Research on Risk Identification for Foreign Companies Investing in Mongolia Infrastructure Construction Industry Based on Complex Network Technology

Ruicheng Yang, Wenjing Zhao, Qi Jiang and Wei You

School of Finance, Inner Mongolia University of Finance and Economics, Hohhot 010000, China.
Email: ruicheng-yang@163.com

Abstract. In order to identify and circumvent the investment risk of foreign companies in Mongolia, this paper constructs a risk factor system for foreign companies to invest in Mongolian infrastructure construction industry. Using the dynamic data of relevant risk factors from 2010 to 2016, the adjacency matrix and the edge weights of the risk factors were calculated. Based on this, a complex risk network is established to calculate the node importance of each risk factor. On the basis of node importance, the paper analyses the risk of foreign companies investing in Mongolian infrastructure construction industry, and divides the risk factors into three levels.

1. Introduction
The backward infrastructure of Mongolia has severely restricted its economic development. In order to develop the economy and participate in regional economic cooperation, the Mongolian government has launched a series of policies to improve its infrastructure construction and provided support for foreign companies' investment in infrastructure construction. The introduction of these policies has attracted many foreign companies (especially Chinese ones) to invest in Mongolia's infrastructure industry. However, Mongolia's complex investment environment will bring greater investment risks to foreign companies, and may cause huge losses to them. Therefore, how to identify and analyze these investment risks is an urgent problem for foreign companies investing in the infrastructure industry of Mongolia.

Mongolia's changeable investment environment constitutes a complex system. The mature complex network technology in recent years can better analyze the correlation between risk factors, and can analyze the nature and function of the system as a whole. The maturity of complex network technology has attracted many scholars to use its advantages to explore various issues. T. Wilhelm and J. Kim (2008) systematically explain what complex network graphs are. Kitask and Gallos (2010) proposed that the importance of nodes is related to the location of nodes in the network, and obtained more accurate ranking index of node importance using K-kernel analysis method. Rumi Ghosh and Kristina Lerman (2011) comprehensively evaluated the importance of nodes from all aspects of network nodes, and proposed a method to quantify the importance of nodes based on the actual situation. Allen and Gale (2000) pioneered the use of complex networks to study systemic risk of banks; Newman and Juyong (2003) established a social network model to simulate the real social network by studying the statistical characteristics of social networks. These results provide a good technical reference for the study of enterprise investment risk using complex network in this paper.

In this paper we will construct a complex network identification model for the risk of foreign companies investing in Mongolian infrastructure construction industry, and analyze the importance of each risk factor...
to the overall investment risk. To provide technical support for foreign companies to better understand risks before or during their investment and timely insight into the changes of risk factors.

The data in this paper comes from Mongolian National Bureau of Statistics, EFW(Economic Freedom of the World), WDI(World Development Indicators) and IMF(International Monetary Fund).

2. Evaluating Procedure and Methodology

2.1. Evaluating Procedure

Now we present the evaluation procedure in Figure 1 with three stages: risk factor system construction, design of complex network and risk identification. The specific analysis process is shown in the figure1.

![Figure 1. Evaluating procedure.](image)

2.2 Evaluation Method of Complex Network

In this section, we will construct a risk complex network for foreign companies to invest in infrastructure construction industry in Mongolia. The main steps are as follows:

**Step 1: Designing a complex network.** Complex networks consist of nodes and edges connecting each node. Risk factors will be taken as nodes, and the relationship among risk factors will be taken as edges.

Calculate the correlation coefficient $\rho$ between each risk factor. Determine a threshold $\theta$ based on the real situation. If the correlation coefficient between the two nodes is less than $\theta$, then there is no edge connection between the two nodes; otherwise, there are edges connecting the two nodes. Based on this, $A = (a_{ij})$ denotes the adjacency matrix, where:

$$a_{ij} = \begin{cases} 1, & \text{If node } v_i \text{ and } v_j \text{ are connected} \\ 0, & \text{Otherwise} \end{cases}$$

(1)

According to the established adjacency matrix, we can directly determine whether there are edge connections among the risk factors nodes.

$w_{ij}$ shows the edge weight that represents the interactive degree or distance between node $v_i$ and $v_j$, which is decide by $w_{ij} = 1/|\rho_{ij}|$.

Where $\rho_{ij}$ is the correlation coefficient between node $v_i$ and $v_j$, it can be calculated by the evolution data from 2010-2016 of all the risk factors;

**Step 2: Computation of Node Degree Value and Average Degree Value.** The node degree value $D_i$ of the node $v_i$ is the sum of the weights of all the edges connected with node $v_i$, which reflects the...
importance of a node. It is used to express its influence on adjacent nodes. The average value $\bar{D}$ is the arithmetic mean of all node degrees: $\bar{D} = \frac{1}{n} \sum_{i=1}^{n} D_i$.

**Step 3: Calculating the risk factor node efficiency.** The efficiency $I_i$ of node $v_i$ is defined as:

$$I_i = \frac{1}{n-1} \sum_{j=1,j \neq i}^{n} \frac{1}{d_{ij}}$$  \hspace{1cm} (2)

where $n$ is the number of total nodes in the network, $d_{ij}$ is the distance from node $v_i$ to node $v_j$.

**Step 4: Calculating the Node Importance of Risk Factor.** Node importance depends on the efficiency value and node degree value both nodes themselves and adjacent nodes. Denote the $C_i$ is the importance value of node $v_i$, and it can be calculated by

$$C_i = I_i \times \sum_{j=1,j \neq i}^{n} w_{ij} D_i l_j / \bar{D}^2$$  \hspace{1cm} (3)

3. Results and Discussion

Based on the data collected, applying the evaluation method of complex network, we obtain the adjacency matrix (see Table 1), and further derive the corresponding weight matrix that represents the relations among these risk factors (see Table 2). All calculations are implemented by MATLAB2016a. The adjacency matrix $A = (a_{ij})$ and edge weight matrix $B = (b_{ij})$ are as follows:

**Table 1.** Adjacency matrix table $A = (a_{ij})$.

| Node | 1(R1) | 2(R2) | 3(R3) | 4(R4) | 5(R5) | 6(R6) | 7(R7) | 8(R8) | 9(R9) | 10(R10) | 11(R11) | 12(R12) |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------|---------|---------|
| 1(R1)| 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0       | 0       | 0       |
| 2(R2)| 1     | 0     | 0     | 1     | 0     | 0     | 0     | 0     | 0     | 0       | 0       | 0       |
| 3(R3)| 1     | 0     | 1     | 1     | 0     | 0     | 0     | 0     | 0     | 0       | 0       | 0       |
| 4(R4)| 0     | 0     | 0     | 0     | 0     | 1     | 0     | 0     | 0     | 0       | 0       | 0       |
| 5(R5)| 1     | 1     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0       | 0       | 0       |
| 6(R6)| 0     | 1     | 1     | 1     | 0     | 0     | 0     | 0     | 0     | 0       | 0       | 0       |
| 7(R7)| 0     | 1     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0       | 0       | 0       |
| 8(R8)| 1     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0       | 0       | 0       |
| 9(R9)| 0     | 0     | 0     | 0     | 0     | 1     | 0     | 0     | 0     | 0       | 0       | 0       |
| 10(R10)| 1   | 1     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0       | 0       | 0       |
| 11(R11)| 1  | 1     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0       | 0       | 0       |
| 12(R12)| 1 | 1     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0       | 0       | 0       |

**Table 2.** Weight Matrix Table $B = (b_{ij})$.

| Node | 1(R1) | 2(R2) | 3(R3) | 4(R4) | 5(R5) | 6(R6) | 7(R7) | 8(R8) | 9(R9) | 10(R10) | 11(R11) | 12(R12) |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------|---------|---------|
| 1(R1)| 0     | 1.3   | 1.63  | 0     | 1.41  | 0     | 0     | 1.38  | 0     | 1.69    | 1.6     | 1.23    |
| 2(R2)| 1.3   | 0     | 0     | 0     | 1.18  | 1.99  | 1.95  | 0     | 0     | 1.23    | 1.7     | 1.93    |
| 3(R3)| 1.63  | 0     | 0     | 1.43  | 0     | 1.74  | 0     | 0     | 0     | 0       | 0       | 0       |
| 4(R4)| 0     | 1.43  | 0     | 0     | 1.42  | 0     | 0     | 0     | 0     | 0       | 0       | 0       |
| 5(R5)| 1.41  | 1.18  | 0     | 0     | 1.42  | 0     | 1.63  | 0     | 1.41  | 0       | 0       | 0       |
| 6(R6)| 0     | 1.99  | 1.42  | 1.42  | 0     | 0     | 0     | 0     | 0     | 0       | 0       | 0       |
| 7(R7)| 0     | 1.95  | 0     | 0     | 0     | 0     | 0     | 1.53  | 1.7    | 0       | 0       | 0       |
| 8(R8)| 1.38  | 0     | 0     | 1.63  | 0     | 0     | 0     | 0     | 0     | 0       | 1.57    | 1.46    |
| 9(R9)| 0     | 0     | 0     | 0     | 0     | 1.53  | 0     | 0     | 0     | 0       | 0       | 0       |
| 10(R10)| 1.69| 1.23  | 0     | 0     | 1.41  | 0     | 1.7   | 0     | 0     | 0       | 1.94    | 1.73    |
| 11(R11)| 1.6| 1.7   | 0     | 0     | 0     | 0     | 1.57  | 0     | 1.94  | 0       | 1.47    | 0       |
| 12(R12)| 1.23| 1.93  | 0     | 0     | 0     | 0     | 1.46  | 0     | 1.73  | 1.47    | 0       | 0       |

Table 1 shows the results of the adjacency matrix of the risk factors. 1 represents the edge connection between two nodes, and 0 represents the disconnection of two nodes. Table 2 gives the weight of edges between two nodes. For example, $b_{10}=1.38$ shows the weight of the edges between node $R_8$ and $R_1$ is 1.38, which indicates that the distance between the two nodes is 1.38. Note that
the smaller of the weight between two connected nodes, the stronger of the interactive effect between the two risk factors will be.

3.1 Complex Network Diagram of the Risk Factors

Based on the adjacency and weight matrices (see Table 1 and Table 2, respectively), we illustrate intuitively the layouts and their interrelationships of risk factors with the Pajek software, i.e., the complex network diagram of risk factors as shown in Figure 3. Here, the node size represents the different degree value, and the node color represents the different level of the node importance.

![Complex Network Diagram of Risk Factors](image)

**Figure 2.** Risk factors complex network diagram.

3.2 Quantitative Analysis Using the Importance of Risk Factors

Node importance is an index that considers the importance of nodes in the network as a whole. It combines the efficiency and degree of nodes of the nodes themselves and their adjacent nodes. From formula (3), we derive the importance value of all risk factors, and further rank them according to their respective value as follows:

**Table 3. Importance value of each risk factor.**

| Rank | Risk factor | Importance value | Risk level   |
|------|-------------|------------------|--------------|
| 1    | R_2-Employment control | 0.4535 | First level |
| 2    | R_1-Policy stability    | 0.4410 |            |
| 3    | R_{12}-Living infrastructure | 0.3465 | Second level |
| 4    | R_{10}-Labor disputes | 0.3431 |            |
| 5    | R_5-extern debt/GDP | 0.3331 |            |
| 6    | R_{11}-Cultural religion | 0.2763 |            |
| 7    | R_9-Transportation capacity | 0.2265 |            |
| 8    | R_6-Short-term External Debt/Total External Debt | 0.2071 | Third level |
| 9    | R_7-exchange rate | 0.1510 |            |
| 10   | R_3-GDP | 0.1374 |            |
| 11   | R_4-Inflation | 0.0500 |            |
| 12   | R_5-Technological risk of labor force | 0.0160 |            |

Table 3 shows the ranks, importance value and risk level classification of each risk factor, in which these risk factors are divided into three levels. To avoid the loss of investing in Mongolian infrastructure construction industry, the foreign companies should lay more stress on the risk factors of the first and the second levels and pay due consideration to the risk factors of the third level.
4. Conclusion
This paper identifies the risk of foreign companies investing in Mongolian infrastructure construction industry by using complex network technology, and constructs a risk system and draws an intuitive diagram of risk complex network for them. By using this complex network, the paper classifies and analyses the risk of foreign companies investing in Mongolian infrastructure construction industry. It is concluded that foreign companies needs to focus on the first-level and second-level risks of importance. The first-level risk factors of importance are: employment control, policy stability; and the second-level risk factors of importance are: living infrastructure, labor disputes, foreign debt/GDP.

5. Reference
[1] Allen F and Gale D 2000 Journal of Political Economy Financial contagion pp 1-33
[2] Ghosh R, Leman K 2011 A framework for quantitative analysis of cascades on networks: Proc. Int. Conf. on web search and data mining
[3] Marwan N, Donges J F and Zou Y 2009 Complex network approach for recurrence analysis of time series Physics Letters A pp 4246-4254
[4] Kitsak M, Gallos L K and Havlin S 2010 Identification of influential spreaders in complex network Nature Physics pp 888-893
[5] M. E. J. Newman and Juyong 2003 Why social networks are different from other types of networks Phys Rev E Stat Nonlin Soft Matter Phys 68(2):036122
[6] T. Wilhelm and J. Kim 2008 What is a complex graph Physica A: Statistical Mechanics and its Applications pp 2637–2652