Risk Assessment Indicators for Technology Enterprises: From the Perspective of Complex Networks

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1 Introduction

In recent years, the technology industry has adopted different business models from the traditional industry to increase market share and pursue future excess returns as far as possible (Rometty, 2006; Johnson et al., 2008). These companies have built their strength through free services, cash subsidies and the acquisition of new companies. The technology companies' business model assumes that value is created not only by producers but also by customers and other members of the ecosystem. From this perspective, enterprises in the Internet industry only need to make strategic investments and acquisitions in a series of fields to acquire businesses and users in this field, and through these businesses to lay out infrastructure construction and serve existing users, so as to strengthen their position in the digital economy. This business model concept challenges the assumptions of traditional value creation and value acquisition theories (Shuhidan et al., 2016), and further promotes more technology enterprises to gain monopoly status through similar frequent acquisitions and investments. However, the continuous investment and acquisition of these technology enterprises does not take profit as the first purpose, but depends on whether the field can provide infrastructure, technology, service or product supporting services for its core business development, which leads to the fact that the acquired technology-based companies are often unable to make profits now or even in the future (Carpenter et al., 2003).

The risks in the technology industry are mainly concentrated in law, equity, technology, management, etc. (Etges et al., 2017; Trott, 2012). For example, S Romanosky et al. (2019) considered data leakage and security incidents caused by

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technical problems of technology companies, which led to legal lawsuits. Therefore, they considered the way of network construction to study loss insurance. Tu et al. (2014) studied the risks implied in supply chain management of technology enterprises and found that supply chain management ability was closely related to innovation ability. Teece et al. (2016) used traditional economic methods to explain the uncertain risks of scientific and technological innovation enterprises. There are also domestic research on the related risks of science and technology enterprises.

In a large number of risk researches on technology companies, the data used are mostly from income statement, cash flow statement, balance sheet and other data in financial statements. But clearly, these quantitative content is not the only factor to measure the enterprise risk, the information in the financial reports of enterprises not only includes the disclosure of the objectivity of digital information, also including the enterprise risk assessment of board, management and analyst, so the evaluation cannot be measured only by objective of digital information. Our target is to combine these abstract narratives with the quantitative information in the financial statements, to explore the hidden relationships therein, and to explain the unique risk characteristics of technology enterprises. Specifically, the political Outlines, risk descriptions and strategic developments in financial reports are often communicated to investors through written statements that are difficult to quantify in risk studies and have not been taken into account in previous studies.

Therefore, this study using the results of the abstract text messages to build risk network of enterprise technology, by focusing on analysis of financial report for risk, strategy, such as content description, we put this kind of non Euclidean domain in the form of data processing for containing the network relations, the network contains a risk of infection probability, the probability of infection and the total risk associated. In the past, a large number of enterprise risk studies were mainly based on stock price, daily return rate and other securities market information (Sakamoto & Vodenska, 2017; Xu et al., 2017).

Therefore, the analysis of abstract text information in financial statements to build risk network is the first contribution of this paper. The second contribution of this paper is to extract the most significant risk factors of science and technology enterprises through the analysis of network characteristics, and construct the RLC risk measurement index based on these risks. In order to prove the effectiveness of the indicators, this paper selects the financial reporting data of global top100 technology enterprises to verify the correlation with risk measurement indicators (RLC). The experiment shows that the net income of technology enterprises is significantly negatively correlated with RLC risk index, that is to say, the higher the risk level factor of technology enterprises is, the lower the net income of enterprises will be. In addition, the model can predict the future net income level of enterprises through the risk level coefficient, and the risk level factor has a significant negative correlation with the stock price. Through this study, the management level, government regulatory departments and legislative organs of technology enterprises can better understand the nature of the correlation between development and risks of technology enterprises, and take actions to manage and avoid the risks of technology enterprises according to the actual needs of macroeconomic development.

2 Risk Network Construction

Based on the classic method of complex networks (Albert & Barabási, 2002; Boccaletti et al., 2006), define the risk of science and technology enterprises association network consists of two basic elements: node v e and the associated way, it will be deemed v v collections, as a collection of e, e and e of each side (association) has a v e a pair of point (I, j) and the matching, then the whole network can use the symbol G = (v, e). If G has n nodes, it is denoted as V = (1, 2 ..., n), and suppose.

The network can be completely described by the matrix $G = (g_{ij})_{n \times n}$. At the same time, because the complex system is a typical directed network, it can be judged that $G = (g_{ij})_{n \times n}$ is an asymmetric matrix.

For the degree k_i of node v_i in the network, it is defined as the number of edges connected to the node: $k_i = \sum_{j=1}^{n} g_{ij}$. Namely, the connection probability between a new node and the original node.

In the same way, the probability of edges connected by a node is: $P(k_i)^{\rightarrow} = \frac{k_i{}^{\rightarrow}}{\sum_j k_j}$, the value represents the infection intensity of a node. From scientific and technological enterprise internal risk evolution mechanism analysis, suppose the system unstable state is only one risk source i before, if the risk source i can lead to other risks occurred one after another, the influence of the risk source i ability stronger, namely $P(k_i)^{\rightarrow}$ value is higher. This indicates that the more likely a risk factor is to play a risk-induced role in the system, the more attention should be paid to it. On the contrary, a low value indicates that a node has less influence on the outside world.

However, the true contagion capacity of risk sources must also take into account the vulnerability of other nodes in the whole risk system. Therefore, the probability of nodes being connected is also required: $P(k_i)^{\leftarrow} = \frac{k_i{}^{\leftarrow}}{\sum_j k_j}$, which represents the sensitivity of a node to attack. The larger the value is, the more vulnerable the node is to infection by other risks, and conversely, the less susceptible it is to infection by outsiders. Referring to previous studies (Xu et al., 2020), the core mechanism of network construction in this paper is to determine whether there is a direct induction relationship between different risk factors. If there is a direct infection, then the directed circuit of both sides of the infection will be established.

Liu (2012) defined emotional analysis as the research field of analyzing people's views, emotions, evaluations, attitudes and emotions on entities such as products, services, individuals, organizations, events, issues, topics and their attributes. In fact, the environmental and linguistic differences between the author and the reader make emotional analysis an extremely difficult task.

This paper focuses on the evaluation of corporate risk, development and future expectations by the board of directors, management and analysts in corporate financial statements. These texts are mixed with political overview, risk description, development strategy and other contents. According to the method of literature induction, the statement of "pointing nature" about risks in the financial report was sorted out (as shown in Table 1), relevant nodes were extracted, and a network was

Table 1 Sample node extraction

Original financial statement (case)	Semantic analysis
Breaches of our cybersecurity measures could result in unauthorized access to our systems, misappropriation of information or data, deletion or modification of user information, or a denial-of-service or other interruption to our business operations.	Business risk – network security vulnerability
	Operational risk – data privacy risk
	Legal risk – consumer complaint risk
Our revenue growth also depends on our ability to continue to grow our core businesses as well as businesses we have acquired.	Business risk – critical business service capabilities
	Investment risk – acquisition, investment, alliance risk
We may also face protectionist policies that could, among other things, hinder our ability to execute our business strategies and put us at a competitive disadvantage relative to domestic companies in other jurisdictions.	Legal risk – constraint risk
	Operational risk – international business capability risk
If we are not able to continue to innovate or if we fail to adapt to changes in our industry, our business, financial condition and results of operations would be materially and adversely affected.	Investment risk – innovation and industry change risk
We face risks relating to our acquisitions, investments and alliances.	Investment risk – acquisition, investment, alliance risk

constructed according to the relationship between nodes, with a total of 660 nodes and 840 edges. All the nodes in the network are from the risks mentioned in the financial report, and the connections in the network are from the language expressed by the analyst. The extraction process is shown in Fig. 1.

Since most technology companies choose to go public in the United States, the financial report data is referred to (https://www.sec.gov). The semantic analysis of this paper relies on Alibaba's 2019 financial statements. According to the results of semantic analysis, the network diagram (Fig. 2) is constructed, and corresponding annotation is made for significant risk factors. In addition, for convenience of analysis, this paper ranks the risk amount (Degree), risk contagion amount (Outdegree) and risk infected amount (Indegree).

Based on the analysis of the above three networks, we summarize the important risk nodes under the three conditions of connectivity, connectivity, and connectivity as legal risk, business risk, investment risk, and operational risk.

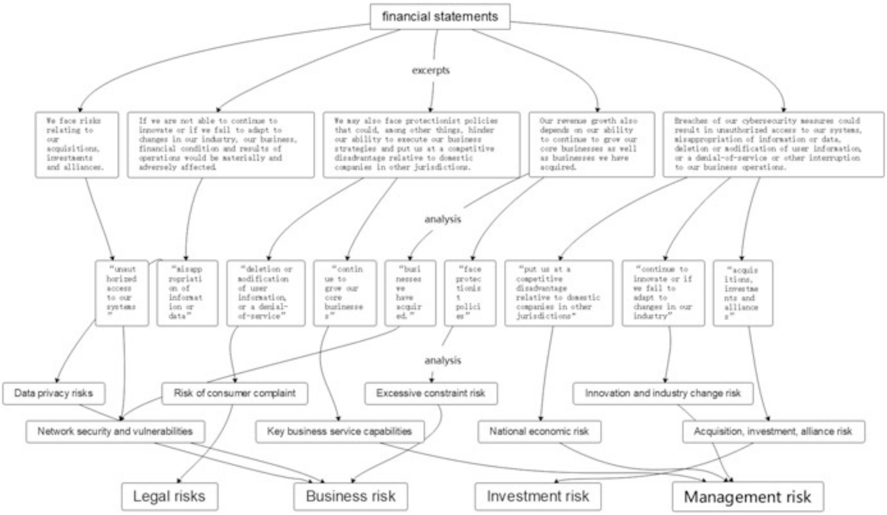

Fig. 1 Node extraction process diagram

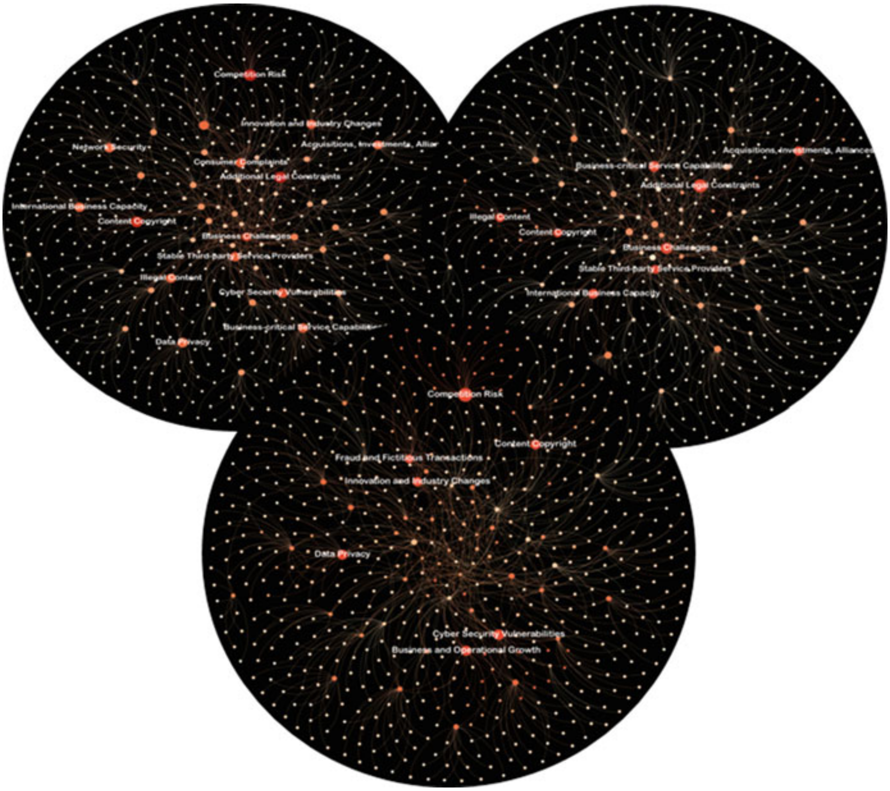

Fig. 2 Risk relational, risk relational of connectivity and Risk relationship of outliers

3 Construction of Risk Metrics

Through semantic analysis of the text data in the financial report, this paper constructs the risk network, and sorts the degree of connectivity, connectivity and degree of the network, and finally extracts the four categories of legal risk, business risk, investment risk and operational risk as the significant risk sources.

1. Legal risk indicators

Too many lawsuits will seriously affect the business development, income level and market competition of technology enterprises. As for the legal risk, this paper takes the number of legal proceedings as the risk faced by technology enterprises under the legal environment. Tech companies, for example, had the highest number of lawsuits of any industry, according to SEC data, suggesting the sector faces higher legal exposure than other sectors. We consider that laws are mainly made by national judicial departments and regulatory departments, so in general, this type of risk belongs to the category of external risks. Therefore, this paper adopts the annual litigation growth rate of the technology industry to reflect the external risks faced by enterprises. To be specific, the higher the rate of litigation in the industry, the greater the risk faced by the enterprise.

2. Business risk indicators

Business risks include business problems caused by technical problems in science and technology enterprises. For example, the main business of science and technology enterprises will cease to be serviced due to technical problems, which will have a great impact on science and technology enterprises. Business risks also include the decline of market share in the process of business development due to competition, industry changes and other reasons. Combining these two points, we use the growth rate of operating income to reflect the business risk. When using this indicator, we consider that the decline in business growth rate may be due to the smaller growth space caused by the size of the enterprise itself. However, the actual technology industry often chooses to expand new businesses to avoid the “ceiling” problem of a certain business. Therefore, the decline in business growth rate can still indicate the potential risks faced by enterprises.

3. Investment risk indicators

Technology companies are using strategic investments and acquisitions in a range of sectors to strengthen their leadership in the digital economy. These investments and acquisitions are not for profit in the first place, but depend on whether the field is relevant to the current primary business or whether it provides the infrastructure, technology, services or products for its business development. However, such strategic investments and acquisitions continue to adversely affect the financial performance of Alibaba’s technology businesses. For example, buy companies with low margins or losses that may not make a profit at all in the future. To this end, we use the ratio of net cash flow generated by investment activities to capital to reflect the investment risk of enterprises. The bigger this index is, the greater the risk of investment and merger will be.

4. Indicators of operational risk

Business risk refers to the change of market value caused by the change of production and operation in external environment of science and technology enterprises, which affects the change of future cash flow of science and technology enterprises. The management risk of the technology industry on the one hand, mainly comes from general complex and changeful market environment, on the other hand, in general, the cycle of the product is through the start-up stage, growth stage, mature stage and decline stage, but the products of science and technology cycle is compactness, initial risk big, the investment is more, other companies are scrambling to imitate and high speed of knowledge update makes the products in the recession time is shorter, thus entered a new round of cycle. Therefore, this paper USES the ratio of net cash flow generated from operating activities to total capital to reflect the operating risk of an enterprise. This index reflects the amount of each capital invested in operating activities. The bigger the index is, the greater the operating risk is.

In addition, the objective of this paper is to build a comprehensive index to reflect the risk quantification situation of science and technology enterprises, so we use dimension reduction method to reasonably constitute the unified index of these four types of risks to objectively reflect the real risk situation of enterprises. In order to make the comprehensive index lose as little information as possible in the original variables, so as to achieve the purpose of comprehensive analysis of the collected data, principal component analysis (PCA) is adopted to achieve dimensionality reduction of the four risk dimensions. Suppose there are n samples, and each sample has p variables, thus an $n \times p$ matrix is formed:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1p} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{np} \end{bmatrix}$$

The original variables are $x_1, x_2 \cdots, x_p$, and the comprehensive index is set as q_1, $q_2 \cdots, q_k$ $(p \leq k)$, then

$$\begin{cases} q_1 = l_{11}x_1 + l_{12}x_2 + \cdots + l_{1p}x_p \\ q_2 = l_{21}x_1 + l_{22}x_2 + \cdots + l_{2p}x_p \\ \cdots\cdots \\ q_k = l_{k1}x_1 + l_{k2}x_2 + \cdots + l_{kp}x_p. \end{cases}$$

l_{ij} shall satisfy the following conditions:

Table 2 KMO and Bit spherical inspection

KMO	0.582	
Bartlett	Approx. Chi-Square	240.738
	df	6
	Sig.	0

Table 3 Common factor variance

	Initial	Extract
Litigation growth rate	1	0.725
Increase rate of main business revenue	1	0.459
Investment efficiency	1	0.469
Operational efficiency	1	0.624

1. q_i is not related to q_j, where $i \neq j$ and $i, j = 1, 2 \cdots, k$
2. q_1 is the largest deviation of all linear combinations of $x_1, x_2 \cdots, x_p$, q_2 is the largest deviation of all linear combinations of $x_1, x_2 \cdots, x_p$ independent of q_1, and by the same way, q_k is the largest deviation of all linear combinations of x_1, $x_2 \cdots, x_p$ independent of $q_1, q_2 \cdots, q_{k-1}$.

Then the comprehensive variable $q_1, q_2 \cdots, q_k$ is called the principal component variable of the original variable $x_1, x_2 \cdots, x_p$.

Determine the load l_{ij} of each synthetic variable q_i on all original variables $x_1, x_2 \cdots, x_p$, and get the score of each synthetic variable. Then, according to the relevant literature, the variance contribution rate of each index was calculated to calculate the comprehensive score of each enterprise so as to measure the risk of each enterprise:

$$RLC = \frac{\omega_1}{\sum_{i=1}^{k} \omega_i} q_1 + \frac{\omega_2}{\sum_{i=1}^{k} \omega_i} q_2 \cdots + \frac{\omega_k}{\sum_{i=1}^{k} \omega_i} q_k \quad (1)$$

The ω_i is the variance contribution rate of the comprehensive variable q_i.

The premise of principal component analysis is to preprocess the data and conduct correlation test to determine whether this method can be used for analysis. According to Bartlett test, P value is less than 0.05 and KMO value is greater than 0.5, which basically meets the requirements. Principal component analysis can be performed, and the test results are shown in Table 2. In addition, Table 3 shows the common degree data of all variables and the information extraction of the original variable by the new factor. The common degree value of all the original variables is higher than 0.4, which means that the original variable has a strong correlation with the new factor and the factor can effectively extract the information.

In this paper, according to the extraction principle of eigenvalues greater than 1, variance contribution rate and cumulative variance contribution rate of initial common factor eigenvalues are solved according to principal component analysis, and the number of common factors is determined by variance analysis. Table 4 shows that the eigenvalues of the first two factors are greater than 1, so the principal components of the first two factors are extracted for evaluation as comprehensive factors.

Table 4 Population variance explained by factors

	Initial eigenvalues			Extract the sum of squares and load			Sum of squares of rotation loaded		
Element	Total	% of the variance	Cumulative %	Total	% of the variance	Cumulative %	Total	% of the variance	Cumulative %
1	1.261	31.535	31.535	1.261	31.535	31.535	1.233	30.823	30.823
2	1.015	25.374	56.909	1.015	25.374	56.909	1.043	26.086	56.909
3	0.977	24.414	81.323						
4	0.747	18.677	100.00						

Table 5 Component score coefficient

	Factor1	Factor2	Factor3	Factor4
F1	0.217	0.248	0.559	−0.628
F2	0.809	−0.538	0.119	0.074

Table 5 shows the component score coefficient matrix. Through this matrix, the scores of two comprehensive factors can be calculated, namely:

$$\begin{cases} F_1 = 0.217x_1 + 0.28x_2 + 0.559x_3 - 0.628x_4 \\ F_2 = 0.809x_1 + 0.538x_2 + 0.119x_3 - 0.074x_4 \end{cases} \tag{2)–(3}$$

Where x_1 is the growth rate of litigation, x_2 is the growth rate of operating income, x_3 is the net cash flow generated from investment activities/total assets, and x_4 is the net cash flow generated from operating activities/total assets.

The new two factors reflect the enterprise risk level from different aspects, and it is difficult to make a comprehensive evaluation by using a single common factor. Therefore, the comprehensive score is considered to be calculated according to the variance contribution rate corresponding to each common factor as the weight, that is, the required risk factor coefficient (RLC) is obtained:

$$RLC = \frac{30.823}{56.909} \times F_1 + \frac{26.086}{56.909} \times F_2 = 0.489x_1 - 0.113x_2 + 0.353x_3 - 0.31x_4 \tag{4}$$

4 Empirical Test of Risk Metrics

In this paper, risk level factors are obtained based on risk network construction, and risk measurement index (RLC) is obtained accordingly. In order to verify the scientific nature of this index, this paper analyzes and studies the correlation between the development level of science and technology enterprises and RLC. The data takes the global top100 technology companies by market capitalization as samples, and adopts the financial statements and stock price data from 2005 to 2019. The data are obtained from the Wind database and the open data set published by the us securities commission.

In terms of variables, the development level of an enterprise adopts net income, which reflects the total profit of an enterprise, that is, the income or income balance after deducting business costs, taxes and other expenses from the total income, which can directly reflect the development status of an enterprise. The control variable is the logarithmic form of assets and the r&d investment level of the enterprise (R&D expense/asset). The r&d investment level will inevitably affect the development of the enterprise. The success of r&d investment may bring qualitative development to the enterprise, while the failure will bring capital loss to the enterprise, which will have an impact on the development of the enterprise.

Table 6 Regression results

Variable	Net income
RLC	-1.647^{***} (−2.734)
Ln(assets)	24.837^{***} (17.245)
R&D/Assets	101.261^{***} (2.568)
Constant	-559.604^{***} (−15.836)
Observations	1170
Adjusted R-squared	0.294
RLC/RLC	1
Stock Price/RLC	-0.081^{***}

Note: ***, ** and * mean significant at the level of 1%, 5% and 10%, respectively. The value of t is in parentheses

Therefore, the following model is constructed:

$$\text{Net Income} = \alpha + \beta \text{RLC} + \gamma \text{R}\&D/\text{Assets} + \delta \text{Ln}\,(\text{Assets}) \tag{5}$$

Table 6 reflects the results of regression and correlation analysis. The experiment shows that the net income of enterprises is significantly negatively correlated with RLC, that is, the higher the risk level factor of enterprises is, the lower the net income of enterprises will be. Through this model, we can predict the net income level of enterprises through the risk level coefficient, and the risk level factor has a significant negative correlation with the stock price.

Table 6 is the results of regression analysis and correlation analysis. Through regression results, the relationship between RLC and the net income of technology enterprises can be obtained:

$$\text{Net Income}= - 1.65 \times \text{RLC}+101.26 \times \text{R}\&D/\text{Assets}+24.84\times \text{Ln}\,(\text{Assets}) -559.6 \tag{6}$$

According to the experiment, the net income of science and technology enterprises is significantly negatively correlated with RLC, that is, the higher the risk level factor of enterprises is, the lower the net income of enterprises is, which is consistent with the generally recognized relationship between risk and return. Moreover, it can be seen from this model that the risk level coefficient can accurately predict the net income level of science and technology enterprises, and the risk level factor has a significant negative correlation with the stock price, so this index is scientific to a certain extent.

The rapid development of science and technology enterprises is bound to be accompanied by the acquisition and investment of other enterprises, so as to enhance their comprehensive strength, but at the same time, it will also bring many hidden dangers, such as labor disputes, legal compliance and other problems. One of these pitfalls, especially for foreign technology firms, can bankrupt a technology firm rather than allow it to expand rapidly. Of course, due to the nature of science and technology enterprises being eliminated without development, domestic science and technology enterprises are bound to choose the world's advanced technologies for their own development. Therefore, domestic science and technology enterprises have to acquire or cooperate with foreign science and technology enterprises. Hidden dangers such as legal compliance and copyright will have a huge negative impact on enterprises. It is worth noting that the acquisition and investment behaviors of science and technology enterprises centering on the development of science and technology do not necessarily promote the growth of their net income. While focusing on innovation and development, science and technology enterprises cannot ignore the hidden dangers in the process.

5 Conclusion

Based on science and technology in the earnings of Euclidean domain data, considering to build the network transmission of infection, infection and risk total three network, combined with the feature of the network to complete the core of many risk factors for the enterprise internal risk source filtering, extracting legal risk, business risk, investment risk, management risk four types. After that, this paper quantifies the four indicators, constructs the risk measurement index (RLC), and calculates the risk quantification results of science and technology enterprises.

In order to prove the scientific nature of the index, this paper selects the net income and stock price of the global top100 technology enterprises to verify the correlation between risk measurement index (RLC). The experiment proves that RLC has a significant negative correlation with corporate net income and stock price, and RLC can predict corporate net income and stock price. In addition, although science and technology enterprises have a high requirement for innovation ability, innovation is not a decisive factor, and the overall risk of science and technology enterprises plays a decisive role in inhibiting the development of enterprises.

Although the technological innovation of technology enterprises may bring huge improvement to the enterprise's net income and stock price, technology enterprises often ignore the risk of copyright and labor disputes that follow the innovative technology, and the inaccurate positioning of mass demand may encounter unpredictable business risks. If technology enterprises only pursue the development of their main business, but blindly invest and acquire, they will misjudge the overall life cycle and thus bring more operational risks. This is still a serious problem in the development process of the world's top technology enterprises. These risks cannot be ignored because of the huge profits brought by a few successful scientific and technological innovations. Therefore, while improving our competitiveness in the industry through scientific and technological innovation, we should also pay attention to the control ability of risks, so as to ensure the healthy and steady development of the scientific and technological industry.

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