The Interconnected Risks within Green Entrepreneurial Ecosystems

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Abstract. The risk coupling mechanism of green entrepreneurship ecosystem is taken as the research object. Aiming at the characteristics of its fuzzy boundary and incomplete information, the grey relation coupling model is used to empirically analyse the grey relation degree between the risk indicators of the green entrepreneurship ecosystem subsystems and the overall coupling degree of the system from 2016 to 2021 in China. Meanwhile, the grey relation degree of the system is tested for the trend. Finally, three major management insights are drawn to promote the synergistic development of multi-party subjects, improve the utilisation efficiency of industrial construction platforms and maintain the sustainable development of the natural environment. The article provides a reference idea for the vertical green entrepreneurship field and the horizontal risk coupling field of other industries.

Keywords: Green entrepreneurial ecosystems; Risk coupling; Grey relation analysis; Coupling degree; Sustainability

1 Introduction

As environmental problems become more and more prominent and the process of ecological civilisation construction in China continues to advance, how to ensure the maximum optimisation of environmental benefits at the same time as rapid economic growth has become an urgent problem in China. Green entrepreneurship, as a product of the development of the new era, focuses on the entrepreneurial activities of "balancing righteousness and profit", which helps to promote the synergistic development of the economy and the ecological environment, and is regarded as an important driving force of regional entrepreneurship[1], and has become a regular practice of many large-scale enterprises, such as Alibaba's Carbon Neutral Initiative.

In this context, green entrepreneurship is no longer limited to corporate-level behaviour, but has become a key force in promoting the construction of China's ecological civilization. The green entrepreneurial ecosystem is an interacting and co-evolving system of green entrepreneurs and the entrepreneurial ecosystems on which they depend[1]. In the development process of green entrepreneurship ecosystem, due to its high scientific and technological content, the complexity of the main system, the quality of management personnel requires high characteristics, entrepreneurial entity and the environment in which they are located in the high degree of uncertainty, so green entrepreneurship to bring great benefits at the same time, green entrepreneurship ecosystem there are a number of risks,

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including economic risk, market risk, policy risk, technological[2] risk and entrepreneurial environmental risk, and so on. And it should be noted that the risks of the entrepreneurial system often do not exist in isolation from each other, and there is often a coupling relationship between different risk factors, for example, the coupling relationship between technology and the market, the immaturity of technology may lead to products that are difficult to satisfy the market demand, while the low demand of the market may lead to the stagnation of technological development. The main purpose of the research on the system risk coupling mechanism is to deeply understand the nature and characteristics of the mutual influence between different risks of the system, so as to better formulate the risk management strategy, which is conducive to guiding the direction of enterprise innovation and prolonging the life cycle of the enterprise.

There are two pressing issues in green entrepreneurship research that need to be addressed: one is that green entrepreneurship ecosystem risk research is still in the process of exploration in theory and practice at home and abroad, and green entrepreneurship ecosystems have not yet formed a more unified definition; the other is that the current research on green entrepreneurship mainly focuses on the theorisation of entrepreneurial characteristics, entrepreneurial elements, entrepreneurial mechanisms, etc., and the research in the field of green entrepreneurial ecosystem risk is relatively blank, especially in the quantitative research is almost invisible. In view of the above theoretical deficiencies, this study gives a more standardised definition of green entrepreneurship ecosystem on the basis of reviewing the previous literature, and fills in the gaps in the related fields by constructing a risk coupling model for green entrepreneurship ecosystem, which also provides important managerial inspirations for the good development of green entrepreneurship ecosystem.

2 Literature review

2.1 Green entrepreneurship

Since the industrial revolution, the "brutal" entrepreneurial development model of industrial enterprises in various countries has caused great damage to the Earth's environment and reduced the sustainability of economic development, and the climate problems of the twenty-first century have been significant, with global warming, the destruction of forests and vegetation, and frequent natural disasters posing a serious threat to the future of humankind[3]. In the past five years, research related to green development and entrepreneurial ecosystems has shown explosive growth[4], Tang Yi[5] expressed green entrepreneurship as meeting market demand through eco-innovation and realising co-benefits in terms of economics and non-economics, Li Huajing[6] systematically introduced the innovation value, innovation mechanism, and innovation outlook of green entrepreneurial ecosystems, Kai Hockerts and Rolf Wüstenhagen[7] proposed that startups and market occupiers each play a role in the transformation process to industrial sustainability, and the studies of Andreoni and Levinson[8], Wang Min and Ying Huang[9], etc. pointed out that technological progress is an important and effective means of solving environmental pollution problems in the long term.

According to ecosystem theory, organisms and their natural environment are inseparable, and the two form a homogeneous whole, i.e. ecosystem, through the interaction of matter and

energy. The study of entrepreneurial ecosystem is a cross-cutting theory derived from the combination of ecosystem-related theories and modern social systems, with the help of ecological metaphors to realise the in-depth deconstruction of the connotation and extension[10]. The concept of entrepreneurial ecosystem research was firstly proposed by Cohen in 2006, and Cai Li et al. have continuously enriched and improved the conceptual system, which can be expressed as a community formed by interacting entity (government, investment institutions, enterprises, etc.) in a specific region (policy incentives, talent pool, culture and other elements of entrepreneurial environment)[11], [12].

As for the green entrepreneurship ecosystem, its connotation can be regarded as the fusion of green entrepreneurship and entrepreneurship ecosystems, which is characterised by the intersection of multiple disciplines, etc.[4]. According to Li Huajing[6], the green entrepreneurial ecosystem can be added to the entrepreneurial ecosystem to express: the entrepreneurial entity and the entrepreneurial environment to form an interaction, and to improve the level of entrepreneurial activity and its contribution to sustainable development. It can be seen that the green entrepreneurship ecosystem places more emphasis on greenness than the entrepreneurship ecosystem and can achieve the mutual promotion of economy and ecological civilisation, which can be roughly represented in Figure 1. This paper defines a green entrepreneurial ecosystem as a cluster of interacting entity (government, investment institutions, enterprises, etc.) in a specific region (i.e., the environment of entrepreneurship, influenced by policy systems, macroeconomics, and other elements) with the goal of achieving economic and ecological benefits.

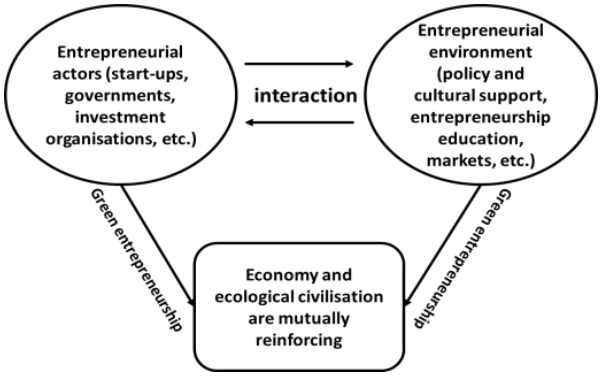

Fig. 1. Conceptual map of green entrepreneurship ecosystems.

2.2 Entrepreneurial risk management and coupling mechanisms

2.2.1 Entrepreneurship risk management

Entrepreneurial risk management is a key aspect in the field of entrepreneurship. The behaviour of entrepreneurs in discovering or predicting risk factors and their possible outcomes by applying various methods before a risky event is risk identification[2], and effective risk identification can provide a basis for decision-making prior to risk management.

Nowadays, most of the risk management models for entrepreneurial enterprises through brainstorming, interviews, Delphi techniques and literature research[13], such as selecting

appropriate indicators from the dimensions of financial risk, jurisdictional risk, technological risk and market risk[14] after the use of expert research, factor analysis methods[15], and other methods to build a review system, during which or will continue to make use of big data analysis[16], multivariate models, machine learning and other methods to further quantitatively assess the size of the risk, and then set a number of risk level boundaries based on the specific model data, according to which to judge the risk level of the enterprise, and in addition, there are also a part of scholars who use the questionnaire-based empirical research to assess the risk of entrepreneurship[17] .

2.2.2 Coupling mechanism

The theory of coupling mechanisms has its origins in physics, and is used to describe the way in which two or more systems or factors work together to build a new and complete system, and reach a state that no single system can reach.

Many scholars have invested in the theoretical and empirical research on the coupling system of various industries in reality, for example, Wang Junling[18] et al. researched the coupling mechanism between technological innovation and economic growth in China's iron and steel industry. Qi Zhenhong[19] et al. studied the symbiotic coupling mechanism of carpet agro-ecological industry chain under the perspective of game interaction mechanism.

In the coupling mechanism research, the past are focused on the economy and the environment or industry ecological coupling and coordinated development, in the risk of the coupling mechanism is more scarce, this paper based on the actual situation targeted to take the grey relation coupling model quantitative green entrepreneurial ecosystem risk coupling mechanism research.

3 Structure and risk coupling mechanisms of green entrepreneurial ecosystems

3.1 Green entrepreneurship

In a green entrepreneurial ecosystem, the core enterprise of green entrepreneurship is the cornerstone of green entrepreneurship, which is closely connected with other green entrepreneurial entity through green supply chain and green entrepreneurship network, and participates in the whole process of green product development. In the green supply chain, upstream and downstream enterprises and competing and cooperating enterprises provide the core enterprise with raw materials, competitive pressure and effective cooperation resources to promote the development of green entrepreneurship.

In the green entrepreneurship ecosystem, the natural environment is the core element, and environmental pressures have led to increased demands and catalysed green entrepreneurship. The market environment is mainly market demand and market competition, and a good market environment plays a significant role in the sound operation of the green entrepreneurship ecosystem. In addition, the policy environment greatly determines the direction of the entrepreneurial ecosystem, which can inspire the promotion of green entrepreneurship development, and guarantee the stable development of the whole system. It can stimulate and

promote the development of green entrepreneurship and guarantee the stable development of the whole system.

3.2 Mechanisms of operation of risk-coupled systems

The mechanisms of risk will be understood here in terms of its generation and development, as shown in Figure 2. Risk elements are initially generated and can be translated into risk indicators to be measured and assessed, and over time, some risk elements interact with each other and form coupling effects, which increase or generate risky accidents and bring losses to the entire entrepreneurial ecosystem. Such losses may lead to deviations in system benefits from initial projections. Over time, different risk elements can interact with each other and form coupling effects, which can increase or generate risky incidents and bring losses to the entire entrepreneurial ecosystem. Such losses can lead to deviations in system benefits from initial expectations, which can be corrected by continuous feedback from deviations in expectations brought about by incidents in the system.

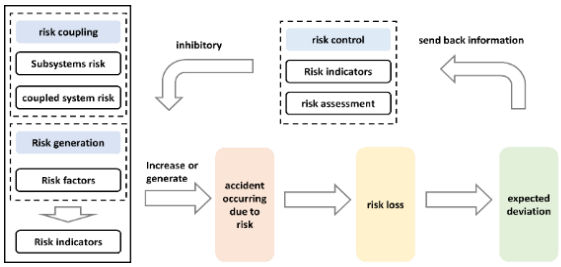

Fig. 2. Risk warning and control.

4 Coupled risk modelling of green entrepreneurial ecosystems

4.1 Coupling degree evaluation index system

The coupling degree of green entrepreneurship ecosystem entrepreneurship entity and entrepreneurial environment risk is mainly used to reflect the degree of synchronisation and mutual influence of the risk of the two systems, so the evaluation of the coupling degree of the overall risk of the system is evaluated in the context of the level of development of the two subsystems. As the green entrepreneurial ecosystem related research has not yet been perfected, many measurement indicators related research is still less, this paper combines part of the literature, the National Bureau of Statistics, the Ministry of Ecology and Environment of the People's Republic of China, and the data indicators of various government departments and research reports, constructed the green entrepreneurial ecosystem entrepreneurship entity subsystem and entrepreneurial environment subsystem coupling degree evaluation indicators, as shown in Table 1.

Indicators are selected on the basis of the following:

(1) Entrepreneurial entity subsystem risk development indicators. Green entrepreneurial entities can be seen as consisting of producers, green supply chain networks, and consumers. Based on the positioning of entrepreneurial roles, corresponding indicators are selected to

represent their development. Producers are mainly responsible for researching and developing theories and related technologies, and producing results. Their technology research and development situation, R&D funds, and personnel investment are key points; The supply chain network is responsible for the commercialization of entrepreneurial achievements, including technology transformation and product production. Its technical contract transaction amount and the enterprise's production capacity (as reflected by the total amount of fixed assets investment) are key indicators; The use and purchase of products by consumers play a feedback role in the overall ecosystem experience, so the number of WeChat reports in the ecological environment system is selected as its reflection indicator.

(2) Entrepreneurial environment subsystem development indicators. Entrepreneurial environment elements mainly include market environment, natural environment, policy environment and economic environment. Among them, sustainable development is the core objective, which is specifically reflected in the natural environment risk, and is represented by using the investment funds for environmental pollution control, the number of environmental emergencies, and the number of enterprises carrying out mandatory cleaner production audit and evaluation nationwide. As the green industry is more extensive, the specific market is difficult to measure, so the energy-saving service industry as a representative of the characterisation, and the number of energy-saving service industry enterprises to reflect the competitive environment of the market. During the operation and development of the green entrepreneurial ecosystem, it will be entity to many relevant environmental protection policy constraints, in order to protect the ecosystem for more rational development, the number of local environmental protection standards and the number of national people's congress recommendations are selected as indicators. Finally, the national GDP per capita and gross domestic product are used to represent the economic environment.

Table 1. Green entrepreneurship ecosystem risk coupling evaluation index system.

Primary Indicator	Secondary indicator	Tertiary indicator
Green entrepreneurial entity subsystem risk level	Green Technology R&D RisksX_1	Green patent applications (number)
	Enterprise R&D funding riskX_2	R&D investment by industrial enterprises above designated size (billion yuan)
	Corporate R&D personnel investment risk X_3	Number of R&D personnel (10,000)
	Risks related to the application of technology in the green sector X_4	Transaction value of technology contracts (in billions of yuan)
	Enterprise production and construction risks X_5	Total investment in fixed assets (billion yuan)
	Government technology R&D support risk X_6	National financial expenditure on science and technology (billion yuan)
	Consumer risk X_7	Number of WeChat reports on the national eco-environmental system (times)
Level of risk in the green entrepreneurial	Market environment risk X_8	Number of enterprises in the energy-saving services industry (number)
	Policy environment risk	Local environmental protection standards

Primary Indicator	Secondary indicator	Tertiary indicator
environment subsystem	X_9、X_{10}	(projects) Number of NPC recommendations undertaken (number)
	Economic environment risk X_{11}、X_{12}	National GDP per capita (million yuan) Gross Domestic Product ($bn)
	Sustainability risk (natural environment risk)X_{13}、X_{14}、X_{15}	Total investment in environmental pollution control (billion yuan) Number of environmental emergencies (times) Number of enterprises assessed for mandatory cleaner production audits nationwide (nos.)

The sources of data for the above indicators are the website of the National Bureau of Statistics, the website of the State Intellectual Property Office, the National Eco-Environment Report, the website of the Ministry of Ecology and Environment of the People's Republic of China, and data on relevant indicators from 2016 to 2021 compiled from online sources.

4.2 Grey relation coupling model

Grey relation coupling model is a kind of analysis method based on grey system theory, which does not require a high number of samples and does not need a typical distribution law[20], and it can be used to analyze the degree of correlation between multiple factors and their influence on a certain goal, which is suitable for the study of coupling relationship between systems with a small number of samples and fuzzy boundaries in this paper. Its main idea is to find out the degree of correlation between factors and their influence on the target by analyzing and processing uncertain and incomplete information, so as to make a decision.

The grey relation coupling model is selected to calculate the grey relation degree and system coupling degree of the risk indicators of the entrepreneurship entity subsystem and entrepreneurial environment subsystem, so as to study the current situation and coupling status of the interaction and connection between the two systems, and the specific calculation steps are as follows:

(1) Determination of the analyzed series (reference and comparison series)

The reference sequence is the development indicator of the entrepreneurship entity subsystem, denoted by $Y_j(t)$ （j =1，2，…，m），where j is the jth indicator of the reference sequence, which denotes the value of the development indicator in year t. The comparison sequence is the development indicators of the entrepreneurial environment subsystem, denoted by $X_i(t)$ （i =1，2，…，n），where i is the ith indicator of the comparison sequence, denoting the development indicator data in year t.

(2) Pre-processing of variables

The raw sequence data is normalized to remove the effects of magnitude and direction.

$$\mathrm{Y_j'(t)} = \frac{\mathrm{Y_j(t)}}{\overline{\mathrm{Y_j(t)}}} \tag{1}$$

$$X'_j(t) = \frac{X_j(t)}{\overline{X_j(t)}} \tag{2}$$

Where $\overline{X_j(t)}$, $\overline{Y_j(t)}$ are the average values of the ith entrepreneurial entity risk indicator and the jth entrepreneurial environment subsystem risk indicator, respectively.

(3) Computed sequence of differences (math.)

The indicator series data for the corresponding years are subtracted and absolute values are taken to obtain the difference series, denoted by $\Delta ij(t)$.

$$\Delta_{ij}(t) = \left|Y_{jt}(t) - X_{jt}(t)\right| (i = 1,2,\dots,n; j = 1,2,\dots,m; t = 1,2,\dots,k) \tag{3}$$

(4) Calculate the grey relation coefficient

The grey relation coefficient $rij(t)$ is used to measure the degree of correlation between the ith indicator in the entrepreneurial environment subsystem and the jth indicator in the entrepreneurial entity subsystem at year t, where ρ denotes the discrimination coefficient, which is usually taken to be 0.5, and $minmin$ and $maxmax$ stand for the two-pronged minimal differences, respectively and bipolar maximum difference, respectively.

$$r_{ij}(t) = \frac{minmin\left|\Delta_{ij}(t)\right| + \rho maxmax\left|\Delta_{ij}(t)\right|}{\left|\Delta_{ij}(t)\right| + \rho maxmax\left|\Delta_{ij}(t)\right|} \tag{4}$$

(5) Calculate the inter-subsystem correlation matrix

The inter-subsystem correlation matrix $Rij(t)$ is obtained by pooling the values of different time points into one, i.e., averaging the values of different years to obtain a matrix of correlations between the subsystems $Rij(t)$ where $ii$and j denote the indicator sequences of the two subsystems, respectively.

$$R_{ij}(t) = \frac{1}{t\sum_{t=1}^{k} r_{ij}(t)} \tag{5}$$

(6) Calculate the system coupling

The system coupling degree $C(t)$ is used to measure the degree of system coupling between the entrepreneurial agent and the entrepreneurial environment at year t, which is obtained by averaging the matrix of correlations between the subsystems, where m and n are the number of indicators for the two subsystems, respectively.

$$C(t) = \frac{1}{m * n}\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}(t) \tag{6}$$

According to related research, when $0 < C(t) \leq 0.3$, it indicates that the two subsystems risk coupling is in the state of low disordered coupling; when $0.3 < C(t) \leq 0.5$ it indicates that the two subsystems risk coupling belongs to the medium degree of coupling, and it is in the state of basic disjointedness; when $0.5 < C(t) < 0.8$, it indicates that the two subsystems risk coupling is in the stage of benign coupling. When $0.8 < C(t) < 1$, it indicates that the two subsystems risk coupling is in a highly coupled state.

4.3 Grey relation trend test model

This paper utilizes the trend test coefficient[21] to calculate and observe trends in risk coupling.

Definition 4.1 Let there be two sets of one-dimensional sequences respectively: $X_i = \left(x_i(1), x_i(2), \ldots, x_i(n)\right)^T$ 、 $X_j = \left(x_j(1), x_j(2), \ldots, x_j(n)\right)^T$. The feature difference between sequences X_i and X_j at position k is:

$$r_{ij}(k) = |x_i(k) - x_i(k)| = \left|s_{ij}(k)\right| \tag{7}$$

Then the sequence of characteristic differences is:

$$R_{ij} = |S_{ij}| \tag{8}$$

Definition 4.2

The characteristic difference series R_{ij} is shown in Definition 4.1, and the basic form of the trend test is: $\mathrm{r_{ij}(k)} = \mathrm{ak} + \mathrm{b}$, which is satisfied by the least squares estimate:

$$\begin{cases} \hat{a} = \dfrac{12\sum_{k=1}^{n} k r_{ij}(k) - 6(n+1)\sum_{k=1}^{n} r_{ij}(k)}{n(n+1)(n-1)} \\ \hat{b} = \dfrac{1}{n}\sum_{k=1}^{n} r_{ij}(k) - \dfrac{\hat{a}}{2}(n+1) \end{cases} \tag{9}$$

$\hat{a}$ is the trend test coefficient of the sequences X_i and X_j about grey relation, which reflects the trend of sequence correlation change. When $\hat{a} = 0$, it means that there is a tendency to remain constant between the sequences; when $\hat{a} > 0$, it means that there is a tendency to increase between the characteristic difference sequences and a tendency to decrease the relationship between the sequences, and vice versa.

5 Empirical results and analyses

5.1 Grey relation and system coupling between entrepreneurial entity and entrepreneurial environment

In this paper, the data are first pre-processed, the specific steps are as follows: first calculate the average value of each indicator, and then divide the value of each element in the indicator by the average value, the standardised data are shown in Table 2.

Table 2. Standardised data on risk indicators, 2016-2021.

Systems	Indicator	year					
		2016	2017	2018	2019	2020	2021
Level of risk in the green entrepreneurial entity subsystem	X_1	0.8275	1.0518	1.1851	1.0434	1.2130	0.6792
	X_2	0.8123	0.8916	0.9648	1.0369	1.1334	1.1610
	X_3	0.8295	0.8629	0.9371	1.0270	1.1198	1.2236
	X_4	0.5246	0.6173	0.8138	1.0300	1.2992	1.7150

Systems	Indicator	year					
		2016	2017	2018	2019	2020	2021
Level of risk in the green entrepreneurial environment subsystem	X_5	0.8566	0.9303	0.9851	1.0383	1.0684	1.1212
	X_6	0.7828	0.8666	0.9930	1.1294	1.0754	1.1529
	X_7	0.3773	0.7418	1.4334	1.1232	1.3258	0.9985
	X_8	0.8572	0.9045	0.9490	0.9649	1.0385	1.2859
	X_9	0.8246	0.6825	1.4218	1.0237	1.2370	0.8104
	X_{10}	1.2686	1.2881	1.0456	1.1518	0.6567	0.5891
	X_{11}	0.8026	0.8891	0.9771	1.0457	1.0711	1.2143
	X_{12}	0.7912	0.8854	0.9782	1.0497	1.0785	1.2170
	X_{13}	0.9700	1.0036	0.9456	0.9629	1.1193	0.9986
	X_{14}	1.1692	1.1615	1.1000	1.0038	0.8000	0.7654
	X_{15}	0.5955	1.0565	0.7980	0.9293	1.2764	1.3443

Construct a sequence of entrepreneurial entity subsystems and entrepreneurial environment subsystems from the data values in the above table. X_1=（0.8275，1.0518，1.1851，1.0434，1.2130，0.6792），…，X_{15}=（0.5955，1.0565，0.7980，0.9293，1.2764，1.3443）. The grey relation degree matrix and sub-system coupling of indicators between entrepreneurial entities and entrepreneurial environment sub-systems can be obtained by bringing them into the data formula of grey relation and coupling, and using Matlab to calculate.

Table 3. Relation degree between entrepreneurship entity and each risk indicator of entrepreneurial environment.

	green entrepreneurial environment subsystem							
	Indicator	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
green entrepreneurial entity subsystem	X_1	0.67	0.78	0.61	0.72	0.71	0.71	0.70	0.66
	X_2	0.84	0.68	0.51	0.93	0.92	0.79	0.57	0.65
	X_3	0.87	0.70	0.51	0.92	0.92	0.80	0.58	0.68
	X_4	0.72	0.73	0.54	0.73	0.73	0.68	0.59	0.82
	X_5	0.85	0.64	0.51	0.90	0.88	0.78	0.59	0.60
	X_6	0.80	0.62	0.55	0.91	0.92	0.72	0.55	0.60
	X_7	0.61	0.79	0.53	0.65	0.66	0.66	0.56	0.64

The results in Table 3 show that the role of risk coupling is more obvious: grey relation degree between the risk elements of the two subsystems is between (0.5, 0.95), and there is a more obvious correlation between the risks, indicating that attention should be paid to good deployment of preventive work in the development of the system.

Table 4. Intersystem coupling degree.

year	2016	2017	2018	2019	2020	2021
system coupling degree	0.6742	0.6924	0.7224	0.8431	0.7077	0.5894

As can be seen from the data in Table 4, the risk coupling between entrepreneurial entities and the entrepreneurial environment sub-system over the years is between 0.5 and 0.9, which is in the range of medium to high coupling. It should be noted here that a high risk coupling represents a high degree of cooperation between systems, although risks can easily affect each other, for example, policy risk leads to increased technology risk, but it also means that technology is more likely to evolve in harmony with well-coordinated policies.

5.2 Analysis of factors influencing the coupling of entrepreneurship entityand entrepreneurial environment

On the basis of the calculation of the coupling degree between subsystems in the previous section, this section adopts grey relation analysis to further analyse in depth the influencing factors of the coupling degree between subsystems.The numerical size of the grey relation degree represents the degree of positive correlation on the influence of the whole system, the larger the value is, the larger the degree of influence of the index on the system as a whole is.

(1) Taking the coupling degree between the green entrepreneurial entity subsystem and the entrepreneurial environment subsystem as the reference sequence, and taking the entrepreneurial entity subsystem risk indicator as the comparison sequence, use formula 4-1 to 4-5 to calculate the grey relation degree between the reference sequence and the comparison sequence, and the results of the calculation are shown in Table 5.

Table 5. Grey relation degree of green entrepreneurship entity-system coupling degree

	indicator	relation degree	Ranking
Entrepreneurship entity Subsystem	X_1	0.7808	4
	X_2	0.7835	3
	X_3	0.7659	5
	X_4	0.5834	7
	X_5	0.8349	1
	X_6	0.8191	2
	X_7	0.6485	6

The sorting of grey relational degrees in the table indicates that special attention should be paid to the risk of enterprise production and construction development: X_5 (enterprise production and construction strength (fixed asset investment) has the most significant impact on the overall coupling degree of the entrepreneurial ecosystem, and fixed assets are the power foundation of the ecosystem.

(2) The same steps to calculate the grey correlation between the green entrepreneurial environment and the system coupling get Table 6.

Table 6. Grey relation degrees between green entrepreneurial environment and system coupling degree

	Indicator	relation degree	Ranking
entrepreneurial environment subsystem	X_8	0.7925	3
	X_9	0.7253	7
	X_{10}	0.7301	6
	X_{11}	0.7964	2
	X_{12}	0.7917	4
	X_{13}	0.8524	1
	X_{14}	0.7717	5
	X_{15}	0.6498	8

From Table 6, it can be concluded that the focus should be on sustainable development: sustainable development, especially environmental pollution control (X_{13}), has the greatest impact on the overall coupling of the system, and a favourable ecological environment should be actively created.

5.3 Testing the grey relation degree between entrepreneurship entity and entrepreneurial environment

In this section, we perform a trend test on the results of the calculations in the previous section.

Table 7. Trend test for green entrepreneurial entity and green entrepreneurial environment

	green entrepreneurial environment subsystem							
	Indicator	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
green entrepreneurial entitysubsystem	X_1	0.08	-0.02	-0.02	0.07	0.06	0.02	-0.01	0.06
	X_2	0.02	0.03	0.02	0.01	0.01	-0.01	0.01	-0.01
	X_3	0.01	0.04	0.03	-0.001	-0.003	0.002	0.01	-0.02
	X_4	0.01	0.07	0.05	0.02	0.02	0.02	0.03	0.01
	X_5	0.02	0.02	0.02	0.002	0.001	0.0004	0.01	-0.001
	X_6	0.01	0.03	0.01	0.01	0.01	-0.01	-0.001	0.002
	X_7	-0.03	-0.03	-0.07	-0.03	-0.03	-0.10	-0.08	-0.02

As can be seen from the table 7., in terms of trend coefficients, the trend test coefficients of consumer risk(X_7) in the entrepreneurship entity subsystem and all risk indicators in the entrepreneurial environment subsystem are negative, which indicates that there is a trend of decreasing in the sequence of characteristic differences, and there is a trend of increasing in the relationship between the sequences. The focus should be on its development, the marginal benefits of consumer risk are increasing, and increased attention to consumer risk favours the development of the entire ecosystem and improves consumer confidence.

In addition, duplication of investment in the construction of fixed assets should be avoided and emphasis should be placed on improving the efficiency of the use of existing production equipment: enterprise production and construction efforts(X_5) and entrepreneurial environment subsystem of all risk indicators trend test coefficients are positive, indicating that the characteristics of the difference series has a tendency to increase, the relationship between the series has a tendency to decrease. It indicates that the marginal benefit of further increase in fixed asset investment is decreasing.

(2) The volatility of the relationship between each risk element in the green entrepreneurship ecosystem and the overall coupling degree sequence of the system as well as the trend of change were examined, and the results are shown in Table 8.

Table 8. Correlation test for coupling of each risk element to the system.

	Indicator	Trend test
entrepreneurship entity subsystem	X_1	0.016
	X_2	0.032
	X_3	0.039
	X_4	0.057
	X_5	0.031
	X_6	0.018
	X_7	-0.062
	X_8	0.051
entrepreneurial environment subsystem	X_9	-0.027
	X_{10}	-0.005
	X_{11}	0.033
	X_{12}	0.032
	X_{13}	0.033
	X_{14}	-0.015
	X_{15}	0.039

From Table 8, we can get: it is necessary to raise the attention of consumer risk, policy risk and sustainable development risk: except for consumer risk(X_7), policy risk(X_9&X_{10}) and sustainable development risk(X_{13}&X_{15}), the trend coefficients of the rest of the risk indicators and the overall coupling degree of the system are greater than zero, which indicates that the correlation between these risk indicators and the overall coupling degree of the system has a tendency to decrease, and we should pay attention to the consumer risk, policy risk and sustainable development risk, which have a tendency to increase the correlation between the risk indicators and the overall coupling degree of the system.

5.4 Management insights and recommendations

After the above empirical analyses of risk coupling in green entrepreneurial ecosystems, this section summarises and distils three managerial insights for the most important part.

1) Promote the synergistic development of multiple entity

The degree of coupling between the risk indicators and the system is high, indicating that they are not isolated entity, the process of system development when the elements of the unified coordination, improve the level of green entrepreneurship management and technological capabilities, focusing on preventing and controlling the amplification of the coupling of the system risk, the coupling of factors into a pure economic development coupling, rather than the coupling of the risk of amplification.

2) Improve the utilisation efficiency of the industrial construction platform

The correlation degree between fixed asset inputs and other risk indicators of the system shows a decreasing trend, and its continued construction inputs play a smaller role in the overall development of the system, although it has a greater impact on the overall coupling degree of the system, and it should reduce the duplication of inputs of fixed assets and focus on improving the utilisation efficiency of the fixed asset industrial construction platform. This can be achieved by establishing a sound asset management system and strengthening internal coordination and communication.

3) Firmly maintain the sustainable development of the natural environment

Since sustainable risk is the main influence factor of the risk coupling development of green entrepreneurship ecosystem, and green benefit itself is the core goal of green entrepreneurship ecosystem, all parties in the green entrepreneurship ecosystem should focus on the maintenance of the sustainable development of the natural environment, keeping in mind to adhere to the sustainable development of the green economy.

6 Conclusions

Through the grey relation coupling model, this study quantitatively analyses the relevant risk indicator data in China during the period of 2016-2021, deeply analyzes the degree of correlation of each risk element within the system, reveals the mechanism of risk coupling of green entrepreneurial ecosystems, and provides a scientific and reliable theoretical basis for the management and development of the system.

The main academic contributions of this study include: firstly, the definition and structure of green entrepreneurship ecosystem is given through the research and combing of the literature, secondly, the operation mechanism and characteristics of the risk coupling system of green entrepreneurship ecosystem are analysed, and then for different green entrepreneurial entity and environments, the risk indicators are selected to measure the risk level of entrepreneurial entity subsystems and entrepreneurial environment subsystems and a grey The grey relation coupling model is used to quantitatively calculate the grey relation between the relevant risk indicators and the coupling degree between the systems and their influencing factors, which fills the gaps in the relevant fields, provides new ideas for the subsequent research on green entrepreneurship vertically, and extends to the research on the risk coupling system of other industries horizontally.

The limitations and future improvement directions of this study are as follows: 1. When dealing with more complex and changeable problems, we can consider introducing other models or methods, such as neural network model, support vector machine, etc., to improve

the accuracy and reliability of analysis results. 2. When conducting trend test, a variety of methods can be used for comparative analysis to reduce errors and uncertainties that may be caused by a single method. At the same time, we can make a comprehensive judgment on the trend test results by combining the actual situation and expert opinions. 3.When determining sub- system risk indicators of green entrepreneurship ecosystem, further reference can be made to theories and practices in related fields to improve the indicator system and improve the representativeness and accuracy of indicators.

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