

# Research on Financial Risk Path Identification of Chinese Energy Enterprises Based on ISM-MICMAC Model

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**Abstract.** As an important resource commodity related to the global economic lifeline, energy is the material basis for the survival and development of human society. With its identity as a major energy importer and consumer, China must ensure the stability of production and operation of energy enterprises, of which the identification and control of financial risks is of vital importance. Therefore, this paper first uses multiple risk identification methods to identify 9 external and 8 internal key risk factors affecting energy corporate finance in both external and internal dimensions, respectively. Then the ISM and MICMAC methods were used to construct a progressive multi-level structural model of the interactions of key risk factors, and the risk factors were classified by combining the driving power and dependence power of each key risk factor to reveal the interactions among the risk factors. The results showed that 5 partition levels were extracted from 17 risk factors according to ISM model and MICMAC analysis placed all factors into dependent quadrant and independent quadrant. This study reveals the internal relationship between risk factors and is of great significance to the financial risk identification and management of Chinese energy enterprises.

**Keywords:** Energy Enterprises, Financial Risks, Risk Identification, ISM Method, MICMAC Method.

## 1. Introduction

Since the industrial revolution, energy has been a vital strategic resource for every country. The energetic material represented by oil not only affects the political pattern of the world but also affects the peace of the world. It is one of the material bases for human survival. Under the background of the 'double carbon' target, the energy enterprises led by new energy enterprises have promoted the development of China. Compared with developed countries, energy companies in developing countries such as China are still in their infancy, and response and risk analysis still need to be mature. Business risk management is an integral part of an effective and comprehensive business management system [1] and the risk control of the enterprise becomes particularly important. In recent years, research in this area has been increasing.

Using models and algorithms: Liu et al. [2] used the complete fuzzy analytic hierarchy process (FAHP) to calculate the overall risk level of PGSUVE. The results of factor identification include market risk, social politics and environment, ability, cooperation and coordination, alliance formation, risk participation, and profit distribution. The feasibility and consistency of the method are verified by comparing it with the best-worst method (BWM) and random multi-criteria acceptability analysis (SMAA). Provide a reliable basis for the study of risk factors. Chebotareva et al. [3] used the specific energy Logit model to evaluate the external and internal factors affecting the default of Russia's RES project. Study risk dynamics at different stages of the life cycle of renewable energy projects and assess the effectiveness of national measures to support the renewable energy industry. To provide direction for studying the risk factors of energy enterprises. Su et al. [4] used a multi-level fuzzy global valuation method to assess the financial risks of new energy-listed companies. They applied the model to rank the impact of B-type new energy companies on their financial risks. Wu et al. [5]

established the risk assessment model for energy contract management projects using the enhanced hierarchy method and the fuzzy global evaluation method and took the energy contract management project implemented by China Petroleum Ningxia Petrochemical Company as an example of risk assessment. In recent years, many scholars have used ISM (Interpretative Structure Method)-MICMAC (Cross-Impact Matrix Multiplication Applied to Classification) model to analyze the relationship between complex system factors and the dependence and driving force between variables. Li and Yuan [6] studied the green transformation mechanism of the manufacturing industry based on the ISM-MICMAC model. Zhao et al. [7] studied the use of early warning indicators for power grid companies through the ISM-MICMAC model. The ISM-MICMAC model's applicability in identifying risk factors in energy enterprises is demonstrated.

In summary, energy business risk research has accumulated rich results, but there needs to be more systematic path analysis and research on the correlation between risks. Given this, this paper constructs 17 financial risk index systems of energy enterprises from internal and external dimensions, constructs the financial risk path model of China's energy enterprises using ISM, and explores the relationship and path between various factors. MICMAC was used to classify the influencing factors. Through the analysis of different levels, the direct and indirect factors affecting the financial risk of energy enterprises can be understood more intuitively and clearly by observing the hierarchy diagram and the interpretative structural model diagram. Moreover, put forward corresponding countermeasures to explain the financial risk path of Chinese energy enterprises. The research results will be of great significance to the risk response of Chinese energy enterprises and provide a practical reference for studying the enterprise risk path.

## **2. Construction of a Financial Risk Index System for Energy Enterprises**

### **2.1. Construction of external factors index system**

The spillover effect of external factors on systemic financial risk is driven by stock market volatility and investor sentiment toward financial markets. In contrast, energy market risk and exchange rate changes have a significant but short-term impact. Risk recurrence among energy companies is higher, from 70.7% (Petrobras) to 92.7% (Total Financial Elf), with an overall system average of 84.7%. Compared with the stock market spillover effect (39.5%), global banks (78%), credit spreads (74.78%), or exchange rates (76%), the number of energy companies is more significant. Among them, the occurrence of force majeure factors such as the Russo-Ukrainian War, the Sino-US trade war (2018), and the outbreak of COVID-19 (2020) will lead to an increase in systemic risks. The systematic impact of rising raw material prices and company-level risks in the energy industry.

Among them, there is a negative significant cross relationship when the market risk increases, when the stock market is in a bullish state, and the clean energy index is in a bearish state. Among them, the deterioration of the economic environment and the increase of external credit default risk have damaged the productivity of the energy industry, resulting in a sharp decline in corporate income and increased competition in the industry. These companies must pay fixed costs and expenses, leading to poor business performance. The performance of companies with impaired goodwill is negatively affected by COVID-19, which is closely related to the business risks brought by goodwill. As shown in Table 1.

**Table 1.** External factors of energy enterprises

Secondary Indicators	Tertiary Indicators	Code	Reference
Exterior	Increased systemic financial risk spillover	S1	[8]
	Deteriorating economic environment	S2	[9][10]
	Increased external credit default risk	S3	[11]
	Increased market risk	S4	[10]
	Force majeure factors occur	S5	[12]
	Energy enterprise policy dividend disappears	S6	[13]
	Competition within the industry intensifies	S7	[11]
	Raw material prices rise	S8	[12] [14]
	Energy firms hit by sanctions	S9	[15]

**2.2. Construction of internal factors index system**

In the process of enterprise operation, some sensitive data are involved, and some enterprises master monopolistic technology. Such information leakage will lead to a decline in customer credit and the sharp decline in enterprise income.

Financial risk refers to the loss of the company's solvency due to improper financing methods, unreasonable financial structure, poor management of capital assets, and unscientific investment methods, which may lead to the loss of solvency of the company and lead to the decline of investors ' expected returns. As one of the three most active factors in productivity, people are the foundation and key to business success. Talent is vital in the enterprise and is the typical embodiment of enterprise competitiveness. The development and technology of the new energy industry in developing countries such as China are not mature. New energy development faces many difficulties. Therefore, it is of great significance to cultivate new energy engineering talents.

Credit rating is an essential way for investors to continuously understand the company's credit status and an important tool to expose corporate credit risk. In addition, corporate strategy is the basis for business activities, goals, and long-term development. Leaders ' personal decisions are of great significance to the organization's development. As the risk management of the energy supply chain is an important cornerstone to ensure China's energy security, damage to the supply chain will significantly impact enterprises. Because of the unclear rights and responsibilities in the process of enterprise operation, the failure of an internal control system, the failure of audit and risk control departments, and a series of business risks, it may lead to the situation that enterprise operation is difficult to reverse. As ownership structure is the basis of corporate governance structure, the corporate governance structure is the specific form of ownership structure. Different ownership structure determines different organizational structure, which determines the different corporate governance structure, and ultimately determines the behavior and performance of enterprises. As shown in Table 2.

**Table 2.** Internal factors of energy enterprises

Secondary Indicators	Tertiary Indicators	Code	Reference
Interior	Enterprise internal information technology is leaked	S10	[16]
	Internal financial indicators decline	S11	[17]
	Talent Loss in Energy Enterprises	S12	[18]
	Corporate credit rating declined	S13	[19]
	Corporate strategic decision-making errors	S14	[20][21]
	Enterprise supply chain damaged	S15	[22][23]
	Increased business risk	S16	[24]
	Changes in corporate ownership structure	S17	[25]

**3. ISM Method**

ISM is a widely used expert-based systems science method that originated from structural modeling. Since its introduction in 1974 by J. Warfield, it has been extensively used in policy analysis

[26] as well as in risk analysis [27] and recent years in management research [28]. The basic idea of ISM is to decompose a complex system into several subsystems by combing through the practical experience and knowledge of experts and to establish a multi-level structural model, which is clearly and concisely visualized in a directed graph. In this process, it is necessary to analyze the direct and indirect binary relations between factors and factors and map this conceptual model into a directed graph.

**Step1:** This method has been described as the following six steps **Factor Identification**

Identify and list the variables or factors that affect the system considered.

In practical use, the factors considered are often numbered for convenience, Formula (1):

$$S = \{S_1, S_2, S_3, \dots, S_n\} \quad (1)$$

In the formula,  $S_i (i = 1, 2, \dots, n)$  represents the  $i$ -th factor affecting the system.

**Step2: Structural Self-Interaction Matrix Construction**

Consider the variables identified in Step1, and perform pairwise comparisons ( PWC ) between all factors to find or establish contextual relationships between variables and variables, and do further study on these variables.

Structural self-interaction matrix (SSIM) is subsequently constructed for the variables, indicating the pairing relationship between the system variables considered. In the construction of SSIM, we designed a matrix-based questionnaire to evaluate the relationship between every two factors in pair. A panel of experts invited participated in the study of this stage and determined the relationship between each pair of factors according to the following rules.

Four symbols (V,A,X and O) are used to denote the direction of the relationship between the variables ( $i$  and  $j$ ):

(1) If factor ( $i$ ) contributes to factor ( $j$ ), then the panel of experts fills symbol (V) in SSIM;

(2) If factor ( $j$ ) contributes to factor ( $i$ ), then the panel of experts fills symbol (A) in SSIM;

(3) If factor ( $i$ ) contributes to factor ( $j$ ) and vice versa, then the panel of experts fills symbol (X) in SSIM;

(4) If factor ( $i$ ) does not contribute to factor ( $j$ ) and vice versa, then panel of experts fills symbol (O) in SSIM;

(5) The principal diagonal of the SSIM is all filled in with symbol (X);

**Step3: Initial and Final Reachability Matrix Construction**

Firstly, we directly convert the SSIM matrix into zero and one matrix ( ZOM ), that is, the initial reachable matrix ( IRM ), by Boolean operation according to the corresponding rules of the four types of symbols in Step2. The corresponding relationship is as follows :

(1) Symbol (V) in SSIM is corresponded to 1 of ( $i,j$ ) value and 0 of ( $j,i$ ) value in the reachability matrix.

(2) Symbol (A) in SSIM is corresponded to 0 of ( $i,j$ ) value and 1 of ( $j,i$ ) value in the reachability matrix.

(3) Symbol (X) in SSIM is corresponded to 1 of ( $i,j$ ) value and 1 of ( $j,i$ ) value in the reachability matrix.

(4) Symbol (O) in SSIM is corresponded to 0 of ( $i,j$ ) value and 0 of ( $j,i$ ) value in the reachability matrix.

Furthermore, in addition to the direct binary effect between factors, the logical transitivity of the relationship between different factors also needs to be considered and checked. In addition, at this stage, the validity of expert opinion is also taken into account, and potentially inconsistent places of ZOM are revised to create a reliable matrix for further study, called the Final Reachability Matrix ( FRM ). The FRM matrix is the center of subsequent research.

**Step4: Level partitions**

Divide FRM obtained in Step 4 into different levels. The rules for dividing levels are as follows :

- (1) First of all, derive reachability sets and antecedent sets for each factor in FRM. Both of reachability set and antecedent set include the factor itself. Besides, the reachability set also contains the other factors that it may affect, and the antecedent set includes the other factors that may have an impact on it.
- (2) Afterwards, the intersection of the reachability set and the antecedent set of all factors is derived in order to determine the hierarchy of the different factors.
- (3) For variables with exactly the same reachability set and intersection set, they are assigned the top-level in the ISM hierarchy, which will not lead the other factors above their own level in the hierarchy. Thereafter, the top-level variables are removed from the consideration for subsequent hierarchical division ;
- (4) The same operation is performed on the matrix after eliminating the top-level variables, and the iterative process continues until each variable is assigned its corresponding level;

**Step5: Drawing of directed graph**

According to the contextual relationships between the variables identified in Steps 1-3 and the partition levels obtained in Step 4, a preliminary directed graph containing transitive links is obtained, which is composed of nodes and edge lines. And then in order to obtain the final directed graph, all indirect transitive links ought to be removed.

Nodes and edges represent factors and their interdependence respectively, that is, directed graphs are visual representations of factors and their interdependence. In the figure, the top-level factors are placed at the top of the directed graph, the second-level factors are placed at the second level, and so on until the bottom-level factors are placed at the lowest point of the directed graph.

**Step6: ISM Model Construction**

By replacing the factor nodes with the statement of factors in the directed graph established in Step5, the final ISM model is obtained. Review the ISM to check possible conceptual inconsistencies and make necessary modifications.

**4. MICMAC Method**

MICMAC analysis refers to the cross-impact matrix multiplication applied to classification, which was developed by Duperrin and Godet (1973) [30]. The MICMAC method allows a simple way to identify complex problems [31]. It is often used to analyze the indirect relationship between elements in a system and is widely considered as an important management tool for in-depth analysis of the system. The main purpose of MICMAC analysis is to classify the factors according to the size of the driving and dependence power based on the characteristics of matrix multiplication and determine the key variables of the driving system. And the premise of MICMAC analysis is to obtain the FRM matrix first.

In practical applications, the ISM method is usually used to obtain the FRM (final reachability matrix), and then the driving power and dependence power of each factor are calculated based on the FRM. The driving power  $DR(i)$  refers to the degree of influence of the facctor on other factors, and the dependence power  $DE(j)$  refers to t the degree of influence of other factors on the factor. The two can be calculated as follows: Formula (2) (where  $a_{ij}$  is the element of line and column j in the FRM matrix):

$$\begin{cases} DR(i) = a_{i.} = \sum_{j=1}^n a_{ij} \\ DE(j) = a_{.j} = \sum_{i=1}^m a_{ij} \end{cases} \quad (2)$$

According to different driving force and dependence, all factors considered can be divided into the following four categories [32] and plotted on the graph (Fig.1).

**Autonomous quadrant:** The variables in Quadrant-I are autonomous variables with weak driving force and weak dependence. These variables are less attached to the system and can be disconnected from the system; **Dependent quadrant:** The variables in Quadrant-II consist of dependent variables with weak driving potentials but strong dependency power, which are usually at the top of the ISM model. **Linkage quadrant:** The variables in Quadrant-III are the Linkage variables with strong driving power, and also have strong dependence power. They play a connecting role in the system, usually located in the middle of the ISM model. **Independent quadrant:** The variables in the Quadrant-IV include independent variables with strong driving force but weak dependence power, which are at the bottom of the ISM model.

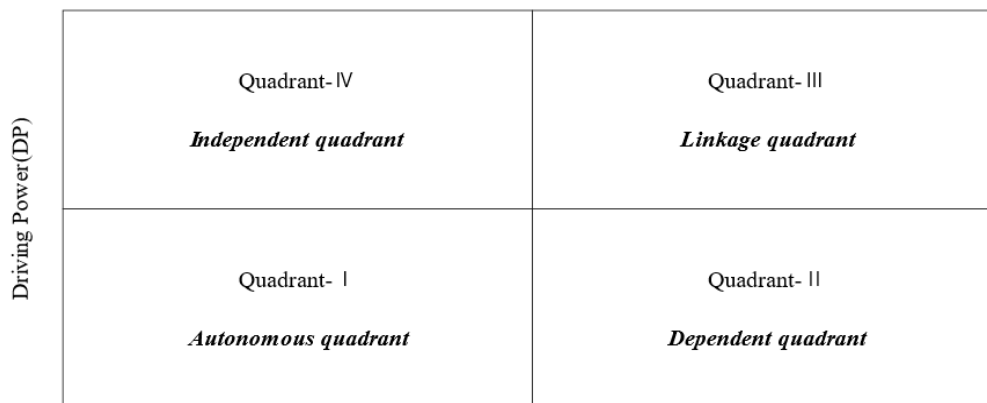


Figure 1. Driving and dependence power diagram

## 5. Model Application and Analysis

### 5.1. ISM Analysis

After extensive consultation with internal managers of energy companies, relevant research scholars, and internal discussions within the ISM group, the study determines whether there is a direct impact between the two elements, based on which the adjacency matrix A is constructed. The construction rule is: if the elements have a direct impact, the matrix internal value is 1, otherwise the value is 0. The adjacency matrix constructed according to this logic is shown in Table 3 :

Table 3. Adjacency matrix A

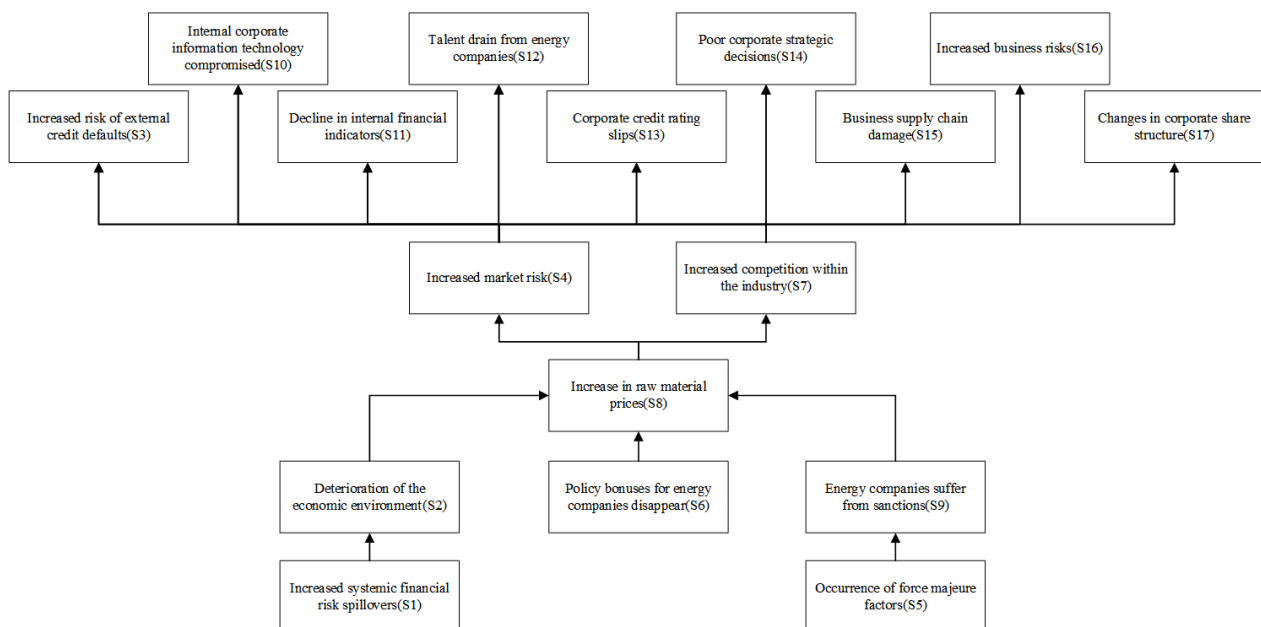
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
S1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0
S2	0	0	1	1	0	0	1	1	0	0	0	1	1	0	1	1	0
S3	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0
S4	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	1	0
S5	0	1	0	1	0	0	0	1	1	0	0	0	0	0	1	1	0
S6	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1	0	1
S7	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	0
S8	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0
S9	0	0	0	1	0	0	1	1	0	0	1	1	0	0	1	1	1
S10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
S11	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0
S12	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
S13	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1
S14	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1
S15	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
S16	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
S17	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0

Based on the adjacency matrix, using Boolean algebra operation rules, the process is calculated by MATLAB software, and the reachable matrix M is generated. The 01 value of matrix M reflects whether there is a path of factors influencing factors. Reachable matrix M as shown in Table 4.

**Table 4.** Reachable matrix M

	S1	S2	S3	S4	S5	S6	S7	S8	S10	S11	S12	S13	S14	S15	S16	S17
S1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1
S2	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1
S3	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1
S4	0	0	1	1	0	0	1	0	1	1	1	1	1	1	1	1
S5	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
S6	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1
S7	0	0	1	1	0	0	1	0	1	1	1	1	1	1	1	1
S8	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1
S9	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1
S10	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1
S11	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1
S12	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1
S13	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1
S14	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1
S15	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1
S16	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1
S17	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1

According to the reachability matrix to determine the hierarchical relationship between factors, it can be divided into five levels, thus constructing the ISM hierarchical framework of financial risk influencing factors of Chinese energy enterprises, as shown in Figure 2:



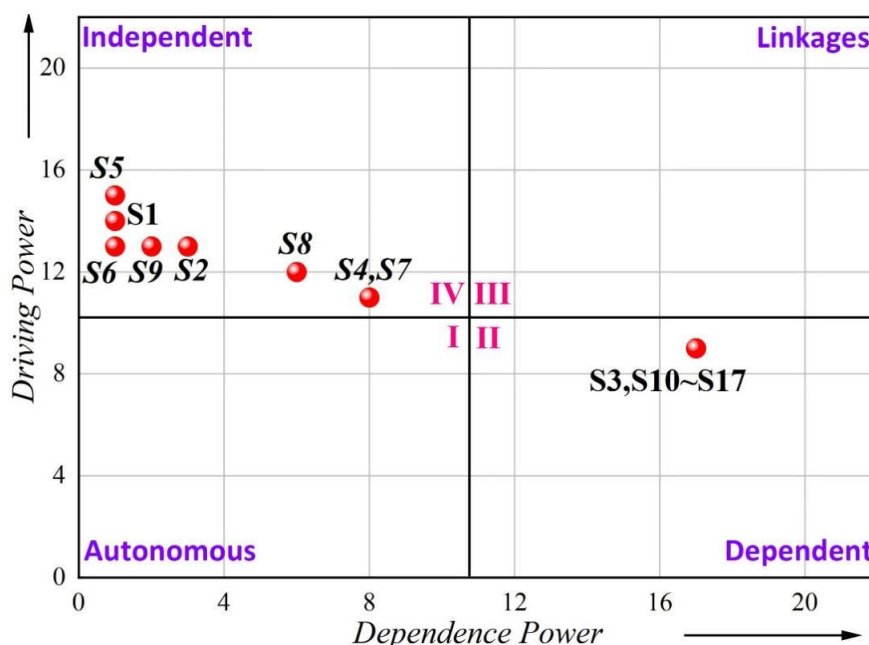
**Figure 2.** Hierarchical Framework of Financial Risk Factors of Chinese Energy Enterprises

As shown in Figure 2, the financial risk influencing factors of energy enterprises constitute a five-level system, and there is a transmission path within it. The top-level elements include nine factors : S3, S10, S11, S12, S13, S14, S15, S16 and S17. Most of the elements in this layer are internal factors of enterprises, which are the direct causes of financial risks for enterprises. At the same time, they are also the ultimate impact target of the path, and there is an interactive relationship between them. The second and third layers of the model are transitional elements, including S4 and S7, which connect the fundamental causes of the bottom layer with the direct influencing factors of the top layer and are

the influencing paths in the model. The fourth and the fifth layer elements are the essential macro elements, including S8, S2, S6, S9, S1, and S5, which are all basic influencing factors, closely related to the economic environment and belong to the deeper root causes, which affect the top-level goals by affecting the transition elements. With the help of the ISM interpretative structural model, we have divided the main influencing factors into levels and obtained the action path between the various elements.

### 5.2. MICMAC Analysis

Based on the reachability matrix  $M$ , the dependence and driving force of each element can be obtained by using the cross-influence matrix multiplication (MICMAC): the dependence is the sum of the elements of the element in the corresponding column of the reachability matrix  $M$ , that is, the element depends on how many elements in the system; the driving force is the sum of the corresponding row elements of the element, that is, how many elements in the system can be driven by the element. The average value of the dependence and driving force of the 17 elements is 10.76. The error line of the average value is used as the dividing line to distinguish four quadrants: independence, dependence, linkage, and spontaneity. The resulting Power map is shown in Figure 3.



**Figure 3.** Energy enterprise financial risk factors MICMAC analysis quadrant diagram

As shown in Figure 3, the influencing factors in the model can be divided into two categories: dependent cluster factors in the second quadrant and spontaneous cluster factors in the fourth quadrant.

There are 9 dependent cluster elements in the second quadrant: S3, S10 ~ S17. S3 is the increase of external credit default risk, S10 ~ S17 belong to the internal factors of the enterprise, all of which have high dependence. These factors are located at the top of the ISM model and need to be driven by other factors to have a direct impact on the financial risk of energy enterprises. When solving this kind of problem, other factors need to be considered first. The industry environment such as increased overall market risk and excessive competition will lead to external.

There are 8 spontaneous cluster elements in the fourth quadrant: S1, S2, S4 ~ S9. S1, S2 are macroeconomic environment factors, S5 is force majeure events, and S4, S6 ~ S9 are the influencing factors of the energy industry, which have a high driving force and low dependence. Among them, S1 and S5 have the highest driving force and are at the bottom of the ISM model, which is the root cause of the impact path. The increase in systemic financial risk spillover leads to financial market volatility and has a significant impact on the stability and large-scale trading of the energy market. Force majeure events, such as the Russo-Ukrainian War, have had a huge impact on international energy trade and are also a huge challenge to the financial stability of today's energy companies. The

two jointly drive internal competition at the energy industry level, raw material prices, and other factors, which have an impact on individual enterprise factors. To prevent and control financial risks, we should pay more attention to the financial system and the international situation, take preventive measures, and timely control the risk spillover to the energy industry from the root of the transmission mechanism.

In summary, internal factors such as the increase of external credit default risk and the leakage of internal information technology depend on the strong driving force of external factors such as the increase of systemic financial risk spillover. The latter is the basic cause of corporate financial risk, by affecting the former; the former is highly dependent, often because of the latter transmission effect directly on energy companies. Thus, we identify the transmission path of financial risk factors of energy enterprises.

## 6. Conclusions

(1) Among the external factors. Increased external credit default risk (S3) is the top-level factor that directly affects the financial risk of energy enterprises, which possesses weak driving potential and strong dependence power. In addition, all other external factors are independent factors, with strong driving force and weak dependence power. Furthermore, increased systemic financial risk spillover (S1) and Force majeure factors occur (S5) are the core underlying factors affecting financial risks, and have the greatest impact on other factors.

(2) Raw material prices rise (S8) is at the highest centrality of all influencing factors and is a key aspect of managing corporate financial risk. The other five external factors: Deteriorating economic environment (S2), Increased market risk (S4), Energy enterprise policy dividend disappears (S6), Competition within the industry intensifies (S7), and Energy firms hit by sanctions (S9) are in the middle level with medium driving force and weak dependency. While compared with external factors, all internal factors from S10 to S17 are top-level factors with low driving power and high dependence power, which are the direct influencing factors of corporate financial risk.

(3) The research in this paper is helpful for Chinese energy enterprises to avoid and prevent financial risks in advance, it will be more meaningful to focus on the spillover of relevant systemic risks of energy enterprises, policy measures and raw material prices.

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