Study on risk evaluation of intellectual property pledge loan based on fuzzy analytic hierarchy process

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Abstract. From the six aspects of the risk of intellectual property itself, intellectual property rights technology uses risks, risks of intellectual property laws, intellectual property rights market risk, business risk, macro environment of intellectual property, build a comprehensive intellectual property rights pledge loan risk evaluation index system, and by the fuzzy analytic hierarchy process (ahp) combining qualitative and quantitative, ultimately determine the pledge loan risk level. This paper makes an empirical analysis of the selected cases, and the research results show that the fuzzy analytic hierarchy process can effectively quantify the risk of intellectual property pledge loans, which is conducive to the risk judgment and identification of this kind of pledge loans.

1. Introduction

Intellectual property pledge loan, as a relatively new form of financing, means that enterprises or individuals apply to banks for financing after assessing the intellectual property they legally own. On June 26, 2019, an executive meeting of the State Council pointed out support for expanding intellectual property pledge financing and expanding financing channels for science and technology enterprises. With the increasing calls for solving the financing problems of enterprises, the demand for intellectual property pledge loan business increases substantially. At present, the domestic intellectual property pledge financing operation mode mainly include Beijing mode, Shanghai Pudong mode, Wuhan mode, involving banks, enterprises, government, guarantee companies as the main body. But because of the particularity of the intellectual property, intellectual property pledge loan business is in higher risks compared with the traditional business pledge. Therefore, how to effectively identify and grasp the risk of intellectual property pledge loans has become the key to the development of intellectual property pledge financing business. According to the existing literature, the problem of intellectual property pledge loan mainly focuses on the judgment of various risk factors in the process of intellectual property pledge, and how to control risks after quantifying each risk factor. From the perspective of market environment, Li linqi (2019) analyzed the risk factors that affect ipr guarantee financing of small and medium-sized science and technology enterprises. Yang Qianyu (2014) made a comparative analysis of the legal regulation of intellectual property licensing financing in the United States and proposed a new system construction. Xiao Xia (2018) discussed how to promote IP pledge financing from the perspective of local government. Sang Kaibing (2017) analyzed the dilemma faced by small and micro technology enterprises in IP pledge financing from the aspects of intellectual property, policy system, market risk control and economic subject participation. Yin Xiaonan (2016)
established the risk evaluation model of intellectual property pledge financing from the perspective of financiers by using VIKOR method and ahp theory. In the process of intellectual property pledge, whether a bank lends money to an enterprise depends largely on the bank's assessment of risks. Therefore, it is very necessary to quantify the influencing factors of qualitative risk judgment. Based on previous studies, this paper uses fuzzy analytic hierarchy process to combine qualitative analysis with quantitative analysis. From the six aspects of the risk of intellectual property itself, intellectual property rights technology uses risks, risks of intellectual property laws, intellectual property rights market risk, business risk, macro environment of intellectual property, construct a multi-level risk evaluation structure model, and through risk quantification to provide reference for the risk assessment of intellectual property pledge financing.

2. Factors influencing the risk of intellectual property pledge financing

2.1 Risk factors of intellectual property

Intellectual property is an intangible asset with great uncertainty, so the risk of intellectual property is often the main obstacle to impawn financing. The risks of intellectual property are related to the following factors: 1. The inherent risks of intellectual property. Inherent risk refers to the possibility of misstatement of intellectual property transactions and account balances before considering relevant internal controls. The inherent risk of intellectual property is determined by its inherent nature. Therefore, higher the inherent risk of intellectual property is, higher the risk of pledge financing will be; 2. Core nature of intellectual property. The core nature refers to the degree of intellectual property in enterprise technology. The core of intellectual property is directly related to the profits of enterprises. Therefore, greater the core of intellectual property is, lower the risk of pledge financing will be; 3. Quality of intellectual property. Quality includes economic quality, cultural quality, technical quality and legal quality. High quality can make enterprises form a strong competitive advantage and directly affect the value of intellectual property. Therefore, higher quality of intellectual property is, lower the risk of pledge financing will be; 4. Substitution of intellectual property. Substitutability refers to the degree to which an intellectual property is replaced by other technologies or patents. The stronger the degree of substitution of intellectual property is, the easier it is to be replaced in the market. Therefore, stronger the substitution of intellectual property is, higher the risk of pledge financing will be; 5. Life cycle of intellectual property. Life cycle is divided into four parts: creation, protection, management and operation. It affects the time a competitor enters the market, the company's earnings, and the value of intellectual property. Therefore, longer the life cycle of intellectual property is, lower the risk of pledge financing will be.

2.2 Factors influencing the risk of intellectual property technology utilization

The utilization of intellectual property technology refers to the process in which users seek corresponding competitive advantages or benefits in the process of industrial technology innovation, transfer and diffusion. In this process, a series of risks will be generated, which are related to the following factors: 1. If the degree of perfection of the intellectual property is too low, the smaller the value of transfer, capital contribution, pledge or business operation by the owner or user of the intellectual property will be and the smaller the profit will be. Therefore, the higher the degree of perfection of the intellectual property technology is, the lower the risk of pledge financing will be. 2. Update speed of intellectual property technology. Technology will be along with social development and people demand constantly updated. If the renewal speed of an intellectual property right fails to keep up with the social demand, its competitiveness will be reduced, the demand will be smaller, and the value it brings to the enterprise will be reduced. So the faster the intellectual property right technology is updated, the smaller the pledge financing risk will be.
2.3 Factors influencing the legal risks of intellectual property
At present, the implementation of intellectual property pledge financing business is restricted in many aspects, especially the imperfect laws and regulations, which make it impossible to carry out the business with effective legal protection. There are many contradictions and problems at the legal level, resulting in legal risks, which are related to the following factors: 1. If the ownership relationship of intellectual property is uncertain, the bank will have corresponding legal disputes during the loan. The ownership relationship determines whether the ownership of pledges exists and is effective. Therefore, the more certain the ownership relationship of intellectual property is, the lower the risk of pledge financing will be. 2. Mode of authorization of intellectual property rights. Licensing mode is divided into three ways: general permit, exclusive license and exclusive license. Intellectual property rights of enterprises in different authorization status, with the different scope and strength of will protected by law, the intangible risk also will be different, which leading to differences in profitability of intellectual property. Looser the Intellectual property rights authorized scope is, bigger the pledge financing risk will be. 3. Strength of legal protection of intellectual property rights. If the protection of intellectual property rights is weak, intellectual property rights may be infringed, resulting in decreased profits and increased legal costs. Therefore, stronger the protection of intellectual property rights is, lower the risk of pledge financing will be.

2.4 Factors influencing the risk of intellectual property market
The acceptance of the carrier products of intellectual property in the market affects the profitability of intellectual property. Without the carrier products in the market, it is difficult to create value for enterprises, which increases the risk of intellectual property pledge loan. The risk of intellectual property market caused by market factors is related to the following factors: 1. The supply and demand of the carrier product of intellectual property is the reflection of the market on the supply and demand of intellectual property. When the carrier product is in the buyer's market, the pledge risk is higher. 2. Trading market size. Smaller the scale of intellectual property transaction market is, less applicable the intellectual property and greater the pledge risk will be. 3. The market share of products formed by intellectual property rights. The weaker the monopoly of intellectual property is, the lower the level of innovation, the smaller the market share of products, and the greater the risk of pledge will be. 4. Degree of transferability of intellectual property rights. Intellectual property must be attached to a certain carrier. The stronger its correspondence with the carrier is, the lower the degree of transfer of intellectual property and the greater the risk of pledge will be.

2.5 Factors affecting enterprise risks
The risk of intellectual property pledge loan is affected by the enterprise's financial risk, business risk and credit grade innovation strategy risk. 1. Financial risks. Liquidity risk, credit risk, financing risk and investment risk are important aspects to measure the financial risk of enterprises. The greater the financial risk is, the greater the pledge risk will be. 2. Business risks. The greater the risk of enterprise management is, the greater the risk of pledge will be. 3. Credit rating. The credit rating of an enterprise reflects the level of its credit. The lower the credit rating of an enterprise is, the greater the risk of pledge will be. 4. Strategic risks of enterprise innovation. In small and medium-sized technology-based enterprises, due to the uncertainty of the external environment, their own capacity and the complexity of technological innovation activities, enterprises will face great risks in technological innovation activities. The greater the risk of enterprise's innovation strategy is, the greater the risk of pledge will be.

2.6 Factors influencing macro environmental risks of intellectual property
The influence factors of macro environmental risk of intellectual property include government orientation, interest rate and environmental risk of intellectual property. 1. Government orientation. Government guidance is an important macro factor affecting the risk of intellectual property pledge loans. The active guidance and support of the government can create a good financing environment
and reduce the risk of intellectual property pledge loans for technology-based smes. 2. Interest rate level. The reduction of interest rate is conducive to the reduction of financing costs for enterprises. It not only encourages the development of intellectual property pledge loan business, but also increases the benefit area of financing funds for enterprises. 3. Environmental risks of intellectual property. When the external negative effects of intellectual property technology are too large and the negative effects brought to the society exceed the economic benefits, it will face the risk of being eliminated. The greater the environmental risk of intellectual property technology is, the greater the pledge risk will be.

3. Risk assessment by fuzzy analytic hierarchy process

3.1 Introduction of fuzzy analytic hierarchy process

Fuzzy analytic hierarchy process (fahp) is a systematic analysis method based on the analytic hierarchy process (ahp). It is a systematic analysis method combining qualitative analysis with quantitative analysis proposed by professor T.L. Saaty of American operations research in 1970s. The basic idea of fuzzy analytic hierarchy process (fahp) is to decompose the problem itself according to the nature of multi-objective evaluation problem and the general objective, forming a hierarchical structure from bottom to top. With this method, the impact of each risk factor on the results at each level is quantified and very clear. In the risk assessment, the fuzzy analytic hierarchy process combines the scores of experts. The evaluation results are generally fuzzy, so it is objective and fair to use this method to evaluate the risk of intellectual property pledge financing.

3.2 Specific risk assessment process of fuzzy analytic hierarchy process

3.2.1 Establish a hierarchical model of risk assessment

According to the existing problems in the development of science and technology enterprises, select the above indicators to build the risk assessment index system through literature statistics, news search and enterprise data investigation. As shown in Table 1.

| Table 1. Evaluation index system of intellectual property pledge risk |
|-----------------|-----------------|
| goal level      | level one       |
| Risk of intellectual property pledge loan (K) | Intellectual property risks itself (K1) |
|                 | Inherent risks of intellectual property (K_{11}) |
|                 | The core of intellectual property (K_{12}) |
|                 | Quality of intellectual property (K_{13}) |
|                 | Substitution of intellectual property (K_{14}) |
|                 | The life cycle of intellectual property (K_{15}) |
|                 | Intellectual property technology utilization risk (K2) |
|                 | The degree of perfection of intellectual property technology (K_{21}) |
|                 | Intellectual property technology update speed (K_{22}) |
|                 | Intellectual property legal risks (K3) |
|                 | Ownership of intellectual property rights (K_{31}) |
|                 | The mode of authorization of intellectual property (K_{32}) |
3.2.2 Construct the corresponding judgment matrix

The weight of each level index is determined by expert scoring method. As shown in the above table, the weights corresponding to first-level indicators \( K_1, K_2, K_3, K_4, K_5 \) and \( K_6 \) are \( w_1, w_2, w_3, w_4, w_5, \) and \( w_6 \) meet the following conditions: \( w_1 + w_2 + w_3 + w_4 + w_5 + w_6 = 1 \). The weights corresponding to first-level indicators are written as \( A = (w_1, w_2, w_3, w_4, w_5, w_6) \).

Primary index under the \( K_1 \) index \( K_{11}, K_{12}, K_{13}, K_{14}, K_{15} \) is the weight of corresponding \( w_{11}, w_{12}, w_{13}, w_{14}, w_{15} \), and meet the conditions: \( w_{11} + w_{12} + w_{13} + w_{14} + w_{15} = 1 \), to know the level of the weights for the \( A_1 = (w_{11}, w_{12}, w_{13}, w_{14}, w_{15}) \), the rest of the primary index of each secondary index also set, using the method of the above said their weight were recorded as \( A_1, A_2, A_3, A_4, A_5, A_6 \).

3.2.3 Determine the risk grade scoring criteria

Here, figures are used to scale the relative importance of one index to another. This process of using Numbers to calibrate the degree of judgment is called quantification, and the subjective judgment is converted into specific numbers. A smaller number means less risk, a larger number means more risk, the minimum number is 1, and the number of 10 means the risk is very high. The risk level is divided into five grades: very low risk (1~2), low risk (3~4), medium risk (5~6), high risk (7~8) and very high risk (9~10).

3.2.4 Constructing judgment matrix

Construct a judgment matrix and ask for the opinions of 10 experts, including professional teachers of universities, professional staff of commercial banks, intellectual property patent owners and evaluators of intermediary evaluation institutions. 10 experts were asked to judge and measure each of the second-level indicators. After the measurement was completed, the proportion of experts in each level of risk indicators should be counted and a judgment matrix should be established. If \( a_i \) is defined as the proportion of experts who consider the risk level of this index to be 1, let the judgment matrix of
3.2.5 Determine risk level
Starting from the secondary indicators, conduct fuzzy comprehensive evaluation on the indicators at each level. The fuzzy comprehensive evaluation of secondary indicators is
\[ D = A \left( C_{11}, C_{12}, C_{13}, C_{14}, C_{15} \right)^T, \]
\[ D_2 = A_2 \left( C_{21}, C_{22} \right)^T, \]
\[ D_3 = A_3 \left( C_{31}, C_{32}, C_{33} \right)^T, \]
\[ D_4 = A_4 \left( C_{41}, C_{42}, C_{43}, C_{44}, C_{45} \right)^T, \]
\[ D_5 = A_5 \left( C_{51}, C_{52}, C_{53}, C_{54}, C_{55}, C_{56}, C_{57}, C_{58} \right)^T, \]
Similarly, the establishment of fuzzy evaluation of first-level indicators is the same as the above method, that is, \[ D = A \left( D_1, D_2, D_3, D_4, D_5 \right)^T. \] After constructing the evaluation index, the risk grade is evaluated according to the results of the first-order fuzzy index matrix.

4. Examples of practical application
Select a certain intellectual property pledge project of a certain enterprise and organize 10 experts to score the importance of various indicators under the risk assessment system of intellectual property pledge. The score ranges from 1 to 10. The higher the score, the more important it is. Then the average score of the 10 experts was taken to get the average score of each index. Finally, the average score of each index was divided by the sum of the average scores of the same level of each index, and the index weight of the index was obtained. The risk assessment index weight setting process is shown in Table 2. According to the above operation process, the weights of risk assessment indicators were obtained:
\[ A = \left( 0.2, 0.1, 0.1, 0.3, 0.2, 0.1 \right), \]
\[ A_1 = \left( 0.1, 0.1, 0.3, 0.2, 0.3, 0.3 \right), \]
\[ A_2 = \left( 0.5, 0.5 \right), \]
\[ A_3 = \left( 0.3, 0.3, 0.4 \right), \]
\[ A_4 = \left( 0.3, 0.2, 0.2, 0.3 \right), \]
\[ A_5 = \left( 0.3, 0.2, 0.4, 0.1 \right), \]
\[ A_6 = \left( 0.4, 0.4, 0.2 \right). \]
Ten experts in the field of intellectual property pledge loan were organized to score the business, and the number of experts in the five risk levels of each factor was counted, and the proportion of experts in each level of each factor was obtained, as shown in Table 3.

| Evaluation index | Expert average score | Indexweight |
|------------------|----------------------|-------------|
| Intellectual property risks itself (K₁) | 5.3 | 0.2 |
| Intellectual property technology utilization risk (K₂) | 3.2 | 0.1 |
| Intellectual property legal risks (K₃) | 3.1 | 0.1 |
| Intellectual property market risk (K₄) | 8.5 | 0.3 |
| business risk (K₅) | 5.1 | 0.2 |
| Intellectual property macro environmental risks (K₆) | 2.8 | 0.1 |
| Total | 28 | - |

Table 2. Risk assessment index weight setting
| Evaluation Index                                      | Expert Average Score | Index Weight |
|-----------------------------------------------------|----------------------|--------------|
| Quality of intellectual property (K_{13})           | 9.7                  | 0.3          |
| Substitution of intellectual property (K_{14})      | 6.3                  | 0.2          |
| The life cycle of intellectual property (K_{15})    | 9.6                  | 0.3          |
| Total                                               | 31.8                 | -            |
| The degree of perfection of intellectual property   | 5.8                  | 0.5          |
| technology (K_{21})                                 |                      |              |
| Intellectual property technology update speed (K_{22}) | 5.3                  | 0.5          |
| Total                                               | 11.1                 | -            |
| Ownership of intellectual property rights (K_{31})  | 6.3                  | 0.3          |
| The mode of authorization of intellectual property  | 5.8                  | 0.3          |
| rights (K_{32})                                     |                      |              |
| The strength of legal protection of intellectual     | 8.4                  | 0.4          |
| property rights (K_{33})                            |                      |              |
| Total                                               | 20.5                 | -            |
| Market supply and demand of intellectual property    | 6.5                  | 0.3          |
| (K_{41})                                             |                      |              |
| The size of the intellectual property market (K_{42})| 4.5                  | 0.2          |
| The market share of the product formed by Intellectual property (K_{43}) | 4.3 | 0.2 |
| The degree of market transferability of intellectual property (K_{44}) | 6.7 | 0.3 |
| Total                                               | 22                   | -            |
| Financial risks of enterprises (K_{51})             | 4.7                  | 0.3          |
| Business risks (K_{52})                             | 3.2                  | 0.2          |
| Credit rating of enterprises (K_{53})               | 6.3                  | 0.4          |
| Enterprise innovation strategy risk (K_{54})        | 1.9                  | 0.1          |
| Total                                               | 16.1                 | -            |


| Index | Composite Value | Membership Value |
|-------|-----------------|------------------|
| Policy Orientation (K1) | 5.3 | 0.4 |
| Interest Rates (K2) | 5.7 | 0.4 |
| Environmental Risks of Intellectual Property (K3) | 2.4 | 0.2 |
| Total | 13.4 | - |

Table 3. Experts election of risk levels of each index

| Expert proportion | K1 | K2 | K3 | K4 | K5 | K6 |
|-------------------|----|----|----|----|----|----|
| Very low | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Low | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Moderate | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| High | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

The evaluation matrix is obtained according to the proportion of experts in each indicator at each level:

\[ C_{i1} = \begin{pmatrix} 0.4 & 0.4 & 0.1 & 0.1 & 1 \end{pmatrix}, \quad C_{i2} = \begin{pmatrix} 0.6 & 0.3 & 0.1 & 0.1 & 0 \end{pmatrix}, \quad C_{i3} = \begin{pmatrix} 0.2 & 0.3 & 0.1 & 0.1 & 0 \end{pmatrix}, \quad C_{i4} = \begin{pmatrix} 0.2 & 0.3 & 0.1 & 0.1 & 0 \end{pmatrix}, \quad C_{i5} = \begin{pmatrix} 0.2 & 0.3 & 0.1 & 0.1 & 0 \end{pmatrix}, \quad C_{i6} = \begin{pmatrix} 0.2 & 0.3 & 0.1 & 0.1 & 0 \end{pmatrix} \]

The fuzzy comprehensive evaluation matrix of the second-level index is obtained by fuzzy comprehensive evaluation of the second-level index:

\[ D_1 = \begin{pmatrix} 0.4 & 0.4 & 0.1 & 0.1 & 0 \end{pmatrix}, \quad D_2 = \begin{pmatrix} 0.6 & 0.3 & 0.1 & 0.1 & 0 \end{pmatrix}, \quad D_3 = \begin{pmatrix} 0.2 & 0.3 & 0.1 & 0.1 & 0 \end{pmatrix}, \quad D_4 = \begin{pmatrix} 0.2 & 0.3 & 0.1 & 0.1 & 0 \end{pmatrix}, \quad D_5 = \begin{pmatrix} 0.2 & 0.3 & 0.1 & 0.1 & 0 \end{pmatrix}, \quad D_6 = \begin{pmatrix} 0.2 & 0.3 & 0.1 & 0.1 & 0 \end{pmatrix} \]

Similarly, a fuzzy comprehensive evaluation was conducted on the first-level indicators, and the following results were obtained:

\[ D = \begin{pmatrix} 0.2 & 0.1 & 0.1 & 0.1 & 0.1 \end{pmatrix} = \begin{pmatrix} 0.475 & 0.255 & 0.225 & 0.115 \end{pmatrix} \]

According to the principle of caution, the higher value (2,4,6,8,10) of each risk level was selected to carry out
weighted processing on the assessment results: $0.475 \times 2 + 0.255 \times 4 + 0.225 \times 6 + 0.115 \times 8 + 0.038 \times 10 = 4.62$, indicating that the risk level of this intellectual property pledge loan business is between medium and low.

5. Risk control
Commercial banks should establish risk assessment mechanism and management system of intellectual property pledge financing. Before financing, enterprises and intellectual property used for pledge should be examined. When conducting financing business, risk assessment should be conducted on the pledged intellectual property, and the risk level should be obtained. High-risk businesses should not be handled. After financing, the value of intellectual property should be evaluated regularly and the change of intellectual property value should be controlled. In terms of the risks of intellectual property, pay close attention to the specific risks, life cycle of intellectual property and the emergence of other technologies, and grasp the changes of the trading market. In terms of the risk of intellectual property technology utilization, it is necessary to supervise the degree of perfection of the technology and remind enterprises to strengthen the speed of updating the technology.

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