Research Article

Research on the Prewarning Model of Relationship Risk Levels in Industry Collaborative Innovation Alliances across Provinces in China

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1. Introduction

The risk evaluation at the microlevel needs the professional knowledge and practical experience accumulation of core experts in the industry, and the basic data acquired is a real subjective cognition of innovation subject at the microlevel on the level of relationship risk to adapt to the decision-making at the microlevel. However, the internal participants of the industrial collaborative innovation alliance have been stratified, and the mesosubjects hope to have a direct prewarning of the level of relationship risk within the industry. In particular, under the major background of “the development of an innovation-driven economy”, innovation has been a crucial driving force of the development of the local economy. Governments at all levels positively participate in collaborative innovation alliances and turn to be the important subjects of the alliances to lead other subjects to take part in the collaborative innovation alliance and connect one collaborative innovation alliance after another within the region. As the important subject of the collaborative innovation alliance and the node subject in the collaborative innovation network, the government should focus on the relationships between subjects in the alliance to have a prewarning of relationship risk to lead the new direction of collaborative innovation in the region in the future. The industries within regions and the provinces and cities across the country could predict the self-related relationship risk level of collaborative innovation alliances [1]. Therefore, it is necessary to have a prewarning of risk level and the probability of occurrence of each risk level in their respective regions with mesodata to help the practice community clearly realize and judge the relationship risk of...
the complicated organization and collaborative innovation alliance and make a scientific judgment and decision.

By far, there is less knowledge on the relationship risk of collaborative innovation alliance, and there has been no existing method for reference for the understanding of the field and the effective prevention of risk. The common risk prewarning models are as follows: univariate model, ZETA model, logistic model, probit model, neural network model, and entropy model (including system entropy, relative entropy, management entropy, and even risk entropy). These models have their own strengths and weaknesses. The entropy model is widely used in the study of alliance risk prewarning, but it still needs to acquire data with a subjective judgment which reduces its scientficity of conclusions. The logistics model does not need to satisfy the statistical assumptions such as normal distribution and homogeneity of variance as a linear model. There should be approximate treatment in the process of calculation, but the risk level prewarning does not need to be too precise, so it has been applied to much more fields [2]. Based on the comparison of the risk prewarning models, the study tries to simulate the panel data in recent 5 years with logistic regression to explore the influencing factors of the relationship risk level of industrial collaborative innovation alliance to form a risk prewarning model of industrial collaborative innovation alliance based on mesodata, so as to assist governments at all level to have a prewarning of the risk level of collaborative innovation alliance and the probability of occurrence of each level in the region.

2. Construction of the Relationship Risk Prewarning Model for Industrial Collaborative Innovation Alliances

2.1. Building Up the Ordered Logistic Model. The binary logistic regression could be built as a risk prewarning model for risk prewarning because the dependent variable values are taken as 0 and 1 to show the two situations, having risk and having no risk, so that it could be applied to the field of risk management. The relationship risk of industrial collaborative innovation alliance is at five levels: 1 (very low), 2 (low), 3 (general), 4 (high), and 5 (very high). The binary logistic regression is not suitable for the risk prewarning of industrial collaborative innovation alliance because the dependent variable values are only taken as 0 and 1; however, in the ordered logistic model, there are multiple observed values of dependent variables with sorting results, so the ordered logistic regression model could be built as a model for relationship prewarning of the industrial collaborative innovation alliance. The general expression of ordered logistics is as follows:

\[ y^* = X\beta + \epsilon | X \sim \text{Logit}(0, 1). \]  

\[ y^* \] is the latent variable of dependent variable \( Y \), and \( X \) means the vector of an independent variable \( x_i \). \( \beta \) is an estimated parameter vector and \( \epsilon \) is the random error term. When \( \omega_i, i = 1, 2, 3, 4, 5 \), is set as critical value (threshold) and the value \( y \) depends on the comparison result between \( y^* \) and critical value, the expression of value \( y \) is

\[
\begin{align*}
1. & y^* \leq \omega_1 \\
2. & \omega_1 < y^* \leq \omega_2 \\
3. & \omega_2 < y^* \leq \omega_3 \\
4. & \omega_3 < y^* \leq \omega_4 \\
5. & \omega_4 < y^* \leq \omega_5 
\end{align*}
\]

In expression (2), \( y = 1, 2, 3, 4, 5 \) means the very low relationship risk of collaborative innovation alliance (harmonious partnership among members), the low relationship risk of collaborative innovation alliance (having difficulty in the cooperation and communication among members but it is apt to be overcome), general relationship risk of collaborative innovation alliance (general cooperation and communication among members), high relationship risk of collaborative innovation alliance (needing a long-term communication and negotiation), and very high relationship risk of collaborative innovation alliance (bad partnership among members and being on the verge of disintegration). According to the conditional probability knowledge in Mathematics, the corresponding equations of \( y \) to \( X \) are as follows:

\[
\begin{align*}
P(y = 1 | X) &= P(y^* \leq \omega_1 | X) = \varphi(\omega_1 - X\beta) \\
P(y = i | X) &= P(\omega_{i-1} < y^* \leq \omega_i | X) = \varphi(\omega_i - X\beta) - \varphi(\omega_{i-1} - X\beta) \quad i = 2, 3, 4. \\
P(y = 5 | X) &= P(y^* > \omega_5 | X) = 1 - \varphi(\omega_5 - X\beta)
\end{align*}
\]

The distribution function is the logistic one.

2.2. The Independent Variables in the Ordered Logistic Model

2.2.1. Collaborative Degree. Collaborative innovation alliance is a strategic behavior to achieve certain objectives with a plan, so it is a “social collaboration.” It needs the alliance subject to achieve the organization from being disorder to order, from lowly order degree to the high order degree through the application of their advantages. The process of alliance subject to use their advantages is a collaborative one, so the degree of collaborative highly affects the efficiency of collaborative and the entire relationship between the subjects. Generally speaking, the subjects would have a high cognition and higher trust with each other when the degree of collaborative is higher, so there would be less opportunistic behavior of the subjects. The higher collaborative degree means the stronger resource integration ability of the
2.2.2. Other Independent Variables. In the collaborative innovation alliance, the government is a leading subject since it affects the entire innovation environment and provides new factors for innovation alliance through innovation policy. The government could effectively gather resources to coordinate all innovation subjects through leading to effectively control the relationship between the subjects of collaborative innovation alliance. Generally speaking, governments could achieve their role in innovation alliance through the buildup of innovation environment, such as financial capital investment, innovative talent policy, and financial policy for local innovation. When the innovation factors of a collaborative innovation alliance are sufficient and there are much more resources with high quality to be collaborated by innovation subject, the effect of mutual collaborative would be better and the innovation subjects would get along well with each other because the effect of mutual collaborative would be higher than that of independent innovation. Hence, the influencing factors of the relationship risk level of collaborative innovation alliance are as follows: science and technology expenditure ratio, education expenditure ratio, and financial loan balance ratio. The science and technology expenditure ratio is calculated by the ratio of science and technology expenditure to the GDP of each region in that year, and the factor affects the supply of innovation talents. The financial loan balance ratio is calculated by the ratio of the balance of bank loans in various regions to the GDP of various regions in the current year, and the factor would affect the supply of innovation funds and social support for innovation activities. In this research, the ratio of science and technology to GDP, the ratio of education to GDP, and the ratio of finance to GDP are other independent variables as shown in Table 1.

| Variables                        | Sign | Unit | Type |
|----------------------------------|------|------|------|
| Collaborative degree             | X1   | Decimal — |
| Ratio of science and technology to GDP | X2   | Decimal — |
| Ratio of education to GDP        | X3   | Decimal — |
| Ratio of finance to GDP          | X4   | Decimal — |

2.2.3. Standardized for Independent Variables. As seen from the entire industrial collaborative innovation alliance, the interaction among colleges and universities, scientific research institutions, and agencies and the direct interaction between government and these subjects would be shown in the collaborative degree of independent variables, which would be seen from the index selection in subsequent collaborative measurement while the interaction between the innovation subject, government, and other subjects would be shown through other independent variables. There are different value dimensions of all influencing factors, so the variables above should be standardized. The standardization method in the research is adopted with the range method. The first part in equation (4) is the positive index and the second part of equation (4) is the negative one.

\[
S(x_{ji}) = \begin{cases} 
\frac{x_{ji} - \bar{\beta}_{ji}}{\bar{\alpha}_{ji} - \bar{\beta}_{ji}} & i \in [1, l_1] \\
\frac{\alpha_{ji} - x_{ji}}{\alpha_{ji} - \bar{\beta}_{ji}} & i \in [l_1, n] 
\end{cases}
\]

The source of data is the Statistical Yearbook of Chinese Science and Technology, the Statistical Yearbook of Chinese High-Tech Industry, the Compilation of Scientific and Technological Statistical Data of Colleges and Universities, the Statistical Yearbook of Chinese Torch, and the statistical yearbooks of relevant provinces from 2010 to 2018. However, in the process of model verification, the data of collaborative degree of some independent variables and the data of relationship risk level need to be acquired through a certain approach. Here is an introduction to the acquisition process of the fitting data of the two variables.

2.3. Acquisition of Collaborative Degree Data

2.3.1. Evaluation Method of the Collaborative Degree. As for the evaluation tools of the interaction degree for the subjects of collaborative innovation, many scholars have mentioned...
the collaborative degree many times. The collaborative degree is one of the effective tools to measure the cross-organizational collaborative innovation effect and it could be used to represent the degree of collaborative and consistency of various innovation elements in the compound system [3]. In the study of the collaborative innovation mechanism, the collaborative degree of collaborative innovation system means the degree of consistency of interaction between collaborative subjects in the process of cooperation and the degree of a behavioral collaborative of subjects in the system; the evaluation of collaborative degree could be deemed as a measuring instrument for synergetic innovation [4–6]. With reference to the outcomes of subsequent research on the expansion of the compound system in different studies, this paper builds up a collaborative degree model suitable for the compound system of the collaborative innovation alliance. It is supposed that the compound system of the collaborative innovation alliance is \( S_4 \) and the subsystem of the collaborative innovation alliance is \( S_j \) \((j = 1, 2, 3, 4)\). \( S_1 \) is a subsystem of technology intermediary service; \( S_2 \) is a subsystem of colleges and universities; \( S_3 \) is a subsystem of the scientific research institution; \( S_4 \) is a subsystem of industry. The ordered variable is needed in the entire collaborative process of innovation alliance to describe that \( x_{ji} \) basis could be divided into two types for the impact of dependent variables: the positive influencing factor and the negative one. When \( x_{ji} \) is the positive influencing factor, the larger its value is taken, the higher the order degree of the system would be. When \( x_{ji} \) is the negative influencing factor, the larger its value is taken, the lower the order degree of the system would be. The subvariable of the ordered variable is \( S_j(x_{ji}) = \frac{(x_{ji} - \beta_{ji})}{(\alpha_{ji} - \beta_{ji})}, \quad i \in [1, l_1], (\alpha_{ji} - \beta_{ji}), \quad i \in [l_1, n]. \) The influencing factors built in the compound system of collaborative innovation alliance are positive and negative. With the consideration that the subvariable of the ordered variable would be positive after the processing to not affect the following processing, it should be \( S_j(x_{ji}) = \frac{(x_{ji} - \beta_{ji})}{(\alpha_{ji} - \beta_{ji})} \times 0.9 + 0.1, \ S_j(x_{ji}) \in [0.1, 1]. \) The measurement of the order degree of the ordered parameter of a general subsystem could be used with the geometric average method and the linear weighted average method. The subjectivity could not be overcome when the weight is confirmed with a linear weighted average method, so the geometric average method is used to measure the order degree of subsystem integration fitting subsystem: \( s_j(x_{ji}) = \sqrt[n]{\prod_{i=1}^{n} x_{ji}}. \) According to the evolution of the compound system from disorder to order, it is set with an initial moment as \( t_0. \) If the time setting \( t_0 \) of data acquisition was set to be 2009, the order degree of \( t_0 \) in all subsystems would be \( d_j(t_0), \quad j = 1, 2, 3, 4, \) the next time of evolution process of the compound system is \( t_1 \), and the order degree of time \( t_1 \) is \( d_j(t_1), \quad j = 1, 2, 3, 4, \) so \( t_1 \) is set to be 2010. Similarly, in the next round calculation, \( t_1 \) would be 2011 when \( t_0 \) is taken as 2010, so as to conclude the order degree of the compound system from 2010 to 2018. The collaborative degree of collaborative innovation alliance is \( S(X) = \theta_3 \sqrt[4]{\prod_{j=1}^{4} [d_j^1(x_{ji}) - d_j^0(x_{ji})]}. \) The parameter \( \theta \) is to tune the negative and the positive.

\[
\theta = \min[d_j^1(x_{ji}) - d_j^0(x_{ji})] \neq 0, \min[d_j^1(x_{ji}) - d_j^0(x_{ji})] \neq 0, \quad j = 1, 2, 3, 4.
\]

If the value of \( S(X) \) was bigger, it would mean the optimal collaborative degree of the compound system of collaborative innovation alliance. As the order degree of each subsystem fluctuates differently and exchanges information, materials, and energy with each other, the overall collaborative degree can be positive or negative.

2.3.2. Selection of the Subsystems. One collaborative innovation alliance is a complicated system with diversified subjects and protruding heterogeneity, but the majority of the industry agree that the collaborative innovation alliance is a network innovation organization with collaborative and interaction between diversified subjects, including the core subjects of colleges and universities, incorporations, and research institutions and the auxiliary subjects of governments, financial organizations, intermediary organizations, and innovation platforms. However, the study thinks that collaborative innovation should be a self-organizing system that all innovation subjects keep cooperating with each other and all innovation factors are recycling ceaselessly, and it would attract the exit or entry of all innovation subjects for the open characteristics of the system. The subject of collaborative innovation alliance would not be constant forever, so it would be impossible to focus on the entire microsubject when describing the collaborative process of the entire system. In the practice, it should be described with the subsystem according to the major classification. For example, some researchers divide the IUR technology allocation into three subsystems: subsystem of industry, a subsystem of colleges and universities, and subsystem of research and development [7, 8]. However, along with the profound carryout of collaborative innovation, all innovation subjects have refined and professional distribution in collaborative innovation alliances, so the collaborative innovation system is attracting the participation of various innovation subjects with open characteristics. The subsystem of technology service shows its talent as a crucial bridge to connect all innovation subjects and makes innovation alliance focus on it gradually. Scholars start to have a study on the subsystem of technology serving as a newly born subsystem, and they find that the subsystem has a finer lower-level subsystem composition, such as subsystem of talents and a subsystem of venues [9, 10].

Based on it, the study chooses the following subsystems as the ones for the compound system of collaborative innovation alliance: a subsystem of industry, a subsystem of technology intermediary service, a subsystem of colleges and universities, and a subsystem of the scientific research institution. The study does not deem government as a subsystem since it is the dominant leader of collaborative innovation. In China, the government would interfere agency, such as financial institutions, by affecting the subjects of collaborative innovation alliance with the factor of innovation capital; it would also affect the subsystem of the
industry with tax policy and intervene the factor of innovation talents resources with education policy. The subsystem of government is based on a mixed system, so it would be hard to clarify the boundary with others or analyze the interaction among subsystems if it was deemed as a subsystem. However, the subsystem of government does impose impact on the relationship risk level of collaborative innovation alliance, so the indirect interaction between government and other innovation subjects would be considered in other independent variables when building up the model for relationship risk prewarning of collaborative innovation alliance while the direct relationship between government and others subsystems would be considered in the index to measure the collaborative degree of subsystems [11, 12]. For the selection of indexes of all subsystems on the measurement of collaborative degree, it is shown as follows:

(a) The subsystem of technology service: collaborative innovation alliance has been developed to be a complicated subsystem with the core of knowledge increment and value creation. In the subsystem, it is included with technology trading market, productivity promotion center, and business incubator in the core layer; the technical consultation, scientific and technological novelty search, scientific and technological development, Information Research Institute, and property right exchange in the middle layer; and the technology novelty search, talent market, leasing company, and audit and accounting service organization in the peripheral layer. It has been a necessary bridge for knowledge increment and value creation.

(b) The subsystem of colleges and universities: as an important source to create and spread new knowledge and new technology, colleges, universities, and scientific research institutions could greatly push incorporations to carry out innovation activity. In general, applied colleges and universities could send all kinds of innovation talents for all innovation subjects in the industrial innovation alliance; on the other hand, they could have the cooperation of technical application with the subjects in the alliance with the button of human resources. Knowledge-based colleges and universities with higher innovation levels would work with scientific research institutions to have a breakthrough knowledge innovation for serving the national strategy and social development. All innovation subjects in the industrial alliance would coordinate with colleges and universities to gain the resources they lack to solve their insufficient innovation capability. It is the innovation factor of a collaborative innovation alliance: the supplier of talents, technology, and knowledge.

(c) The subsystem of scientific research institutions: also as an important source to create and spread new knowledge and new technology, scientific research institutions could also great push incorporations to carry out innovation activities. However, the role of scientific research institutions in the collaborative innovation alliance is different from that of the subsystem of colleges and universities. The role of colleges and universities is to provide vast innovation personnel for the subsystem of industry. The innovative knowledge and innovative technology that these personnel are equipped with would provide important innovation factors for the subsystem of industrial innovation; meanwhile, it would achieve the exchange of the materials, ability, and information among the subsystems to provide a crucial motivation for the evolution of the entire compound system. However, besides the scientific research and the creation of innovative knowledge, scientific research institutions would also participate in the formulation of relevant innovation policies or laws, provision of strategic planning, and so on with an identity of expert [6]. It would impose an impact on the evolution of the compound subsystem of the collaborative innovation alliance by affecting the peripheral environment of the alliance. It is the innovation factor of collaborative innovation alliance: the supplier of knowledge.

(d) The subsystem of the industry: economic profit-driving is an important motivator for a collaborative innovation alliance. The alliance is dominated by industry and oriented by market demand, but there are still so many restricting factors between the ability of industry and the demand of the market, so subsystem of the industry could not satisfy the market demand as an independent system and it needs the collaborative with other subsystems to acquire the resources and ability to satisfy the market demand to achieve the economic profit and undertake social responsibility [13, 14].

2.3.3. Selection of Index of Four Subsystems. The index system built in the previous evaluation process is based on the input-output index. Du Biyun et al. measured the collaborative degree of measures the collaborative degree of the IUR technology alliance innovation system in the six provinces of the middle region with a compound system of collaborative degree model, and the ordered parameter selected by them is still the index of the input-output index when confirming the ordered parameter of a subsystem of scientific technology alliance [8]. The compound system of collaborative innovation alliance is social collaborative, while social collaborative has a purpose. The behavior of the collaborative subject is directly controlled by the objectives of the subject, so the evaluation on the collaborative degree should try to begin from the subject behavior. Therefore, it is necessary to choose an ordered parameter of the subsystem in the index of collaborative behavior among the subjects. Some researches begin from a complex system theory and dissipative structure theory to suggest a measurement method of regional collaborative innovation based on collaborative degree-management entropy when studying the
measurement of collaborative innovation ability in the region [9]. There are two index systems selected by them: order degree of innovation subject and knowledge transfer degree. The index of order degree of innovation subject is selected with a large number of indicators of interaction between innovation subjects. Through the empirical comparison of collaborative degree and management entropy, it is found that the result of the two models is basically consistent so as to prove the scientificity and effectiveness of measurement. It also provides an effective reference for the index selection to the quantitative measurement of collaborative innovation alliance. Based on these, the study selects the following indexes for all subsystems of collaborative innovation alliance when confirming the empirical data of collaborative degree. Above all, the whole index of collaborative innovation alliances is shown in Table 2, where (a) stands for the subsystem of technology service; (b) stands for the subsystem of colleges and universities; (c) stands for the subsystem of scientific research institutions; and (d) stands for the subsystem of industry.

The source of data is the Statistical Yearbook of Chinese Science and Technology, the Statistical Yearbook of Chinese High-Tech Industry, the Compilation of Scientific and Technological Statistical Data of Colleges and Universities, the Statistical Yearbook of Chinese Torch, and the statistical yearbooks of relevant provinces from 2010 to 2018. Given the inconsistent dimensions of the original data, there would be errors when directly participating in the calculation and processing, so the paper uses the level difference method to standardize the original data.

2.3.4. Measurement of the Collaborative Degree. There are four subsystems in the compound system of collaborative innovation alliance: the subsystem of technology service, the subsystem of colleges and universities, the subsystem of scientific research institutions, and the subsystem of industry. By describing the mutual roles of the four subsystems, the order degree of the four subsystems in 30 provinces (cities) around the country and then the collaborative degree of the compound system are “integrated” through the order degree of the four subsystems, as shown in Table 3, so as to get the data of independent variable collaborative degree for the model of relationship risk prewarning of the collaborative innovation alliances.

3. Acquisition of Relationship Risk Level

3.1. Selecting Original Data Indexes to Confirm Relationship Risk Level. The theoretical study of collaborative innovation alliance could be traced to the IUR cooperation. It is suggested by Etzkowitz and Leydesdroff. They emphasize that knowledge could be an increasing factor of the economy, and they focus on the cognition of innovation subjects. Colleges and universities, industries, and governments are mutually independent and interactive to form a dynamic triple helix to push the sustainable growth of the economy. Later, Leydesdroff thought that the uncertainty, complication, and completion of the system could be presented by the mutual information among three subsystems based on the cognition of information entropy, so as to suggest the index to measure the relationship of the triple helix [10]. The “triple helix” means innovation subjects. Then, everybody studies the cooperation and interaction relationship between subjects with the mutual information of “triple helix”. To explore the relationship between the IUR collaborative and innovation subject, domestic scholars start to integrate the “triple helix” and data mining technology to measure the relationship between innovation subjects. Cai Xiang and Liu Xiaozheng studied the cooperation relationship of government-university-research with the SCI scientific papers, national science and technology standards, and national scientific research fund as the data of the output structure of “triple helix” [15, 16]. Zhuang Tao made the patent data as the original data of “triple helix” output to study the international cooperation of IUR, and he extended the subject of “triple helix” to be four subjects of international cooperation to measure the partnership among subjects to study the interaction between the government-university-research and the international cooperation organization [16]. Hence, based on the previous literature, the paper refers to the study and extension outcomes of above on “triple helix” with the consideration on the availability of data to choose invention patent as basic data. The paper carries out the study among the collaborative innovation subjects through the algorithm of “triple helix” and information theory knowledge to acquire the original data of relationship risk level during the empirical process. There are three types of patents: invention patent, utility model patent, and appearance design. The reason why to choose invention patent as the original data of algorithm of “triple helix” is that invention patents mean the originality with the highest technical content, so it is more suitable for the study on innovation than that of design patent and utility model patent. Hence, in the collection of basic data, the study only adopts the data of invention patents. The invention patent could be divided into job invention patent and nonjob invention patent. The owners of job invention patents are incorporations, scientific research institutions, colleges and universities, and governments. These subjects are closer to that of the collaborative innovation alliance in the study. In the past few years, in the effective invention patents in China, the proportion of nonjob invention patents is decreasing while that of the job one has been increasing. It has increased from 70.1% in 2006 to be 90.0% in 2014, which is increased by nearly 20% in eight years while the foreign countries always keep the high position of 98% for the past five years with an increasing tendency. It ensures sufficient data. With the consideration of the factors mentioned above, the paper chooses the number of service invention patent applications granted as basic data for the calculation of “triple helix”.

3.2. Acquiring the Original Data to Confirm Relationship Risk Level. It confirms to calculate the interaction of innovation alliance with job invention to finalize the basic data of relationship risk level in empirical analysis. The data of job invention is acquired by the website of China National
Table 2: List of the index of four subsystems of the compound system of collaborative innovation alliances.

| Subsystem | Index | Symbol | Unit | Type |
|-----------|-------|--------|------|------|
| (a) Subsystem of technology service | Total number of incorporations served | X11 | Tens of thousands of incorporations | + |
| | Total income of service | X12 | Million yuan | + |
| | Increased sales for the incorporation | X13 | Million yuan | + |
| | Input of government | X14 | Million yuan | + |
| | Full-time equivalent of R and D personnel in colleges and universities | X21 | Tens of thousands of persons per year | + |
| | Internal expenditure of R and D funds in colleges and universities | X22 | Million yuan | + |
| | Government funds for the internal expenditure of R and D funds of colleges and universities | X23 | Million yuan | + |
| | Corporate funds internal expenditure of R and D funds of colleges and universities | X24 | Million yuan | + |
| | External expenditure of R and D funds of colleges and universities | X25 | Million yuan | + |
| | Expenditure of domestic colleges and universities for the external expenditure of R and D funds of colleges and universities | X26 | Million yuan | + |
| | Expenditure of domestic incorporations for the external expenditure of R and D funds of colleges and universities | X27 | Million yuan | + |
| | Expenditure of domestic scientific research institutions for the external expenditure of R and D funds of colleges and universities | X28 | Million yuan | + |
| | Number of applications for R and D projects in colleges and universities | X29 | Item | + |
| | Full-time equivalent of R and D personnel in colleges and universities | X31 | Tens of thousands of persons per year | + |
| | Internal expenditure of R and D funds in colleges and universities | X32 | Million yuan | + |
| | Government funds for the internal expenditure of R and D funds of scientific research institutions | X33 | Million yuan | + |
| | Corporate funds internal expenditure of R and D funds of scientific research institutions | X34 | Million yuan | + |
| | Expenditure of domestic colleges and universities for the external expenditure of R and D funds of scientific research institutions | X35 | Million yuan | + |
| | Expenditure of domestic incorporations and universities for the external expenditure of R and D funds of scientific research institutions | X36 | Million yuan | + |
| | Expenditure of domestic scientific research institutions for the external expenditure of R and D funds of scientific research institutions | X37 | Million yuan | + |
| | Number of applications for R and D projects in scientific research institutions | X38 | Item | + |
| | Full-time equivalent of R and D personnel in large and medium-sized industrial incorporations | X41 | Tens of thousands of persons per year | + |
| | Internal expenditure of R and D funds in large and medium-sized industrial incorporations | X42 | Million yuan | + |
| | Government funds for the internal expenditure of R and D funds of large and medium-sized industrial incorporations | X43 | Million yuan | + |
| | Corporate funds internal expenditure of R and D funds of large and medium-sized industrial incorporations | X44 | Million yuan | + |
| | Expenditure of research institutions for the external expenditure of R and D funds of large and medium-sized industrial incorporations | X45 | Million yuan | + |
| | Expenditure of domestic colleges and universities for the external expenditure of R and D funds of large and medium-sized industrial incorporations | X46 | Million yuan | + |
| | Number of projects for R and D projects in large and medium-sized industrial incorporations | X48 | Item | + |
| | Expenditure for new product development | X49 | Million yuan | + |
| | Proportion of incorporations with R and D activities | X50 | % | + |
Intellectual Property Administration and the websites of Intellectual Property Administration of all provinces. Through the tools of patent searching and analysis in the websites, I set the searching keyword as follows: “patent applicant + application date + code of province” according to the existing searching method. The patent applicants are represented with “Government (G),” “Incorporation (I),” “University (U),” and “Research Institution (R)” (repeated measurement is allowed). According to the appellation of state-owned incorporations and institutions, it would be categorized into the range of “government” if the “ministry,” “bureau,” “department,” or the name of the organization directly under the government were included in the name of the applicant; it would be classified into the range of “incorporation” if the “company,” “plant,” “incorporation,” and “group” were contained in the name; the name of institutions included with “university” and “college” would be classified into the range of “university” and those with the “academy,” “lab,” and “institute” would be classified into the range of “research institution.” The discrimination of “university” and “research institution” is for the methods of the existing IUR studies because there is an obvious distinction in the functions of middle schools and universities and research institutions in the collaborative innovation alliance. The applied university is mainly for the innovation of talent cultivation while the knowledge-based university is to engage in basic innovation activity for the breakthrough innovation to serve for a national strategy. The applied scientific institution is mainly engaged in technical application, but it would be combined with the demand of governments in all places to be the “think tank” of government to advise the government on policies as an expert while the research institution engaging in basic major innovation activity mainly serves for the national strategy. Hence, there would be a distinction between “university” and “research institution” in the text. Besides, there would be respective reports on technical innovation in the statistical yearbook and annual report. As for the cooperation of innovation subjects, if there were two or three names, the name of the patent would be classified to be eight categories as follows: “University–Incorporation (UI),” “University–Government (UG),” “Incorporation–Government (IG),” and “Research Institution–Incorporation (RI),” “Research Institution–University (RU),” “Research Institution–Government (RG),” “University–Incorporation–Government (UIG),” “University–Research Institution–Incorporation–Government (URIG).” Meanwhile, if it was searched by year according to the application date, the province will be given by number. For example, the number of Guangdong is 44, and the frequency of occurrence is counted in each category so that the data after the statistics would be composed of the original database of cooperative patent application research [17]. The original data acquired by the forms is applied for the triple helix model to gain the

| Area/year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|-----------|------|------|------|------|------|------|------|------|------|
| Beijing   | 1    | 2    | 2    | 2    | 2    | 1    | 1    | 1    | 1    |
| Tianjin   | 4    | 3    | 4    | 3    | 4    | 2    | 2    | 2    | 2    |
| Hebei     | 4    | 3    | 4    | 3    | 4    | 2    | 2    | 2    | 2    |
| Shanxi    | 4    | 3    | 4    | 3    | 4    | 1    | 3    | 3    | 3    |
| Inner Mongolia | 2    | 5    | 5    | 5    | 5    | 1    | 1    | 1    | 1    |
| Liaoning  | 1    | 2    | 2    | 2    | 2    | 1    | 1    | 3    | 3    |
| Jilin     | 1    | 2    | 2    | 2    | 1    | 3    | 4    | 3    | 3    |
| Heilongjiang | 1    | 2    | 2    | 2    | 1    | 4    | 3    | 3    | 3    |
| Shanghai  | 3    | 4    | 3    | 4    | 5    | 1    | 2    | 2    | 2    |
| Jiangsu   | 5    | 1    | 1    | 1    | 3    | 2    | 2    | 2    | 2    |
| Zhejiang  | 3    | 4    | 3    | 4    | 4    | 5    | 5    | 4    | 4    |
| Anhui     | 3    | 1    | 1    | 1    | 3    | 2    | 2    | 2    | 2    |
| Fujian    | 5    | 1    | 1    | 1    | 3    | 2    | 5    | 4    | 4    |
| Jiangxi   | 4    | 3    | 5    | 5    | 5    | 4    | 3    | 2    | 2    |
| Shandong  | 3    | 4    | 3    | 4    | 5    | 2    | 2    | 2    | 1    |
| Henan     | 3    | 4    | 3    | 4    | 5    | 2    | 1    | 1    | 1    |
| Hubei     | 4    | 3    | 4    | 5    | 4    | 1    | 1    | 1    | 1    |
| Hunan     | 3    | 3    | 4    | 5    | 4    | 1    | 1    | 1    | 1    |
| Guangdong | 5    | 1    | 1    | 1    | 3    | 5    | 5    | 5    | 5    |
| Guangxi   | 3    | 3    | 3    | 5    | 5    | 4    | 4    | 3    | 5    |
| Chongqing | 3    | 4    | 3    | 4    | 5    | 2    | 2    | 2    | 1    |
| Sichuan   | 3    | 4    | 3    | 4    | 4    | 2    | 2    | 1    | 1    |
| Guizhou   | 4    | 3    | 4    | 3    | 4    | 1    | 1    | 1    | 3    |
| Yunnan    | 1    | 2    | 2    | 2    | 2    | 1    | 1    | 1    | 1    |
| Tibet     | 2    | 4    | 3    | 4    | 5    | 5    | 5    | 2    | 1    |
| Shanxi    | 1    | 2    | 2    | 2    | 1    | 4    | 3    | 3    | 3    |
| Gansu     | 1    | 2    | 2    | 2    | 2    | 3    | 3    | 4    | 3    |
| Qinghai   | 2    | 4    | 5    | 4    | 5    | 2    | 2    | 5    | 2    |
| Ningxia   | 5    | 1    | 1    | 1    | 3    | 2    | 5    | 4    | 2    |
| Xinjiang  | 4    | 3    | 4    | 3    | 4    | 1    | 3    | 3    | 3    |
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4. Verification of the Model for Relationship Risk Prewarning

With the use of the STATA metrological analysis software, the variable Y means the relationship risk level of collaborative innovation alliance, and the variables X1, X2, X3, and X4 are the collaborative degree, science and technology expenditure ratio, education expenditure ratio, and financial loan balance ratio. The control variables are region and degree. Furthermore, the models in Table 4 are added control variables to the mode through "region", "year", X2, X3, and X4 step by step. The results are shown in Table 4.

seen from the p value of independent variables, only the collaborative degree of the independent variable passes the significance test. The collaborative degree could pass the significance test among multiple influencing factors directly related to the relationship risk level of collaborative innovation alliance, so it means that the relationship risk level of collaborative innovation alliance could be predicted with the collaborative degree from the perspective of management and statistical metrology. But other variables which are science and technology expenditure ratio, education expenditure ratio, and financial loan balance ratio are not reasonable to prewarning relationship risk levels in those collaborative innovation alliances. Even the variables “region” and “year” are as a controlled variable put in model (5), model (6), and model (7), and the degree of X1 significance reduces on the contrary. Whether the variables “region” and “year” are controlled or not, the p values of X2, X3, and X4 are still not significant.

And then, seen from the model calculation and tests, the X1, independent variable of collaborative degree, is more reasonable when building up the model for the relationship risk level of collaborative innovation alliance, so STATA is used to fit the equation containing only the degree of the collaborative as an independent variable. The fitting result shows that the whole p value is 0.0001 and the p value of the independent variable, collaborative degree, is 0.068, so both of them pass the significance test. From model (2) in Table 4, the test adds a control variable: region; the results are still significant. It shows that the relationship risk prewarning contains region influence. According to the Statistical Yearbook of Chinese Science and Technology, the east area is Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the middle area is Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan; the west area is Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shanxi, Gansu, Qinghai, Ningxia,
and Xinjiang; the east-north area is Liaoning, Jilin, and Heilongjiang. According to Economic Research Journal, the east area is Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan, and Liaoning; the middle area is Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan; the west area is Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shanxi, Gansu, Qinghai, Ningxia and Xinjiang, Jilin, and Heilongjiang [18, 19]. Comparatively, It shows that the region influence takes place in the east area and middle area, but it does not take place in the west area and northeast area in model (1), model (2), and model (3) from Table 5 according to the classification of the Statistical Yearbook of Chinese Science and Technology. It shows that the region’s influence takes place in the east area and middle area, but it does not take place in the west area in model (5), model (6), and model (7) from Table 5 according to the classification of Economic Research Journal. That means the coordinative degree is more relative to the innovation risk level in the east and middle areas. This research is more suitable for east and middle governments to prewarning innovation levels.

If the time variable is controlled, the correspondent cumulative ratio of ordered results in the east area is as follows:

\[
y^* = -4.1602x
\]

\[
\begin{align*}
1, y^* &\leq -5.8412 \\
2, &-5.8412 < y^* \leq -4.3095 \\
3, -4.3095 < y^* \leq -3.6397. &
\end{align*}
\]

\[
4, -3.6397 < y^* \leq -2.4402 \\
5, y^* > -2.4402
\]

Meanwhile, the odds ratio value in the ordered logistic model means that every increase in the collaborative degree by one unit will lead to an increase of corresponding times of the probability that the relationship risk level will decrease by one level. So, it could be seen from the odds ratio value of the model for relationship risk prewarning that the probability of reducing the risk level by one or more levels will increase by times when the collaborative degree changes by one unit. The probability of the occurrence of each risk level would be predicted from the cumulative ratio of ordered results. The odds ratio is 0.0156 if the time variable is controlled in the east area. So, the probability of reducing the risk level by one or more levels will increase by 0.9844 times. It should be noted that the significant meaning of coefficient in the ordered logistic model is bigger than the meaning of

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|-----------|-----|-----|-----|-----|-----|-----|-----|
| y         | y   | y   | y   | y   | y   | y   | y   |
| x1        | 0.9122*** | 0.7733* | -1.6618** | -1.9144* | -1.8741* | -1.8642* | -1.8838* |
|           | (2.40) | (1.67) | (-2.08) | (-1.92) | (-1.87) | (-1.86) | (-1.87) |
| x2        | -0.2165 | 0.5764 | 0.5028 |
|           | (-0.78) | (0.54) | (0.43) |
| x3        | -0.4799 | -0.4583 |
|           | (-0.83) | (-0.77) | 0.1894 |
| x4        |       |       |       |
| Region No | Yes | No | Yes | Yes | Yes | Yes |
| Year No | No | Yes | Yes | Yes | Yes | Yes |
| Pseudo R2 | 0.0068 | 0.1230 | 0.0383 | 0.1528 | 0.1535 | 0.1543 | 0.1544 |
| Observations | 270 | 270 | 270 | 270 | 270 | 270 | 270 |

z-statistics in parentheses: ***p < 0.01, **p < 0.05, and *p < 0.1.
coefficient itself. The significance of the coefficient is relevant to the value of the independent variable and the value of $\beta$. Hence, the governments at all levels could predict the relationship risk level of industry collaborative innovation alliance in the region.

5. Conclusions

The paper studies the governments at all levels and how to prewarn the innovation risk levels as they are one of the innovation subjects in industry collaborative innovation alliances. This paper makes some contributions about this point which are as follows: (i) the science and technology expenditure ratio, the education expenditure ratio, and the financial loan balance ratio are not reasonable to prewarning relationship risk grades in those collaborative innovation alliances; (ii) the relationship risk prewarning contains region influence. Furthermore, region influence is different among different areas. It is fit for using the collaborative degree to prewarning the risk degree in the east area and middle area, but it is not fit for the west area or northeast area. Using the collaborative degree to predict the risk levels can be suitable for governments which are indicative innovation subjects in industry innovation alliances, but they need to consider the differences among provinces; (iii) the odds ratio value in ordered logistic regression means that every increase in the collaborative degree by one unit will lead to an increase of corresponding times of the probability that the relationship risk level will decrease by one level. The probability of the occurrence of each risk level would be predicted from the cumulative ratio of ordered results.

Certainly, if any industry in the cross-region could refine all subsystems within the industry, it could also refer to the model of the prewarning to predict the level of relationship risk of internal collaborative innovation in the industry. In the future, along with the dynamic change of collaborative innovation alliances, the number of innovative subjects would be increased or decreased. These changes will add the complication and risk of a collaborative innovation alliance. However, only the new subsystem is confirmed through the complicated system of collaborative innovation alliance to predict the relationship risk level of prewarning and the probability of occurrence of each level through the collaborative degree.

Data Availability

The data used to support the findings of this research are included within the article. The source of data is from the Statistical Yearbook of Chinese Science and Technology (2010–2018), the Statistical Yearbook of Chinese High-Tech Industry (2010–2018), the Statistical Yearbook of Chinese Torch from 2010 to 2018, and the Chinese National Intellectual Property Reports from 2010 to 2018. The data of job invention are acquired by the website of China National Intellectual Property Administration and the websites of Intellectual Property Administration of all provinces.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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