehensive weight is a linear combination of k weight vectors, and then,

$$W(k) = \lambda_1 W_1 + \lambda_2 W_2 + \lambda_3 W_3 + \cdots + \lambda_k W_k, \quad (1)$$

where λ_i is the linear combination coefficient, and $\sum_{i=1}^{k} \lambda_i = 1, \lambda_i > 0$.

The cross-entropy loss function is used to construct the following optimization model:

$$\begin{aligned} &\min_{\lambda_1, \lambda_2, \cdots \lambda_k} \quad -\frac{1}{k} \sum_{l=1}^{k} \sum_{m=1}^{n} \left[W_{lm} \log(W(k)) - (1 - W_{lm}) \log(1 - W(k)) \right], \\ &\text{s.t.} \quad \lambda_i > 0, i = 1, 2, 3, \cdots, k \text{ and} \sum_{i=1}^{k} \lambda_i = 1. \end{aligned} \quad (2)$$

Then, $\lambda_1, \lambda_2, \cdots, \lambda_k$ is calculated by the Lagrange multiplier method by substituting $\lambda_1, \lambda_2, \cdots, \lambda_k$ into equation (1) and, finally, normalizing it to get the final combination weight.

The cross-entropy loss function converges faster than the mean square error loss function compared to the conventional game theory combination weighting approach, while also being more straightforward to calculate. The combination weighting approach proposed in this paper is easier to calculate and has a faster rate of convergence. Meanwhile, this article will prove the effectiveness of this method in an empirical analysis.

2.2. Cloud Model. The cloud model is a model of uncertainty transformation between a qualitative concept described in terms of linguistic values and its numerical representation. It has three numerical characteristics: expectation, entropy, and super entropy, denoted as $C(Ex, En, He)$, where the expectation is the central value of cloud drops in the universe of discourse; entropy reflects the level of uncertainty of qualitative concepts, which is determined by the concept's randomness and ambiguity. An increase in entropy implies an increase in the ambiguity of the concept, i.e., an increase in randomness; super entropy is the entropy of entropy, which is determined by the randomness and ambiguity of entropy and reflects the degree of cohesion of cloud droplets. The size of the super entropy represents the magnitude of the dispersion of the cloud, and as the super entropy increases, the randomness of the affiliation increases, as does the thickness of the cloud. The specific steps are as follows.

2.2.1. Build a Standard Cloud. By referring to the previous research results, this paper adopts a five-level risk evaluation system to evaluate the risk of S&T cooperation. Defining the risk evaluation results as five levels, the comment set is {low risk, lower risk, medium risk, higher risk, high risk}, denoted as $V = \{V_1, V_2, V_3, V_4, V_5\}$. Furthermore, bilateral constraints on each level are carried out, and the maximum and minimum values of reviews are represented by $x_{\min}$, $x_{\max}$. At the same time, to avoid the intervention of human factors in the establishment of evaluation grades, this article uses the golden ratio to partition the comment set [24], and taking the central point of the universe 0.5 as the medium risk grade, the medium risk cloud model parameter is $Ex_3 = 0.5, He_3 = 0.005$. Cooperative risk standard evaluation parameters are shown in Table 1, and MATLAB is used to draw standard cloud diagrams, as shown in Figure 1.

2.2.2. Calculating Cloud Parameters of Indicator. On the basis of expert scores, the cloud model parameters of each secondary indicator are calculated based on the reverse cloud model, as shown in the following formula:

$$\begin{cases} Ex_j = \sum_{p=1}^{t} \dfrac{x_{pj}}{t}, \\ En_j = \sqrt{\dfrac{\pi}{2}} \sum_{p=1}^{t} \dfrac{\left|x_{pj} - Ex_j\right|}{t}, \\ He_j = \sqrt{\left|S_j^2 - En_j^2\right|}, \end{cases} \tag{3}$$

where $S_j^2 = 1/t - 1\sum_{p=1}^{t} (x_{pj} - Ex_j)^2$.

2.2.3. Calculate Comprehensive Cloud Parameters. The characteristic parameters of each secondary indicator are combined with the weights of each combination to obtain the cloud model parameters of each primary indicator and the integrated cloud model parameters. The following equation is shown:

$$\begin{cases} Ex = \dfrac{\sum_{q=1}^{t} Ex_q w_q}{\sum_{q=1}^{t} w_q}, \\ En = \sum_{q=1}^{t} \dfrac{w_q^2}{\sum_{q=1}^{t} w_q^2} En_q, \\ He = \sum_{q=1}^{t} \dfrac{w_q^2}{\sum_{q=1}^{t} w_q^2} He_q. \end{cases} \tag{4}$$

2.2.4. Cloud Chart Comparison. On the basis of the derived standard and integrated cloud parameters, the MATLAB software is used to draw the standard and integrated cloud diagrams through the forward cloud generator and to compare and analyze them in order to draw conclusions.

3. The Proposed Method to Evaluate the Risk of a Country's International S&T Cooperation

The RCEP agreement will not only promote economic exchanges among member countries but also cultural exchanges, one of which cannot be ignored is the S&T exchange and cooperation among member countries. With this in mind, we analyze the risks of S&T cooperation in RCEP countries qualitatively and quantitatively, evaluate the risks of S&T cooperation in each member country, and then provide recommendations for S&T cooperation among member countries based on the results.

The World Bank, the World Intellectual Property Organization, the United Nations Conference on Trade and Development database, as well as national statistical and customs offices, provided the data used in this paper. As the data for 2020 and several countries such as Brunei,

Table 1: Evaluation parameters of risk standards for S&T cooperation.

Risk level	Evaluation value	Cloud model digital features
Low risk	(0, 0.2]	(0, 0.103, 0.0131)
Lower risk	(0.2, 0.4]	(0.309, 0.064, 0.0081)
Medium risk	(0.4, 0.6]	(0.5, 0.039, 0.005)
Higher risk	(0.6, 0.8]	(0.691, 0.064, 0.0081)
High risk	(0.8, 1]	(1, 0.103, 0.0131)

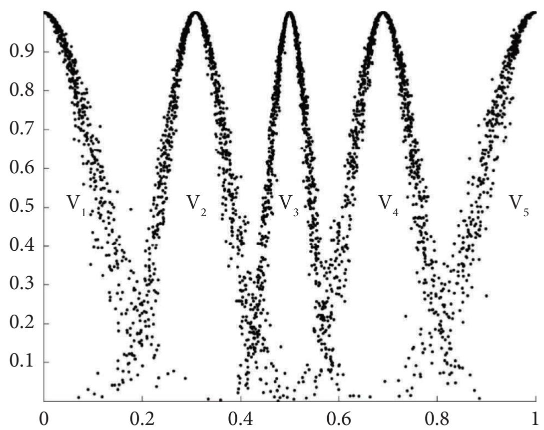

Figure 1: Cloud diagram of risk assessment criteria for technology cooperation.

Cambodia, Laos, and Myanmar are missing, this paper uses the data of the remaining RCEP member countries in 2019 to study the risk of cross-border S&T cooperation.

3.1. Construction of International S&T Cooperation Index System. The influencing factors are regarded as the risk through the analysis of factors impacting international S&T cooperation. And identifying risk factors through the literature review and reading pieces of literature on international cooperation, the existing risk index system is expanded based on existing research, and a total of 15 risk factors related to international S&T cooperation are extracted and summarized. This paper covers five dimensions: economics, politics, culture, society, and technology as well as creates an S&T cooperation risk index system, shown in Table 2, to better adapt to the risk analysis of international S&T cooperation.

3.2. Determination of Indicator Weight at All Levels. According to the risk evaluation index system mentioned previously, in order to analyze the weight of each risk indicator quantitatively, the weight of each indicator is measured by using the entropy method, CRITIC method, and coefficient of variation method in this paper. Based on the combined weighting method of game theory, a new combined weighting method is proposed to solve a problem, which ignores the correlation among indicators in the combined weighting method of game theory. Using MATLAB, it is found that when using the cross-entropy model to solve the combination weight, the primary indicator coefficients λ_i are 0.1757, 0.1208, and 0.7035, and the secondary indicator coefficients λ_j are 0.2700, 0.3062, and 0.4238. When using the game theory method to solve the combination weight, the primary indicator coefficients λ_i are 0.3331, 0.3329, and 0.3340. The coefficients of each secondary indicator λ_j are 0.3283, 0.3313, and 0.3404. By taking them in (1), the risk weights of S&T cooperation obtained by each weighting method are shown in Table 3.

Table 3 holds that there is little difference between the combined weight obtained by the cross-entropy model and the combination weight obtained by the game theory method. Besides, there is little difference between the sorting values under the two methods, that is, the combination weight obtained by the cross-entropy model not only overcomes the defects of the game theory combination weight method but also shows its effectiveness through empirical research.

3.3. Cloud Model Parameter Calculation. In this paper, 15 experts who have a certain understanding of the basic situation of RCEP countries are invited to evaluate each country. A total of 2475 scoring data of 15 experts on the 11 countries studied in this paper are collected, of which the scoring range is $[0, 1]$. The scoring results of the No. 1 expert are given due to the length, as shown in Table 4. The scoring results of other experts will not be repeated.

On this basis, risk assessment is carried out for each country. For China, for example, a total of 15 experts score 15 secondary indicators and a total of 225 scoring data. Based on this, formula (3) can be used to calculate the digital characteristics of China's secondary indicator cloud model, as shown in Table 5.

The political risk of the first level indicator is used as an example, and the cloud model of China's political risk can be obtained as $A_1\,(0.2030, 0.0278, 0.0030)$ by using formula (4), when the three weights of political trust, political corruption, and political stability and the digital characteristics of the cloud model are determined. Similarly, the remaining primary indicator cloud models can be calculated as follows: $A_2\,(0.2987, 0.0259, 0.0136)$, $A_3\,(0.2116, 0.0238, 0.0062)$, $A_4\,(0.3693, 0.0748, 0.0213)$, $A_5\,(0.2857, 0.0250, 0.0122)$. The comprehensive cloud model of China's S&T cooperation risk assessment is obtained through formula (4) by using the weight of each primary indicator and the cloud parameters of each primary indicator, which is $C_C\,(0.2666, 0.0287, 0.0103)$.

Similar to China's S&T cooperation risk assessment procedures, based on the known scores of 15 experts, equations (3) and (4) can be used to derive the cloud model of S&T cooperation risk evaluation for the remaining 10 countries, namely Korea $C_K\,(0.4158, 0.0312, 0.0082)$, Japan $C_J\,(0.3472, 0.0303, 0.0101)$, Australia $C_A\,(0.3840, 0.0277, 0.0103)$, Singapore $C_S\,(0.3126, 0.0274, 0.0075)$, New Zealand $C_N\,(0.4863, 0.0294, 0.0084)$, Malaysia $C_M\,(0.4176, 0.0269, 0.01)$, Thailand $C_T\,(0.4849, 0.0262, 0.0084)$, Indonesia $C_I\,(0.4724, 0.0299, 0.0078)$, Vietnam $C_V\,(0.4932, 0.0326, 0.0099)$, and the Philippines $C_P\,(0.5522, 0.0302, 0.01)$.

Table 2: International S&T cooperation index system.

Level 1 indicator	Mark	Level 2 indicator	Mark	Quantification
Political risk	A_1	Political trust	A_{11}	The number of embassies in the country with one million people
		Political corruption	A_{12}	The global corruption index
		Political stability	A_{13}	Political stability and government capacity coefficients
Economic risks	A_2	Economic growth	A_{21}	Annual growth rate of per capita GDP
		Economic fluctuations	A_{22}	The standard deviation of annual GDP growth rate
		Inflation	A_{23}	The inflation rate
		Trade openness	A_{24}	The trade openness index (ratio of net foreign direct investment inflow to the country's GDP)
Social risks	A_3	Human development	A_{31}	The human development index
		Terrorism	A_{32}	The global terrorism index
		Public order	A_{33}	The crime index
Cultural risks	A_4	Religious culture	A_{41}	Proportion of nonbelievers in the country's total population
		Labor market risk	A_{42}	The unemployment rate
Technical risks	A_5	Independent innovation	A_{51}	The global innovation index
		Achievement transformation	A_{52}	Proportion of intellectual property royalties (accepted) in intellectual property royalties (paid)
		Antiprotectionism	A_{53}	Proportion of high-tech exports in total commodity exports

Table 3: Weight of S&T cooperation indicators.

Primary indicator	Method i	Method ii	Method iii	Method I	Method II	Secondary indicator	Method i	Method ii	Method iii	Method I	Method II
A_1	0.2248	0.1981	0.2114	0.2114	0.2121	A_{11}	0.1378	0.3143	0.1962	0.2162	0.2166
						A_{12}	0.4459	0.3072	0.4129	0.3886	0.3894
						A_{13}	0.4163	0.3785	0.3909	0.3952	0.3940
A_2	0.3156	0.2997	0.2969	0.3039	0.3005	A_{21}	0.1756	0.2384	0.2035	0.2059	0.2066
						A_{22}	0.4416	0.2204	0.3992	0.3536	0.3559
						A_{23}	0.3122	0.3197	0.2889	0.3069	0.3046
						A_{24}	0.0706	0.2215	0.1085	0.1336	0.1329
A_3	0.2085	0.1797	0.2043	0.1975	0.2021	A_{31}	0.4786	0.3547	0.4089	0.4138	0.4111
						A_{32}	0.3457	0.3646	0.3602	0.3569	0.3576
						A_{33}	0.1757	0.2807	0.2310	0.2293	0.2313
A_4	0.0992	0.1365	0.1147	0.1168	0.1146	A_{41}	0.6274	0.5511	0.5718	0.5833	0.5805
						A_{42}	0.3726	0.4489	0.4282	0.4167	0.4195
A_5	0.1519	0.1860	0.1726	0.1705	0.1707	A_{51}	0.5133	0.2751	0.4449	0.4109	0.4114
						A_{52}	0.1777	0.2915	0.2213	0.2303	0.2310
						A_{53}	0.3089	0.4334	0.3338	0.3588	0.3576

[1]In Table 3, method i is the entropy method; method ii is the critic method; method iii is the coefficient of variation method; method I is the game theory combinatorial weighting method; method II is the cross-entropy combinatorial weighting method.

Table 4: Scoring table for risk assessment of S&T cooperation.

	A_{11}	A_{12}	$A_{13} \sim A_{52}$	A_{53}
China	0.2	0.2	⋯	0.78
Japan	0.68	0.1	⋯	0.77
Korea	0.7	0.5	⋯	0.8
Australia	0.78	0.22	⋯	0.66
New Zealand	0.44	0.2	⋯	0.56
Malaysia	0.22	0.2	⋯	0.52
Indonesia	0.6	0.3	⋯	0.5
Thailand	0.7	0.4	⋯	0.51
Singapore	0.5	0.3	⋯	0.45
Viet Nam	0.8	0.4	⋯	0.2
The Philippines	0.9	0.45	⋯	0.23

Table 5: China's secondary indicator cloud model.

Indicator	Cloud model
A_{11}	(0.2100, 0.1588, 0.0547)
A_{12}	(0.3133, 0.1916, 0.0111)
A_{13}	(0.0900, 0.0953, 0.0085)
A_{21}	(0.3000, 0.2089, 0.1178)
A_{22}	(0.2780, 0.1334, 0.0800)
A_{23}	(0.3420, 0.1955, 0.0891)
A_{24}	(0.2527, 0.2234, 0.0978)
A_{31}	(0.2600, 0.1136, 0.0376)
A_{32}	(0.1547, 0.1107, 0.0110)
A_{33}	(0.2133, 0.1977, 0.0681)
A_{41}	(0.3900, 0.2640, 0.0627)
A_{42}	(0.3407, 0.2783, 0.1035)
A_{51}	(0.3100, 0.1253, 0.0471)
A_{52}	(0.2407, 0.1279, 0.0605)
A_{53}	(0.2867, 0.1370, 0.0729)

3.4. Comprehensive Evaluation of the Risks of S&T Cooperation in RCEP Countries. This paper divides the 11 countries into 3 categories based on the size of their GDP per capita in 2019 in order to comprehensively study the risk profile of S&T cooperation among the 11 RCEP member countries: countries with a high level of development, countries with a medium level of development, and countries with a low level of development. Japan, Australia, and Singapore are the only three nations with a high level of development. China, Korea, New Zealand, and Malaysia are the four nations with a medium level of development. Thailand, Indonesia, Vietnam, and the Philippines are the four nations with a low level of development. These three categories of countries are examined separately.

For the three countries with a high level of development, the integrated cloud models are $C_J\,(0.3472, 0.0303, 0.0101)$, $C_A\,(0.3840, 0.0277, 0.0103)$, and $C_S\,(0.3126, 0.0274, 0.0075)$. A comparison between the integrated cloud and the standard cloud was achieved using MATLAB, and the results are given in Figure 2, where the black part is the standard cloud model, and the red part is the integrated cloud model, which will not be repeated.

Among them, Figure 2(a) shows the cloud map of risk evaluation of S&T cooperation in Japan, Figure 2(b) shows the cloud map of risk of S&T cooperation in Australia, and Figure 2(c) shows the cloud map of risk evaluation of S&T cooperation in Singapore. It can be found that the fogging of the composite cloud map is not obvious for all three countries, the cloud drops are more concentrated, i.e., En and He are smaller, and the differences in their risk perceptions among experts are not obvious. For Japan, the cloud droplets are mainly distributed between 0.22 and 0.42, with a risk expectation of 0.3472; for Australia, the cloud droplets are mainly distributed between 0.28 and 0.48, with a risk expectation of 0.384; for Singapore, the cloud droplets are mainly distributed between 0.22 and 0.42, with a risk expectation of 0.3126. In other words, Japan, Australia, and Singapore are all in the " lower risk to medium risk" category. However, it is easy to observe that the risk ranking of those countries is Singapore < Japan < Australia.

For the four countries with a medium level of development, the integrated cloud model is $C_C\,(0.2666, 0.0287, 0.0103)$, $C_K\,(0.4158, 0.0312, 0.0082)$, $C_N\,(0.4863, 0.0294, 0.0084)$, and $C_M\,(0.4176, 0.0269, 0.01)$, respectively, which is similar to the risk assessment of S&T cooperation for countries with a higher level of development, can be obtained from the cloud map of S&T cooperation risk assessment for each country as shown in Figure 3.

Among them, Figure 3(a) shows the risk evaluation cloud map of China's S&T cooperation, Figure 3(b) shows the risk cloud map of Korea's S&T cooperation, Figure 3(c) shows the risk evaluation cloud map of New Zealand's S&T cooperation, and Figure 3(d) shows the risk evaluation cloud map of Malaysia's S&T cooperation. It can be found that the fogging of the composite cloud maps of these four countries is not obvious, the cloud droplets are more concentrated, i.e., En, He is small, and the differences in their risk perceptions by experts are not obvious. For China, the cloud drops are mainly distributed between 0.18 and 0.40, with an expectation of 0.2666; for Korea, the cloud drops are mainly distributed between 0.28 and 0.54, with an expectation of 0.4158; for New Zealand, the cloud drops are mainly distributed between 0.24 and 0.48, with an expectation of 0.4863; for Malaysia, the cloud drops are mainly distributed between 0.30 and 0.50, with a risk expectation of 0.4176. That means, Korea, Malaysia, and New Zealand are at "medium risk to lower risk" and China is at "lower risk to low risk." It is easy to find that the ranking of the risk of S&T cooperation of those countries is China < Korea < Malaysia < New Zealand, and the difference between the risk of S&T cooperation of Korea and Malaysia is less pronounced.

For the four countries with lower levels of development, the integrated cloud models are $C_T\,(0.4849, 0.0262, 0.0084)$, $C_I\,(0.4724, 0.0299, 0.0078)$, $C_V\,(0.4932, 0.0326, 0.0099)$, and $C_P\,(0.5522, 0.0302, 0.01)$. Similar to the above, the risk evaluation cloud for each country can be obtained as shown in Figure 4.

Among them, Figure 4(a) shows the risk evaluation cloud of Thailand for S&T cooperation, Figure 4(b) shows the risk cloud of Indonesia for S&T cooperation, Figure 4(c) shows the risk evaluation cloud of Vietnam for S&T cooperation, and Figure 4(d) shows the risk evaluation cloud of the Philippines for S&T cooperation. It can be found that, similar to the countries mentioned previously, the

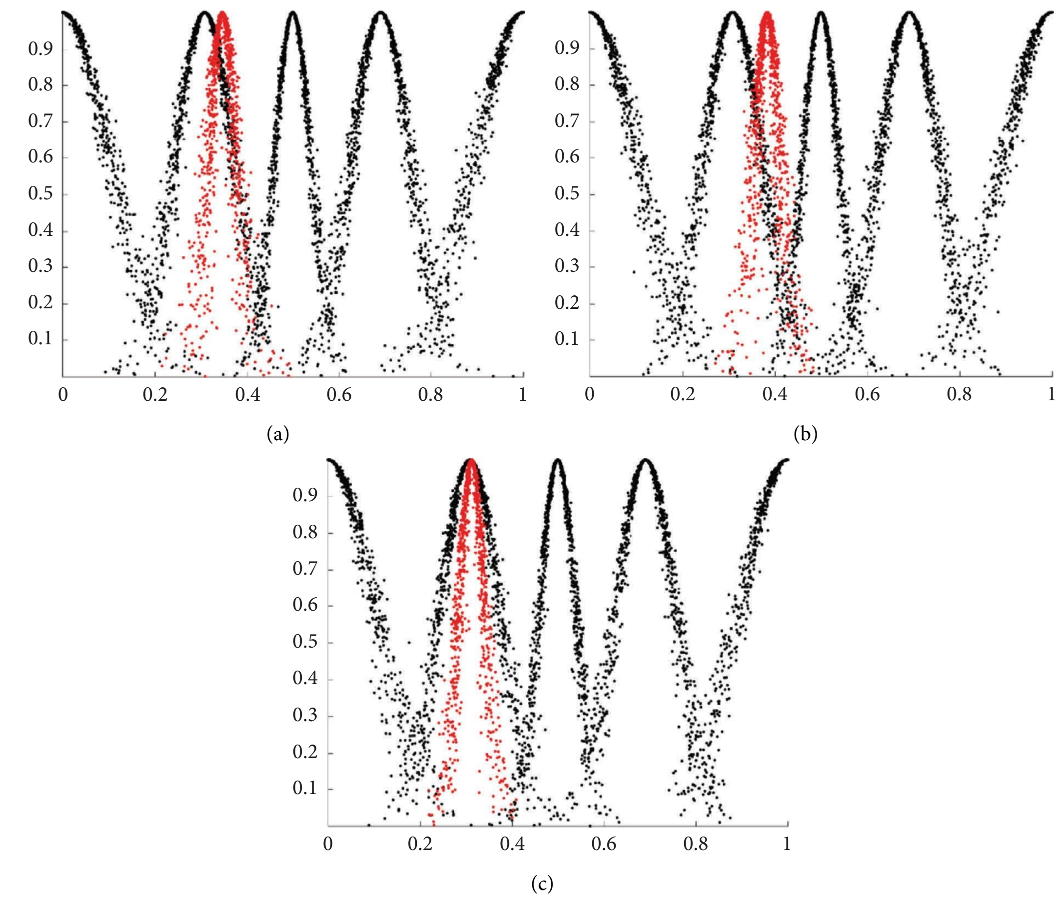

Figure 2: Cloud map of risk assessment of S&T cooperation in countries with high levels of development: (a) Japan, (b) Australia, and (c) Singapore.

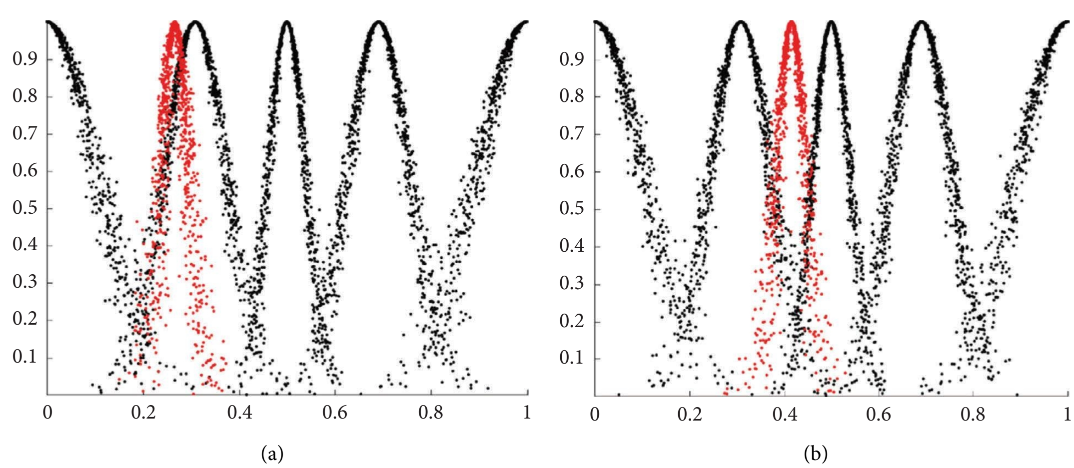

Figure 3: Continued.

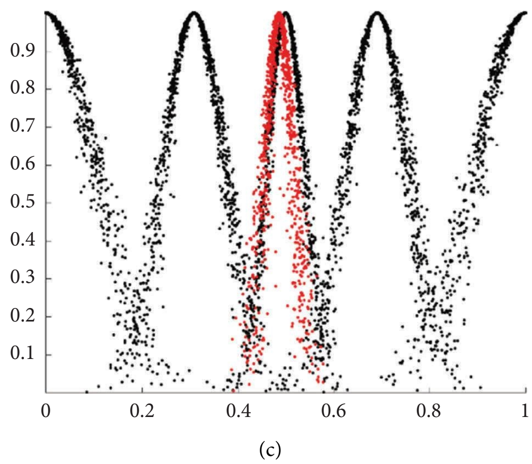

Figure 3: Cloud chart for risk assessment of S&T cooperation in midlevel development countries: (a) China, (b) Korea, (c) New Zealand, and (d) Malaysia.

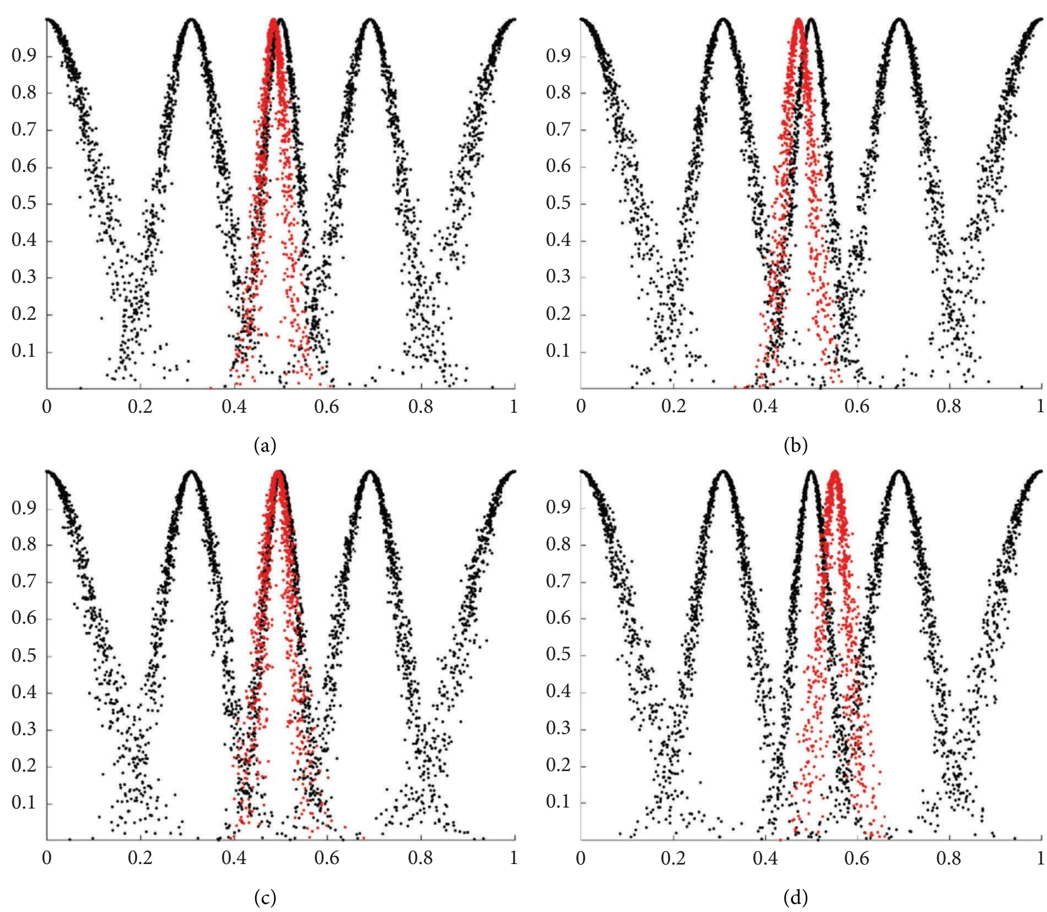

Figure 4: Cloud map of risk assessment of S&T cooperation in low development countries: (a) Thailand, (b) Indonesia, (c) Vietnam, and (d) Philippines.

differences in risk perceptions among experts for these four countries are not significant. For Thailand, the cloud drops are mainly distributed between 0.38 and 0.60, with a risk expectation of 0.4849; for Indonesia, the cloud drops are mainly distributed between 0.36 and 0.59, with a risk expectation of 0.4724; for Vietnam, the cloud drops are mainly distributed between 0.33 and 0.62, with a risk expectation of 0.4932; for the Philippines, the cloud drops are mainly distributed between 041 and 0.65, with a risk expectation of 0.5522. Both Thailand and Indonesia are at "medium risk to lower risk," Vietnam is at "medium risk," and the Philippines is at "medium to higher risk." It is easy to see that for these four countries with a low level of development, the ranking of the risk of S&T cooperation in each country is Indonesia < Thailand < Vietnam < Philippines.

4. Conclusions

RCEP, the largest free trade agreement in the world, is of great significance to the world economy and trade. In addition to the common economic and trade cooperation, the newly introduced cooperation on intellectual property and technology in RCEP is more remarkable, among which the key issue in cooperation is choosing the cooperation partner. A risk assessment index system for S&T cooperation was constructed from a total of five aspects: economics, politics, culture, society, and technology. The weights obtained from the entropy method, CRITIC method, as well as coefficient of variation method were combined through the cross-entropy combination weighting method to ensure the scientific nature of the indicator assignment. On this basis, the cloud model was introduced, and the standard cloud model was constructed by using the golden ratio, and by calculating the parameters of the integrated cloud model, the cloud diagram was drawn and compared with the standard cloud diagram to draw the following conclusions:

(1) Compared with the common game theory combination weighting method, the cross-entropy combination weighting method is not only more convenient to calculate but also takes into account the correlation between indicators. At the same time, it is found that the cross-entropy combination weighting method is effective through the empirical research.

(2) Based on the construction of a system of S&T cooperation risk indicators, the cross-entropy combination weighting method was used to assign weights to the five major types of risks, namely political risk, economic risk, social risk, cultural risk, and technological risk. Economic risks have the greatest impact on national scientific and technological cooperation risks as well as cultural risks the least. In terms of political risks, political stability and corruption are more significant; in terms of economic risks, economic volatility has the biggest influence; in terms of social risks, the state of human development, which represents the economic, social, and cultural development of each nation, cannot be disregarded; in terms of cultural risks, religion also plays a significant role in S&T cooperation because of the diversity of religions and cultures in South and Southeast Asia. In terms of technological risks, the independent innovation capacity of each country is an important factor interfering with the choice of countries.

(3) By constructing a cloud model and using MATLAB to compare the comprehensive cloud map of each country with the standard cloud map, it can be found that the 11 member countries are divided into three categories of countries with high, medium, and low levels of development according to their GDP per capita, and except for China, there is not much difference between the risks of each category of countries. The study finds that the risk of S&T cooperation is highest in countries with low levels of development, second highest in countries with medium levels of development, and lowest in countries with high levels of development. This means that it can be inferred that the risk of S&T cooperation in each country has a negative correlation with the development of that country. For the 11 RCEP members covered in this paper, except for China and the Philippines, their risks fluctuate between low and medium risk, with China's S&T cooperation risk at "low risk to low risk" and the Philippines' S&T cooperation risk at "high risk to medium risk."

There are some subjective limitations in the indicator formulation process of this paper as well as ideal to deal with the relationship between some indicators and risks. Therefore, it is one of our future research works to prove the rationality of the proposed international S&T cooperation risk index system from a statistical perspective. In addition, the simple interpolation method for processing missing data has some errors. Choosing more scientific methods to deal with missing data is also one of our future research works.

Data Availability

The basic data of this article can be downloaded from the official website of the World Development Indicators of the World Bank. The data supporting the results of this study can be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (71163046); the National Social Science Fund of China (16ZDA041); Yunnan Provincial Natural Science Foundation (2018RD004).

References

[1] J. M. Andric, J. Wang, P. X. Zou, J. Zhang, and R. Zhong, "Fuzzy logic-based method for risk assessment of Belt and Road infrastructure projects," *Journal of Construction Engineering and Management*, vol. 145, no. 12, pp. 04019082–04019082.12, 2019.

[2] Y. Wu, J. Wang, S. Ji, and Z. Song, "Renewable energy investment risk assessment for nations along China's Belt and Road Initiative: an ANP-cloud model method," *Energy*, vol. 190, Article ID 116381, 2020.

[3] J. Yuan, X. Li, C. Xu, C. Zhao, and Y. Liu, "Investment risk assessment of coal-fired power plants in countries along the

Belt and Road initiative based on ANP-Entropy-TODIM method," *Energy*, vol. 176, pp. 623–640, 2019.

[4] J. Li, X. Dong, Q. Jiang, and K. Dong, "Analytical approach to quantitative country risk assessment for the Belt and Road initiative," *Sustainability*, vol. 13, no. 1, p. 423, 2021.

[5] Y. Sun, L. Chen, H. Sun, and F. Taghizadeh-Hesary, "Low-carbon financial risk factor correlation in the Belt and Road PPP project," *Finance Research Letters*, vol. 35, Article ID 101491, 2020.

[6] Y. Wu, C. Xu, L. Li, Y. Wang, K. Chen, and R. Xu, "A risk assessment framework of PPP waste-to-energy incineration projects in China under 2-dimension linguistic environment," *Journal of Cleaner Production*, vol. 183, pp. 602–617, 2018.

[7] J. Dahooie, E. Zavadskas, M. Abolhasani, A. Vanaki, and Z. Turskis, "A novel approach for evaluation of projects using an interval–valued fuzzy additive ratio assessment (aras) method: a case study of oil and gas well drilling projects," *Symmetry*, vol. 10, no. 2, p. 45, 2018.

[8] Y. Wu, J. Zhang, J. Yuan, S. Geng, and H. Zhang, "Study of decision framework of offshore wind power station site selection based on ELECTRE-III under intuitionistic fuzzy environment: a case of China," *Energy Conversion and Management*, vol. 113, pp. 66–81, 2016.

[9] Z. S. Chen, X. Zhang, R. M. Rodríguez, W. Pedrycz, and L. Martínez, "Expertise-based bid evaluation for construction-contractor selection with generalized comparative linguistic ELECTRE III," *Automation in Construction*, vol. 125, Article ID 103578, 2021.

[10] Z. S. Chen, X. Zhang, R. M. Rodríguez, W. Pedrycz, L. Martínez, and M. J. Skibniewski, "Expertise-structure and risk-appetite-integratedtwo-tiered collective opinion generation framework for large scale group decision making," *IEEE Transactions on Fuzzy Systems*, vol. 30, no. 12, pp. 5496–5510, 2022.

[11] Y. Wu, Y. Wang, K. Chen, C. Xu, and L. Li, "Social sustainability assessment of small hydropower with hesitant PROMETHEE method," *Sustainable Cities and Society*, vol. 35, pp. 522–537, 2017.

[12] D. Y. Li, D. R. Varma, and S. Chemtob, "Up-regulation of brain PGE2 and PGF2 alpha receptors and receptor-coupled second messengers by cyclooxygenase inhibition in newborn pigs," *Journal of Pharmacology and Experimental Therapeutics*, vol. 272, no. 1, pp. 15–19, 1995.

[13] Y. Xiong, D. Kong, Z. Cheng, G. Wu, and Q. Zhang, "The comprehensive identification of roof risk in a fully mechanized working face using the cloud model," *Mathematics*, vol. 9, no. 17, p. 2072, 2021.

[14] X. Wang, W. Yang, Z. Xu, J. Hu, Y. Xue, and P. Lin, "A normal cloud model-based method for water quality assessment of springs and its application in jinan," *Sustainability*, vol. 11, no. 8, p. 2248, 2019.

[15] C. Yu, M. Liu, X. Xu, and Y. Shi, "The urban rain-flood risk division based on the cloud model and the entropy evaluation method—taking Changzhou as an example," *Journal of Physics: Conference Series*, vol. 1168, Article ID 032087, 2019.

[16] J. Zhao, G. Ji, Y. Tian, Y. Chen, and Z. Wang, "Environmental vulnerability assessment for mainland China based on entropy method," *Ecological Indicators*, vol. 91, pp. 410–422, 2018.

[17] H. W. Wu, J. Zhen, and J. Zhang, "Urban rail transit operation safety evaluation based on an improved CRITIC method and cloud model," *Journal of Rail Transport Planning and Management*, vol. 16, Article ID 100206, 2020.

[18] Q. Wang, S. Li, and R. Li, "Evaluating water resource sustainability in Beijing, China: combining PSR model and matter-element extension method," *Journal of Cleaner Production*, vol. 206, pp. 171–179, 2019.

[19] H. M. Lyu, W. H. Zhou, S. L. Shen, and A. N. Zhou, "Inundation risk assessment of metro system using AHP and TFN-AHP in Shenzhen," *Sustainable Cities and Society*, vol. 56, Article ID 102103, 2020.

[20] Y. Fang, D. Liu, Y. Liu, and L. Yu, "Comprehensive assessment of gas turbine health condition based on combination weighting of subjective and objective," *International Journal of Gas Turbine, Propulsion and Power Systems*, vol. 11, no. 2, pp. 56–62, 2020.

[21] S. Dai and D. Niu, "Comprehensive evaluation of the sustainable development of power grid enterprises based on the model of fuzzy group ideal point method and combination weighting method with improved group order relation method and entropy weight method," *Sustainability*, vol. 9, no. 10, p. 1900, 2017.

[22] J. Li, H. Fang, and W. Song, "Sustainable supplier selection based on SSCM practices: a rough cloud TOPSIS approach," *Journal of Cleaner Production*, vol. 222, pp. 606–621, 2019.

[23] W. Zhao, C. Xiao, Y. Chai, X. Feng, X. Liang, and Z. Fang, "Application of a new improved weighting method, ESO method combined with fuzzy synthetic method, in water quality evaluation of chagan lake," *Water*, vol. 13, no. 10, p. 1424, 2021.

[24] Z. Lu, C. Wei, M. Liu, and X. Deng, "Risk assessment method for cable system construction of long–span suspension bridge based on cloud model," *Advances in Civil Engineering*, vol. 2019, Article ID 5720637, 9 pages, 2019.