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Original Paper

Patent Value Evaluation of Communication Enterprises Based on Real Option Method

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Abstract

Patents are an important asset for a company, especially for telecommunications companies. Evaluating the value of patent portfolios and analyzing the benefits brought by patents is of great significance to the development of communication enterprises with multiple patents. In this paper, the gray GM(1,1) model, random forest algorithm and Monte Carlo simulation are introduced into the B-S option pricing model of the real option method. The gray GM(1,1) model has unique utility for the analysis and modeling of short time series and few statistical data, and has the characteristics of high prediction accuracy and good effect. The random forest algorithm has great advantages in the calculation of revenue sharing rate, and Monte Carlo simulation can optimize volatility parameters. Therefore, the B-S model is used to analyze the 5G patent data of ZTE Co., Ltd. with access technology functions, which has certain operability and reference.

Keywords

Patent valuation, B-S model, gray model, fuzzy hierarchy, Random forest, Monte Carlo simulation

1. Introduction

China's communication industry is in a critical stage of innovation and breakthrough, and the role of intellectual property rights in its development is becoming increasingly important. The emphasis on the development of intellectual property rights in the communication industry is an inevitable requirement for promoting the transformation of economic development mode. With the development of enterprise technology management, patent portfolio theory has emerged, which considers the risks and uncertainties of patents. In China, when the concept of patent portfolio was first introduced, it was also

referred to as "patent investment portfolio". Given the important role of patent portfolio in the survival and development of technology-based enterprises, research on patent portfolio theory has become even more important. Compared to tangible assets, the market value evaluation of patents is more difficult to determine because patents are unique and lack reference for public transactions. The value evaluation of patents is also influenced by uncertain factors such as technology, market, and law, which increases the complexity of the evaluation. Early patent valuation used market benchmarks such as current market price method, reset cost method, and present value of income method for evaluation. However, due to these methods not fully considering risk factors, scholars have proposed patent value evaluation methods based on the real option model.

2. Literature Review

2.1 Basic Theory of Patent Portfolio Value and Its Influencing Factors

Liu and Zhu (2006) pointed out that the patent portfolio theory originated from the issue of R&D resource investment in enterprise technology management. Yue (2012) analyzed the formation mechanism of patent portfolios based on the concepts of value and cost of patent portfolios.

Subsequently, scholars from different countries explored the influencing factors of patent portfolios. Harhoff, Scherer, and Vopel (2003) proposed that the technical value, market value, and legal value of patents vary at different times. Li (2017) believes that the main factors affecting patent value include validity, legal protection scope, market conditions, etc. Lu, Zhou, and Jiang (2014) found that the market influence of patent holders can also affect the value of patents, and other influencing factors include the market value of patent products, industry patent sensitivity, etc. Guo and Yu (2020) found that the number of IPC classifications, patent families, patent citations, and cited patents have a positive impact on patent value in the artificial intelligence market in China.

2.2 Patent Value Evaluation Methods

The research on patent value evaluation methods is gradually enriching. Previous research has mainly focused on traditional cost methods, market methods, and income methods. Fan (2006) concluded through research that the income approach is the main evaluation method, while the market approach plays an auxiliary role, and the cost approach is not suitable for evaluating intellectual property.

The theory of real options is widely used for evaluating the value of patent portfolios. Steward (1977) first proposed the concept of real options, believing that both real options and financial options pursue the minimization of return risk. Wang and Yang (2019) proposed a multiple real options model to address the value evaluation problem of multi-stage R&D projects. Liu (2021) combined the NPV method and the composite real options method to evaluate the value of high-tech enterprises, proving the rationality of the composite real options method. Zhai et al. (2021) proposed a patent portfolio valuation method based on real option theory and Monte Carlo simulation. Xia (2021) analyzed the value of enterprises on the Science and Technology Innovation Board, dividing them into existing value and potential value, and evaluated their existing value using the residual income method. At the same

time, fuzzy mathematics was introduced to quantitatively analyze the uncertainty of potential value, proving the effectiveness of the fuzzy real options method. Wang and Bao (2022) used fuzzy analytic hierarchy process and B-S model to evaluate the value of patent portfolios. The research results indicate that this method can to some extent help enterprises determine the value of patent portfolios.

2.3 Current Status of Research on Value Evaluation of Communication Patents

Wang (2010) first analyzed the importance of patents and pointed out that without independent innovation and independent intellectual property rights, there would be no development of China's communication industry. Dong (2023) pointed out that leveraging industry intellectual property advantages plays an important role in improving industry innovation capabilities, and also helps guide communication enterprises to seize opportunities in the process of technological innovation.

The level of technological innovation in the communication industry plays a crucial role in China's economic and technological strength. This article calculates the net present value using the income method, combined with the theory of real options and the B-S model, to calculate the value of ZTE Corporation's access technology with 5G patents. Meanwhile, using the grey GM (1,1) model to predict sales revenue, optimizing the profit sharing rate using fuzzy comprehensive evaluation method, and improving the measurement of volatility through Monte Carlo simulation. This clearly considers the risks and uncertainties of future predictions, improves the shortcomings of subjective judgment, and makes the results more objective.

3. Establishment of a Patent Portfolio Value Evaluation Model Based on Real Options

3.1 Basic Theory and Approach

Compared to the total of each patent, the value of the overall patent is greater, and its true value lies in the combination formed with other related patents. This article considers patents with the same functionality as a whole and divides the value of patents into two parts. Use the income method to evaluate the actual value of patents, and the real options method to evaluate the potential value of patents.

$$V = PV + C$$

Among them, V - patent portfolio evaluation value, PV - net present value, C - option value

The net present value is determined using the income method, and the specific formula is:

$$PV = \sum_{i=1}^{T} \frac{R_i}{(1+r)^i} \times \alpha \quad (1)$$

Among them, PV - net present value of patent portfolio; Ri - expected income of the patent portfolio in the i-th year; α - Profit sharing rate; R - discount rate; T - Yield period.

After calculating the net present value, the B-S model is used to calculate the value of options to determine the value of the patent portfolio. Assuming that the price of a patent portfolio follows a random fluctuation of a lognormal distribution, the patent value is:

$$V = S \times N(d_1) - X \times e^{-rt} \times N(d_2) \quad (2)$$

$$d_1 = \frac{In(S/X) + (r + \frac{\sigma^2}{2}) \times t}{\sigma \times \sqrt{t}} \quad (3)$$

$$d_2 = d_1 - \sigma \times \sqrt{t} \quad (4)$$

Among them, V - patent portfolio evaluation value; S - The sum of the present value of all income generated during the limited period of the patent portfolio; X - Execution price of patent portfolio; T - Validity period of patent combination; σ— Price volatility of patent portfolio products; R-risk-free interest rate.

3.2 Determination of Income Method Parameters

3.2.1 Determination of Income Period

The yield period of a patent portfolio depends on the validity period of each patent in the portfolio. The validity period of different types of patents varies, and the value of patent portfolios also varies. Therefore, this article uses the average remaining validity period of each patent as the income period of the patent portfolio.

3.2.2 Prediction of Expected Returns on Patent Portfolios

By using a patent portfolio, companies can generate significant revenue, profits, costs, and cash flow benefits in the future. These benefits can be defined as the income earned by a company from asset operations over a certain period of time. To predict a company's revenue, the grey GM (1,1) model can be used. This model is suitable for analysis and modeling with short time series and limited statistical data.

Grey system theory is a new field of control theory first proposed by Chinese scholar Professor Deng Julong. Its characteristic lies in fully utilizing the existing "minimum information" and extracting valuable information based on the "limited information space". The GM (1,1) model is a widely used model in grey system theory. It is a time series prediction model that only requires a small amount of information and data for modeling and prediction, and its prediction results are relatively accurate.

3.2.3 Profit Sharing Rate

For enterprises with a large number of patents, the profit sharing rate is an important factor in determining the value of intellectual property evaluation. The income is generated jointly by the patent portfolio and other assets, so it is necessary to evaluate the income of the two separately. The main methods used by professional evaluators in China to determine the profit sharing rate of patent assets are empirical data methods, such as the three part method and the four part method. However, these methods cannot accurately reflect the differences in the benefits of different intellectual property rights for enterprises. Random forest introduces randomness, has a fast training speed, and can obtain variable importance ranking. Therefore, this study uses the random forest algorithm combined with the technical

net selling price commission rate to determine the profit sharing rate of the patent portfolio.

The random forest algorithm is an integrated machine learning method with advantages such as high classification accuracy and fast training speed. The model uses multiple decision trees organically linked together. Firstly, perform multiple random sampling on the original training samples to obtain multiple sub training samples. Then, for each sub training sample, a decision tree model is constructed using a random set of sub features. Finally, the classification results of multiple decision tree models are combined through the voting method to obtain the final result of the random forest model.

3.2.4 Discount Rate

Using the Capital Asset Pricing Model to determine the discount rate, the formula is:

$$r = r_f + \beta \times (r_m - r_f) \tag{15}$$

Among them, r - discount rate; r_f - Risk free interest rate; β— Beta coefficient;

3.3 Determination of Parameters for the Real Options Method

3.3.1 Current Price of Patent Portfolio

The current price of the patent portfolio can be calculated using the net present value method mentioned earlier, which will not be repeated here.

3.3.2 Patent Portfolio Execution Price

The execution price of the patent portfolio is discounted based on predicted operating costs. The prediction method of operating costs refers to the prediction method of operating revenue.

3.3.3 Risk Free Interest Rate

Generally, short-term treasury bond will be used to approximate risk-free yield in actual assessment. This paper selects the average value of the 10-year treasury bond in 2022 as the risk-free yield r of this paper.

Table 1. Determination of Treasury Bond Yield

time	Yield
January 2022	2.7
February 2022	2.77
March 2022	2.79
April 2022	2.84
May 2022	2.74
June 2022	2.82
July 2022	2.76
August 2022	2.62
September 2022	2.76

October 2022	2.64
November 2022	2.88
December 2022	2.84
	2.76

Data source: China Monetary Network

As shown in Table 1, the average value of 10-year treasury bond in 2022 as the risk-free yield of this paper is 2.76%.

3.3.4 Return Volatility

The volatility σ is the standard deviation of the expected return on assets of an indicator. The higher the value of σ, the stronger the price fluctuation and higher the uncertainty; On the contrary, the smoother the price fluctuation, the lower the uncertainty.

Monte Carlo method is a statistical simulation method that utilizes the repeatable nature of computers to solve various computational problems using random numbers. This article uses Monte Carlo method to simulate net present value to improve volatility. The simulation steps are divided into a total of 6 steps:

(1) Analyze the influencing factors of cash flow and their probability distribution.

(2) Use probability distribution for random sampling to simulate cash flows for each year.

(3) Calculate multiple net present values based on simulated cash flows.

(4) Calculate the average net present value $\overline{NPV}$ and the standard deviation S

(5) Calculate the volatility of the entire stage= $\sigma^* = S / |\overline{NPV}|$

(6) Calculate annual volatility= $\sigma = \sigma^* / \sqrt{n}$

4. Empirical Analysis

4.1 Empirical Case Selection

ZTE is a leading global provider of communication solutions and the largest listed communication equipment company in China. Its products cover multiple fields such as 2G/3G/4G/5G wireless base stations and core networks, IMS, and chips. Due to the particularity of the communication industry, its products usually hold multiple patents. Therefore, valuing ZTE's patents is of great significance.

Patent data is sourced from the Enterprise Knowledge Patent Database (https://patents.qizhidao.com/) Retrieved on July 1, 2023. A total of 22 valid patents were retrieved. Using these 22 patents as a patent portfolio and combining relevant financial data, explore the value of this patent portfolio.

4.2 Valuation Using the Income Approach

Firstly, use past financial data of the enterprise to predict future revenue. Select the revenue data from 2012 to 2022 from the official website of ZTE Corporation Limited. Then, use the grey GM (1,1) model to predict the operating income of the patent portfolio within the remaining validity period of

fourteen years. Grey prediction of ZTE Corporation's revenue for the next fourteen years using Excel is shown in Table 2.

Table 2. Revenue Forecast

time	Revenue (million yuan)
2023	113270.2796
2024	116562.2282
2025	119949.85
2026	123435.9254
2027	127023.3158
2028	130714.9658
2029	134513.9054
2030	138423.2527
2031	142446.2164
2032	146586.0987
2033	150846.2974
2034	155230.3093
2035	159741.7328
2036	164384.2707

According to a survey conducted by the United Nations Conference on Trade and Development, the commission rate for technology trade contracts is mostly controlled between 2% and 6%. In the practice of technology introduction in our country, the commission rate based on net sales price should usually not exceed 5%. Therefore, the range of patent portfolio revenue sharing rate can be determined to be 2% to 5%. In addition, it is necessary to determine the adjustment coefficient, which analyzes the influencing factors of patent portfolio value, and based on the constructed evaluation index system, uses the random forest algorithm to determine the weights of each index. The evaluation index system includes three levels: legal, technical, and market (specific indicators and their meanings are shown in Table 3). Based on the specific situation of ZTE Corporation's patents, determine the comprehensive evaluation criteria for the company's patent portfolio.

All 22 patents of ZTE Communication Co., Ltd. were selected as invention patents. From the average number of citations and citations, the patent combination is 18.63 and 5.18, respectively, both of which are relatively high in frequency. Prove that the scope of the patent technology is broad. From the perspective of the number of countries (regions) in the same family and the number of patent members in the same family, the average number of countries (regions) in the same family is 3, and the average number of patent members in the same family is about 6. The national economic classification involves

8 industries. Prove that the patent portfolio has a higher degree of marketization in the domestic market compared to foreign countries, and continuous exploration is needed in the foreign market.

The average remaining legal protection period of this patent portfolio is 14 years, and it is highly protected. Overall, the comprehensive value of this patent portfolio is relatively high. The specific situation of patents is shown in Table 3.

Table 3. Basic Information of Patents

project	average quantity
Number of citations	18.64
Time Cited	5.18
Number of countries (regions) of the same ethnic group	3.14
Number of patent family members	6.27
Classification of National Economy	8.41
Remaining statutory protection period of patents	13.77
Number of patent claims	25.32
IPC classification number	2.23

Random forest is a flexible and user-friendly machine learning algorithm. This article uses the sklearn library in Python to calculate the weight of each indicator's impact on patent value. The specific situation is shown in Table 4:

Table 4. Weights of Each Indicator

index	weight
Number of patent claims	0.3384
Citation times	0.1349
Number of citations	0.1108
IPC classification number	0.0978
Classification of National Economy	0.0958
Number of patents in the same family	0.0818
Number of countries (regions) of the same ethnic group	0.0787
residual maturity	0.0617

Based on the specific evaluation criteria of the patent (as shown in Table 4), further analyze the specific situation of the patent combination. Obtain the final value of the patent portfolio (as shown in Table 6).

Table 5. Specific Evaluation Criteria for Patents

index	Scoring criteria				
	5	4	3	2	1
technical sophistication	9-10 points	7-9 points	5-7 points	3-5 points	0-3 points
Scope of Patent Combination Rights	Claims greater than 28	Claims greater than 21-28	Claims greater than 14-21	Claims greater than 7-14	Claims greater than 1-7
Number of patents in the same family	9 or more	7-9	5-7	3-5	less than 3
Number of citations	Cited more than 8 times	Cited more than 6-8 times	Cited more than 3-6 times	Cited more than 1-3 times	Cited less than 3 times
Citation times	More than 20 citations	Citation frequency greater than 15-20 times	Citation frequency is 10-15 times	Citation frequency ranges from 5 to 10 times	The number of citations is less than 5
Market Scope	International scale	International small-scale	Large scale domestic	Large scale domestic	Domestic small area scope
Market applications	Application range	Application and Widespread	Widely used	General application	Application restricted
remaining economic life	Over 16 years	12-16years	8-12years	4-8years	Less than 4 years
legal status	empower	open	substantive examination	Unpaid annual fee	reject
validity of the patent	effective	During review	unconfirmed	Expiration of validity	lose efficacy
technical stability	9-10points	7-9points	5-7points	3-5points	0-3points
Infringement risk	0 times	1-3 times	3-6 times	6-8 times	more than 8 times
Corporate reputation	Extremely good	Very good	good	same as	bad

Table 6. Comprehensive Evaluation Values of Patent Combinations

Primary indicators	Secondary indicators	weight	Score	amount to
Technical Value	Number of patent family members	0.0818	3	0.2454
	Number of citations	0.1108	4	0.4432
	Citation Times	0.1349	4	0.5396
market value	Number of countries (regions) of the same ethnic group	0.0787	2	0.1574
	IPC classification number	0.0978	2	0.1956
	Classification of National Economy	0.0958	3	0.2874

	Remaining statutory protection period of patents	0.0617	4	0.2468
legal value	Number of patent claims	0.3384	4	1.3536
				4.0858

According to the formula of dividing the total evaluation score by the total standard score, the adjustment coefficient for the income sharing rate is determined to be 69.38%. According to formula (15), the calculated revenue sharing rate is 4.08%. According to formula (16) of the Capital Asset Pricing Model, the discount rate is calculated to be 23.95%, with the risk-free interest rate referring to the bond yield of 2.76%. The beta value of Tianshi Power is 1.05, and over the past 20 years, the return growth rate of the Shanghai and Shenzhen 300 has been 22.94%, resulting in a risk premium of 13.54%. The average remaining validity period of ZTE's patent portfolio is 14 years. The valuation result based on the income method is 27384.75 million yuan, as shown in Table 8.

Table 7. Evaluation Results of Income Method

Project/ Time	Predicted operating revenue (million yuan)	Income sharing rate	Share amount (million yuan)	discounted rate	Discount period	Discounted value (million yuan)	net present value
2023	113270.280	4.08%	4621.427	23.95%	1	3949.263	
2024	116562.228	4.08%	4755.739	23.95%	2	3278.773	
2025	119949.85	4.08%	4893.954	23.95%	3	2722.117	
2026	123435.925	4.08%	5036.186	23.95%	4	2259.967	
2027	127023.316	4.08%	12270.452	23.95%	5	4442.366	
2028	130714.966	4.08%	5488.167	23.95%	6	1603.004	
2029	134513.905	4.08%	5647.669	23.95%	7	1330.853	273 84.75
2030	138423.253	4.08%	5811.806	23.95%	8	1104.906	
2031	142446.216	4.08%	5980.713	23.95%	9	917.319	
2032	146586.099	4.08%	6154.529	23.95%	10	761.581	
2033	150846.297	4.08%	16270.470	23.95%	11	1624.332	
2034	155230.309	4.08%	16658.670	23.95%	12	1341.74	
2035	159741.732 8	4.08%	17203.230	23.95%	13	1117.871	
2036	164384.271	4.08%	17752.390	23.95%	14	930.662	

Know the patent database in the enterprise (https://himmpat.com/) A total of 38675 patents were retrieved from ZTE Corporation, and there are 22 5G patents with access technology functions. Therefore, the net present value of 5G patents with access technology functions is 1.55776 million yuan.

4.3 Valuation Using Physical Options Method

Against the backdrop of green and low-carbon development and upgrading in the communication equipment industry, China's investment in research and development in the communication industry continues to increase. ZTE Communication Co., Ltd., as a leader in this industry, has good development prospects. The company has invested heavily in research and development, and has made significant contributions to the 5G industry. Therefore, a combination of 22 5G patents with access technology functions can be considered as European call options, and the value of the options can be further evaluated using the B-S model to determine the value of the patent combination.

The current value of the patent portfolio is calculated using the income method based on the basic net present value, which is S=15.5776 million yuan. The execution price of the patent portfolio is obtained through the method of dividing and discounting operating costs (see Table 8 for details). The analysis results of the final execution price are shown in Table 9. The execution price of the patent portfolio is X=14340.34 million yuan. Therefore, the execution price of 22 5G patent combinations with access technology functions is 8.1574 million yuan.

Table 8. Operating Cost Forecast

time	Cost (million yuan)
2023	75978.601
2024	78028.625
2025	80133.962
2026	82296.103
2027	84516.583
2028	86796.976
2029	89138.896
2030	91544.006
2031	94014.009
2032	96550.657
2033	99155.747
2034	101831.127
2035	104578.693
2036	107400.393

Table 9. Execution Price Determination

Project/Time	Estimated operating cost (million yuan)	Cost sharing rate	Share amount (million yuan)	discounted rate	Discount period	Discounted value (million yuan)	net present value
2023	75978.601	4.08%	3099.92 7	23.95%	1	2649.057	
2024	78028.625	4.08%	3183.56 8	23.95%	2	2194.863	
2025	80133.962	4.08%	3269.46 6	23.95%	3	1818.543	
2026	82296.103	4.08%	3357.68 1	23.95%	4	1506.745	
2027	84516.584	4.08%	3448.27 7	23.95%	5	1248.406	
2028	86796.976	4.08%	3541.31 7	23.95%	6	1034.361	
2029	89138.896	4.08%	3636.86 7	23.95%	7	857.014	143
2030	91544.006	4.08%	3734.99 5	23.95%	8	710.075	40.34
2031	94014.009	4.08%	3835.77 2	23.95%	9	588.329	
2032	96550.657	4.08%	3939.26 7	23.95%	10	487.457	
2033	99155.747	4.08%	4045.55 4	23.95%	11	403.88	
2034	101831.127	4.08%	4154.71	23.95%	12	334.633	
2035	104578.693	4.08%	4266.811	23.95%	13	277.259	
2036	107400.391	4.08%	4381.936	23.95%	14	229.721	

Volatility is an indicator that measures the level of risk faced by a company. Selecting the operating revenue, operating costs, operating taxes, and surcharges of ZTE Corporation from 2012 to 2022 on its official website, the company calculated its cash flows for each year. After 4000 Monte Carlo simulations and random sampling, the expected net present value $\overline{NPV}$ was 22362.54 million yuan, with a standard deviation of 9150.73 million yuan. The overall volatility of the project $\sigma^* = S / |\overline{NPV}|$ is 0.41. The annual volatility of the project is $\sigma = \sigma^* / \sqrt{n}$, which is 12.34%.

Table 10. Cash Flow and Its Distribution

time	Cash flow (million)
2012	1819.50
2013	2031.23
2014	2355.10
2015	2876.78
2016	2923.53
2017	3174.99
2018	2657.26

2019	3168.26
2020	3031.97
2021	3822.88
2022	4325.37

According to the relevant formulas of the real options method, it can be obtained that d_1=2.48, d_2 =0.01. After reviewing the normal probability distribution table, N (d_1)=0.993, N (d_2)=0.977. Therefore, the option value of the patent portfolio is V=10085200 yuan. Based on the above results, the value of the patent portfolio is 25.6628 million yuan, which is the sum of the basic net present value and the option value.

In the himmpat patent database (https://himmpat.com/) In the patent value evaluation, it was found that the estimated market current value and highest value of 22 patents were 14.795 million and 28.0164 million, respectively (as shown in Table 11). This article evaluates the value within this range, proving that the results have a certain degree of accuracy within the error range.

Table 11. Patent Value

patent value	current value	The highest value
CN112956222A	45.24	85.72
CN112956222B	45.24	85.72
CN107404748A	54.8	103.76
CN107404748B	54.8	103.76
CN109548038B	92.97	176.04
CN107135547A	64.65	122.42
CN107135547B	64.65	122.42
CN109548038A	92.97	176.04
CN108632922A	54.37	102.96
CN108632922B	54.37	102.96
CN109819486B	83.89	158.85
CN109819486A	83.89	158.85
CN107734546B	65.94	124.86
CN107734546A	65.94	124.86
CN111479297B	84.45	159.91
CN107666688B	95.91	181.62
CN111479297A	84.45	159.91
CN108513325A	52.59	99.58
CN108513325B	52.59	99.58

CN110662213B	44.94	85.10
CN110662213A	44.94	85.10
CN107666688A	95.91	181.62
	1479.5	2801.64

5. Conclusion

From the above results, it can be seen that the value of patent portfolios evaluated by the real options method is significantly higher than that calculated by the income method. The income approach overlooks the option nature of patent portfolios, resulting in a serious undervaluation of their value. For large enterprises such as ZTE, the patent portfolio is the result of research and development innovation, which is crucial for the enterprise. Therefore, a high-quality patent portfolio has a significant impact on the economic and social benefits of enterprises, especially patent portfolios with high levels of technological innovation and widespread market applications can significantly enhance the efficiency of enterprises.

The real options method evaluates the value of patent portfolios by considering future returns and the current state of business operations, providing predictions for future development. However, there are still limitations to the research. For example, the determination of the adjustment coefficient for the profit sharing rate and the selection of indicators do not cover all factors, and the evaluation indicator system still needs to be improved. Some indicators rely on expert judgment, and although the random forest algorithm is used, the results still have subjectivity. In addition, the financial data used is historical data and cannot consider future development changes. Therefore, further research is needed to evaluate the value of patent portfolios.

References

Dong, S. Y. (2023). *Research on the Factors Influencing the Development of Intellectual Property Rights in the Communication Industry*. Beijing: Beijing University of Posts and Telecommunications.

Fan, X. B. (2006). On the Evaluation of Intellectual Property Value. *Theoretical Exploration*, *2006*(05), 74-77.

Guo, Z., & Yu, X. (2020). Analysis of Factors Influencing Patent Value Based on Artificial Intelligence Patent Data in China. *Journal of Intelligence*, *39*(09), 88-94.

Harhoff, D., Scherer, F. M., & Vopel, K. (2003). Citations, family size, position, and the value of patent rights. *Research Policy*, *32*(8), 1343-1363. https://doi.org/10.1016/S0048-7333(02)00124-5

Li, Z. Q. (2017). Analysis of Patent Value Evaluation Based on Single Technology Domain Patent Package. *Communication and Copyright*, *2017*(03), 181-183.

Liu, M. (2021). *Empirical Study on Valuation of High tech Enterprise Mergers and Acquisitions Based on Composite Real Options Method*. Inner Mongolia Autonomous Region: Inner Mongolia

University of Finance and Economics.

Liu, T. T., & Zhu, D. H. (2006). Research on Patent Strategy Based on Patent Investment Portfolio Theory. *Intelligence Journal*, *25*(1), 8-9.

Lu, H. L., Zhou, Y., & Jiang, J. (2014). Research on the Relationship between R&D Input, Patent Output, and Technology Market Development in Chongqing. *Science and Technology Management Research*, *34*(04), 90-96.

Myers Steward, C. (1977). Determinants of Corporate Borrowing. *Journal of Financial Economics*, *1977*(5), 200-215. https://doi.org/10.1016/0304-405X(77)90015-0

Wang, L. (2010). The Impact and Significance of Patents on China's Communication Industry. *Mobile Communications*, *34*(01), 27-31.

Wang, L., & Bao, X. Z. (2022). Research on Patent Portfolio Value Evaluation Based on Fuzzy Analytic Hierarchy Process and Real Options Method. *Chinese Inventions and Patents*, *19*(08), 5-14.

Wang, X. D., & Yang, W. Z. (2019). Research on the Composite Real Options Model for Value Evaluation of Multi stage R&D Investment Projects. *China Asset Appraisal*, *2019*(06), 51-55.

Xia, R. H. (2021). *Research on the Application of Fuzzy Real Options Method in the Value Evaluation of Enterprises on the Science and Technology Innovation Board*. Anhui: Anhui University.

Yue, X. P. (2012). Research on the Formation Mechanism of Patent Combination Based on Value and Cost. *Journal of Intelligence*, *31*(12), 104-108.

Zhai, D. S., Chen, Z. Z., Xu, S., et al. (2021). Research on Patent Portfolio Valuation Method Based on Real Options. *Intelligence Journal*, *40*(06), 200-207.