

Review

A Review of Multi-Agent Game in Intellectual Property Pledge Financing

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Abstract: To promote the theoretical research and business development of intellectual property pledge financing, this paper summarizes the research status of multi-agent game in intellectual property pledge financing. At present, scholars' research on multi-agent game in intellectual property pledge financing mainly focuses on the game between borrowers and lenders, the game between lenders and third-party intermediaries (or platforms), and the game between borrowers, lenders and third-party intermediaries (or platforms). Overall, scholars have conducted extensive research on the game between borrowers and lenders, while research on the game between borrowers, lenders, and third-party intermediaries (or platforms) is relatively weak. Especially when the government implements financial subsidies and interest subsidies for borrowers, financial subsidies for third-party intermediaries (or platforms), and risk compensation for lenders, there is a lack of research on the intellectual property pledge financing game with the government as an independent game subject. Future research can focus on the game between borrowers, lenders, and the government under government incentives, as well as the game between borrowers, lenders, third-party intermediaries (or platforms) and the government under government incentives.

Keywords: Intellectual Property; Intellectual Property Pledge Financing; Multi-Agent Game; Evolutionary Game; Signaling Game; Literature Review

1. Introduction

Intellectual property pledge financing is a financing method in which intellectual property rights holders pledge their legally owned and currently valid intellectual property rights such as patents, registered trademarks, copyrights, etc., obtain funds from banks and other financial institutions, and repay the principal and interest of the funds on schedule (<https://baike.so.com/doc/1882575-1991714.html>). In recent years, under the wave of data capitalization, the extension of intellectual property pledge financing has extended to the data field, and data intellectual property pledge financing has emerged. Data intellectual property pledge financing is a new type of financing method that uses data legally owned by enterprises and certified by data intellectual property registration system or depository platform as pledge, which is of positive significance for promoting the release of intrinsic value of data elements (https://www.cnipa.gov.cn/art/2023/9/25/art_53_187785.html). The intellectual property rights (patent rights, registered trademark rights, copyrights, data, etc.) owned

by technology-based small and medium-sized enterprises can provide important information for banks to judge the future profitability and research and development level of enterprises. They can also become an effective tool to constrain the "moral risk" of enterprises and play a risk mitigation function after loans (Zhao, 2022) [1]. Intellectual property pledge financing provides a new financing approach for technology-based small and medium-sized enterprises with light assets, helping them alleviate financing constraints, reduce financing costs, and improve financing efficiency. Intellectual property pledge financing has become an important measure for technology-based small and medium-sized enterprises to revitalize intangible assets, build market advantages, and enhance innovation and development momentum.

However, due to various reasons such as low commercial value, difficulty in value evaluation, difficulty in disposal and realization, information asymmetry, and imperfect risk sharing and compensation mechanisms, the development of intellectual property pledge financing business is somewhat constrained (Zhao, 2022; Wei, 2023) [1,2]. Market practice shows that there may be multiple subjects such as borrowers, lenders, third-party intermediaries (or platforms) and governments in intellectual property pledge financing. Analyzing the game relationship between multiple subjects is conducive to achieving market equilibrium and improving market efficiency.

This paper will review the research status of multi-agent game in intellectual property pledge financing, to further promote the theoretical research and business development of intellectual property pledge financing. The remaining part of this paper is structured as follows: Part 2 introduces the game between borrowers and lenders; Part 3 introduces the game between lenders and third-party intermediaries (or platforms); Part 4 introduces the game between borrowers, lenders, and third-party intermediaries (or platforms); Part 5 is a brief review.

2. The Game Between Borrowers and Lenders

In the intellectual property mortgage financing business, there is a direct lending relationship between the borrowers and the lenders, so the borrowers and the lenders are the two most basic game subjects. At the moment, scholars mainly discussed the game between borrowers and lenders from the perspective of loan business development, the game between borrowers and lenders from the perspective of loan risk prevention and control, the game between borrowers and lenders under the influence of government, the game between borrowers and lenders under the influence of third-party intermediaries (or platforms), the game between borrowers and lenders under the background of digital finance, and the signal game between borrowers and lenders and so on.

2.1. The Game Between Borrowers and Lenders from the Perspective of Loan Business Development

From the perspective of loan business development, scholars have conducted a series of studies on the market behavior of intellectual property mortgage loans, the development of patent mortgage loans, and the financing mechanism of intellectual property mortgages.

Qian et al. (2011) [3] believed that how to fully utilize the value of intellectual property pledge loans for high-tech small and medium-sized enterprises and benefit from them is a hot issue in current research. The main factors affecting the market are found through the analysis of the evolutionary game model. To obtain good market behavior, corresponding policy suggestions are given. Wu and Wang (2016) [4] constructed and analyzed the game model between cultural and creative industries and credit institutions. The game results show that the patent pledge financing

behavior can converge to the Pareto optimal equilibrium state or the Pareto inferior equilibrium state, but by adjusting the parameters in the model, it can converge to the Pareto optimal equilibrium state, to promote the development of the patent pledge financing loan business of cultural and creative industries. Luo (2017) [5] systematically and deeply analyzed the game process of the financing mechanism of the two parties to the intellectual property pledge by adopting the method of evolutionary analysis and verified the validity of the evolutionary results based on the unitary linear regression analysis, providing theoretical and empirical support for the theoretical circle and certified public accountants to carry out the intellectual property pledge management consulting business.

2.2. The Game Between Borrowers and Lenders from the Perspective of Loan Risk Prevention and Control

From the perspective of loan risk prevention and control, scholars have studied issues such as the pledge rate, loan amount, default risk, and moral hazard of intellectual property pledge financing.

As a core means to control the risk of intellectual property pledge financing, how to make decisions directly affects the risk of financial institutions participating in intellectual property pledge financing. Zhu and Xu (2012) [6] proposed that the pledge rate of patent pledge financing under the complete market model is essentially the result of the game between banks and enterprises, which is in line with the Stackelberg leadership model. From the two dimensions of enterprise default risk assessment and bank risk tolerance, the solution to the game model is transformed into a Nash equilibrium solution, and methods such as VaR risk measurement are used to determine the optimal pledge rate for banks and explore the situation of achieving Nash equilibrium. Zhang (2018) [7] analyzed the dynamic game process between banks and enterprises in the process of setting the pledge rate in a complete market environment using the Stackelberg model and finally introduced a bank-enterprise Nash equilibrium under a certain optimal pledge rate. This research result will provide a reference for banks when determining the amount of intellectual property pledge financing. In addition, Jiang (2024) [8] established a game model for innovative enterprises' intellectual property pledge loans under dynamic stochastic conditions based on the Nash equilibrium theory and provided the optimal decision-making for banks and enterprises under different decisions.

Su et al. (2015) [9] used the expected excess return theory and the methods of value quick calculation and set-valued statistics to isolate the value of intellectual property at various levels. Finally, based on the intellectual property evaluation value, they used game theory to determine the loan amount from the perspective of both borrowers and lenders. Liu and Min (2017) [10] believed that the focus of the game between enterprises and banks in intellectual property pledge financing is the level of loan amount (considering that the size of the loan amount is mainly determined by the evaluation value of intellectual property, assuming that under existing market conditions, the evaluation agency will make reasonable valuations based on the value of the pledge itself and the enterprise). It is influenced by the investment behavior of the enterprise and will adjust the level of loan amount provided based on the judged level of investment risk of the enterprise.

In addition, Chen et al. (2015) [11] established an evolutionary model based on the assumption of incomplete information and analyzed the stability of the equilibrium point obtained. The results showed that the value of the pledged intellectual property and the reward and punishment mechanism established by the bank are of great significance for preventing the default risk and moral hazard of enterprises. For technology-based SMEs with less intellectual property, it is suggested that banks can increase the punishment intensity; for technology-based SMEs with more intellectual

property, it is suggested that banks can require the increase of pledged intellectual property or reduce the pledge rate. Chen and Zhang (2016) [12] used MATLAB to conduct simulation research on the evolutionary game model of technology-based SMEs and banks under intellectual property pledges. The evolutionary game results of three different evolutionary strategies were analyzed. While the game strategies did not converge to a stable value, there were leaders and followers. Due to the lack of stable points, the simulation can also determine the approximate location of the midpoint. Similarly, in some cases, the stable value depends on the initial value, and the order of the stable value is not entirely determined by the order of the larger initial value.

2.3. The Game Between Borrowers and Lenders Under the Influence of the Government

Government policies such as financial subsidies and risk compensation will affect have a direct impact on the game between borrowers and lenders. Scholars have studied the game between borrowers and lenders from the perspectives of mutual funds, loan discounts and guarantee subsidies, loan discounts, and risk compensation.

From the perspective of mutual funds, Zhu and Cheng (2015) [13] constructed a staged loan model for patent pledge loans, with the issuer of patent pledge loans (a mutual fund composed of government, banks, and venture capital institutions) and the applicant of patent pledge loans (enterprises) as the two sides of the game. This effectively reduces the risks for both borrowers and lenders and increases the success rate of patent pledge loans. Among the three parties of government, banks, and venture capital institutions, the government plays a role as a mediator.

From the perspective of loan discounts and guarantee subsidies, Qian (2019) [14] believed that under conditions of information asymmetry, strengthening the security of credit funds has become an important issue in the relationship between banks and enterprises. Under "natural" conditions, the evolutionary trend of the game between banks and enterprises is constrained by the initial conditions of the system and is determined by various key parameters that affect the payment matrix between banks and enterprises. Due to the particularity of patent pledge financing, the objective existence of patent evaluation issues and devaluation issues significantly affects the relevant decisions of banks and enterprises. The study found that two key parameters affect bank decisions: the probability of default of enterprises and the depreciation rate of patents; the evolutionary trend of the game between banks and enterprises significantly depends on the initial state of the system and the values of relevant parameters. Further establishing an evolutionary game model considering policy support, by adding loan discount and guarantee subsidy parameters, the "cooperative" evolutionary trend of patent pledge financing between banks and enterprises has been enhanced.

From the perspective of loan discount and risk compensation, Yang and Chen (2014) [15] used evolutionary game theory to establish an evolutionary game model of intellectual property pledge financing behavior in Chinese high-tech enterprises and analyzed the equilibrium, strategy selection, and influencing factors of intellectual property pledge financing in high-tech enterprises. The study found that the evolutionary system of intellectual property pledge financing behavior selection in high-tech enterprises can converge to both Pareto optimal equilibrium and Pareto inferior equilibrium. By adjusting the parameters in the model, it can achieve Pareto's optimal equilibrium. Compared to the government subsidy mechanism, the risk compensation mechanism is more effective and can promote the realization of intellectual property pledge financing in high-tech enterprises. Xu and Li (2018) [16] proposed a new model of pledge financing based on supply chain

finance, which can effectively help technology-based enterprises solve the dilemma of real estate mortgage financing. Using evolutionary game theory, they analyzed the evolutionary direction of this model under different conditions and concluded that reducing the cost of pledge financing or increasing the return on core enterprises' disposal of pledged intellectual property can promote the system to converge to Pareto optimality. At the same time, they explored the different effects of government subsidies for pledge costs and risk compensation for core enterprises and concluded that government subsidies for pledge costs are more effective than risk compensation for core enterprises in promoting intellectual property pledge financing. In addition, Zhang and Shi (2021) [17] used evolutionary game theory to study whether there is a game between small and medium-sized enterprises and banks under the background of government support and analyzed the evolutionary stability criteria in the financing game. The study showed that under the influence of market mechanisms, the game between small and medium-sized enterprises and banks reaches a state of instability. Under the influence of government subsidies, the government's interest subsidy policy reduces the financing costs of small and medium-sized enterprises and enhances their probability of cooperation with banks for financing. The establishment of a risk compensation fund provides banks with risk compensation and enhances their enthusiasm for lending. Compared to pure market financing models, direct pledge is an important form of intellectual property pledge financing under the influence of the government.

2.4. Borrower-Lender Game Under the Influence of Third-Party Intermediaries (or Platforms)

The participation of third-party intermediaries (or platforms) will have a direct impact on the game between borrowers and lenders, and scholars have studied the game between borrowers and lenders under the perspectives of participation of third-party intermediaries and participation of third-party intermediary platforms, respectively.

Under the perspective of the participation of third-party intermediaries, Jiang (2024) [8] established a game model based on the Nash equilibrium theory to give the optimal quality charge rate and the optimal decision of the game for banks and enterprises under different decisions. Considering the enthusiasm of banks, introducing loan guarantee, using Nash equilibrium to give the best quality charge rate of intellectual property pledge loans. At the same time, compare and analyze the pledge rate with and without loan guarantee and the difference between the bank's and enterprise's returns.

Under the perspective of third-party intermediary platform participation, Gong et al. (2021) [18] further verified it by constructing a perceived return matrix and an evolutionary game model of intellectual property pledge financing for cultural and creative enterprises, using numerical simulation. The study shows that: the higher the lending rate generated by credit assessment, the perceived gain, the value of pledged intellectual property, the rate of return after pledge, the interest rate of financial institution lending, the enterprise and the financial institution default compensation payment, the greater the willingness of cultural and creative enterprises and financial institutions to carry out cooperation, and the stronger the stability of cooperation; the higher the financial institutions' financing interest rate, the enterprise's pledge cost and the financial institution's seeking cost, the smaller the willingness of cultural and creative enterprises and financial institutions to cooperate and the worse the cooperation stability. When the third-party assessment and guarantee

platform participates in the game, the system will evolve in the direction of cooperation between cultural and creative enterprises and financial institutions and reach a stable state.

2.5. The Borrower-Lender Game in the Context of Digital Finance

Digital finance has the characteristics of sustainability, wide coverage, and almost zero marginal costs (Zhang and Luo, 2022) [19], which will have a profound impact on the game between borrowers and lenders. Scholars have studied the game between borrowers and lenders in the context of big data risk control, blockchain risk control, and financial technology, respectively.

In the context of big data risk control, Xia and Sheng (2021) [20] explored the targeted post-loan risk evolution process by constructing a credit risk evolution game model between the participating subjects, and analyze the stability of the equilibrium point, and then study the system credit incentive strategy based on parsing the generation of effective default risk and its elements in the context of big data. The results show that financial institutions set reasonable credit incentive mechanism according to the value of patents pledged by SMEs in science and technology and the principal and interest of the loan, which can effectively reduce the occurrence of effective default credit risk in the context of big data and achieve long-term stable cooperation; at the same time, appropriately transferring the benefits to the trustworthy enterprises and appropriately increasing the cost to the defaulting enterprises can to a certain extent effectively regulate effective default in the ecosystem of patent pledge financing.

In the context of blockchain risk control, Xia and Zhang (2022) [21] explored the coupling between blockchain and credit risk regulation and control of intellectual property pledge financing on the basis of analyzing the source of credit risk of intellectual property pledge financing in the era of big data, and then construct an evolutionary game model to discuss the credit strategy of the main body of the intellectual property pledge financing transaction under blockchain, and carry out numerical simulation through Vensim Analysis. The results show that the reward given by the financial institution when the intellectual property right party pays back the loan on time, the amount of financing information shared between the two parties, and the financial institution's acceptance and processing ability of the financing information have a positive effect on the equilibrium state of the game. At the same time, reasonable regulation of the cost of information technology of the blockchain platform, incentive and punishment strength and risk factor and other indicators will promote the evolution of the game equilibrium state to the ideal state of 'keeping the contract', to build a high-quality credit ecology of intellectual property pledge financing.

In the context of financial technology, Qian et al. (2018) [22] constructed a signal game model between borrowing enterprises and investors for the new mode of financing combining internet finance and patent pledge and analyzed the strategic choices of the two parties involved as well as the influencing factors of the equilibrium state. In addition, Xu and Lu (2022) [23] used evolutionary game theory and system dynamics model to explore the mechanism of two intellectual property pledge financing modes, namely, the establishment of fintech subsidiaries by commercial banks and the reliance on third-party intermediary service institutions in the context of fintech and carried out a sensitivity analysis of key variables. The study found that: when increasing rewards and punishments or setting credit penalties for subsidiaries, SMEs in science and technology and commercial banks can reach a stable state of cooperation under long-term evolution; under the same

circumstances, credit penalties for fintech subsidiaries are more effective in deterring SMEs in science and technology.

2.6. Borrower-Lender Signaling Game

To address the problem of 'pledge signal failure', scholars have studied the signal game between borrowers and lenders under the perspectives of intangible asset pledge financing and patent pledge financing respectively.

Under the perspective of intangible asset pledge financing, Wang et al. (2017) [24] found through the dynamic game analysis of incomplete information that: only through appropriate incentive-compatible constraints to reach a segregated equilibrium state can guarantee the smooth implementation of intangible asset pledge financing; the government through the standardization of the valuation stage of intangible assets, severe punishment of counterfeiting enterprises and the protection of private information of enterprises applying for loans, and other policy measures can all increase the enterprise counterfeiting costs and encourage enterprises to apply for loans in good faith; banks can have a deterrent effect on enterprise counterfeiting through the implementation of different pre-credit due diligence, but differentiated lending strategies should be used with caution. Liu and Nie (2017) [25] argued that high-tech enterprises are currently facing two major problems that result in credit constraints. One is the prominent problem of information asymmetry between enterprises and financial institutions; the other is the lack of effective pledges. However, in fact, some intangible assets information delivered by enterprises can reflect their real types to a certain extent, which helps to alleviate the dilemma of information asymmetry. Meanwhile, intangible assets can replace fixed assets as an effective pledge. Considering these issues, they established a two-step credit game model and a signaling game model for intangible asset pledge loans. Both identified and proved the feasibility and effectiveness of intangible asset pledges in the lending process. It was found that the development path of the intangible asset pledge market is the same as the transition from pooling equilibrium to separating equilibrium in the signaling game model.

Under the perspective of patent pledge financing, to promote the smooth implementation of the new patent pledge financing model which focuses on the audit of enterprise's scientific and technological innovation ability, Hu and Zhu (2021) [26] used the signal game model to analyze the market equilibrium state of this financing model and combined with the parameters in the game model to study the dilemmas of its implementation. It is found that the financing model has the problems of 'patent pledge financing market failure' and 'pledge financing market inefficiency' in the implementation process. It is suggested that the government should take measures to increase the economic cost, technical cost, and the cost of breach of trust of the patent quantity disguise, to ensure the effective operation of the patent pledge financing market, and on the basis of this, use a combination of loan subsidies and scientific and technological policy tools to regulate the number of enterprises that can be financed, so as to improve the overall market efficiency of patent pledge financing. Xie et al. (2022) [27] believed that low-tech enterprises through the disguise of patents so that financial institutions are unable to confirm their technical level through the loan signals, resulting in the problem of 'patent signal failure'. Through the signaling game model, the causes and hazards of this phenomenon can be analyzed, and the interaction mechanism between industry-university-research cooperation and patent pledge financing is discussed. The results show that industry-university-research co-operation can help reduce the information asymmetry between borrowers and

lenders in the patent pledge market, thus alleviating the market inefficiency caused by 'patent signal failure'. On the other hand, patent pledge financing can also have a positive impact on the decision-making process of the university-industry research cooperation of technology-based enterprises.

In addition, Qian et al. (2018) [22] constructed a signaling game model between borrowing enterprises and investors for the new mode of financing combining internet finance and patent pledge and analyzed the strategic choices of the two parties involved as well as the influencing factors of the equilibrium state. The study shows that, considering the dynamics and incompleteness of information transmission, the realizable value of patent pledges and the cost of information masking are the key factors affecting the equilibrium of the Internet finance market. Therefore, improving the efficiency of patent pledge financing on P2P platforms should be achieved by accelerating the construction of intellectual property trading platforms, introducing the Internet financing credit mechanism, strengthening the internal supervision of financing projects on P2P platforms and improving the information disclosure mechanism of P2P platforms.

3. The Game Between Lenders and Third-Party Intermediaries (or Platforms)

In the intellectual property pledge financing business, there is not only a game between borrowers and lenders, but also a game between lenders and third-party intermediaries (or platforms).

In terms of the game between lenders and third-party intermediaries, Wang and Sun (2023) [28] believed that the purpose of intellectual property pledge financing is to solve the problem of shortage of funds for SMEs. However, information asymmetry between financial institutions and businesses increases credit risk and often leads to government intervention as a guaranteed provider, leading to unreasonable risk distribution among stakeholders. The distribution nature of blockchain technology is suitable for enabling long-term operating mechanisms. In this study, they used an evolutionary game model between banks and guarantee institutions to study the effects of repayment rates and other key parameters on equilibrium. The model and numerical simulation results show that the risk allocation rate within a certain range is beneficial to the adoption of blockchain technology. Besides, they suggest that the government should subsidize the technology costs used for banks to build blockchain platforms, rather than directly funding their business operations.

In terms of the game between lenders and third-party intermediary platforms, Zhang (2019) [29] analyzed the cooperation mechanism between intellectual property pledge financing platforms and financial institutions. The subject of the intellectual property pledge financing is divided into two parts : intellectual property pledge financing platform and financial institutions, using the evolutionary game theory combined with dynamic equation income matrix and copying the cooperation mechanism, to analyze the spread rate, lending, cooperation cost, supervision cost for the influence of income distribution, then constructing a revenue distribution model between intellectual property pledge financing platforms and financial institutions. On this basis, the income sharing mechanism among the participants in the pledge financing platform is studied by utilizing the theory of cooperative game. The theory of cooperative game, the minimum core method and the improved minimum core method are adopted to establish the income distribution model, then giving relevant solution steps. The example verifies the feasibility and effectiveness of the cooperative game method in the income distribution among the partners within the intellectual property pledge financing platform.

4. The Game Between Borrowers, Lenders, and Third-Party Intermediaries (or Platforms)

In the financing business of intellectual property pledge, there are not only games between borrowers and lenders, as well as games between lenders and third-party intermediaries (or platforms), but also games between borrowers, lenders, and third-party intermediaries (or platforms).

In the game between borrowers, lenders, and third-party intermediaries, Tong (2014) [30] based on the intellectual property pledge financing mode of science and technology-based SMEs, established a game model between commercial banks, guarantee institutions and science and technology-based SMEs from the perspective of cost-benefit, to seek a reasonable joint guarantee sharing ratio to diversify risks. It is found that the underwriting proportion of guaranteed institutions is related to the expected value of the financing collateral of small and medium-sized technology enterprises. In the joint guaranteed mechanism of cooperation between commercial banks and guarantee institutions, the latter need to assume a large proportion of insurance. Zhang and Shi (2021) [17] utilized evolutionary game theory to study the evolutionary process of financing behavior and stability criteria of the tripartite game between SMEs, banks and guarantee institutions under the background of whether there is government support, and then analyze the evolutionary stability strategies of different market players in the financing game. The research shows that: under the market mechanism, the game between SMEs and banks reaches the Pareto optimal state and the instability of this state is high; the intervention of guaranteed institutions to realize the risk sharing with bank loans, prompting the system to converge to the optimal state. Under the role of the government, the government's discount interest policy reduces the financing cost of SMEs and enhances the financing cooperation probability with banks; and provides risk compensation to enhance the motivation of bank loans. Compared with the pure market financing mode, the indirect pledge under the action of the government is an important form of intellectual property pledge financing. In addition, Chen et al. (2022) [31] believed that third-party guarantee institutions participating in the intellectual property pledge financing process can provide guarantee, disperse the risks borne by financial institutions, improve the success rate of pledge financing, and promote the innovation and development of enterprises. They used the evolutionary game theory and the MATLAB to discuss the intellectual property pledge financing problem of innovative enterprises and commercial banks under the participation of the third-party guaranteed institutions. It is found that when innovative enterprises maintain low credit risk and face high credit punishment, they will actively perform repayment in the process of pledge financing; the commercial banks are more inclined to provide loans to innovative enterprises to avoid risks and reduce financing costs; the third-party guaranteed institutions will actively act as intermediaries to provide guarantee.

In terms of the game between borrowers, lenders, and third-party intermediary platforms, Huang et al. (2018) [32] explored the stability of the bank's intellectual property pledge financing model and formulated effective optimization strategies. They used an evolutionary game model to explore the issue of intellectual property pledge financing between commercial banks and technology-based SMEs with the assistance of third-party intellectual property evaluation platforms. Research has found that cooperation between commercial banks and third-party intellectual property evaluation business platforms can not only solve the problem of financing difficulties for technology-based SMEs, but also achieve bank credit risk sharing and default compensation, greatly reducing the risk of commercial banks' lending to small and medium-sized enterprises. Xu et al. (2019) [33] used an evolutionary game model to explore how the intellectual property pledge financing

cooperation mechanism between commercial banks and technology-based SMEs was established with the participation of third-party intermediary platforms. Research has found that cooperation between banks, enterprises, and third-party intermediary platforms is the most stable state only when the level of corporate credit risk is lower, banks can obtain loan risk guarantees, and third-party intermediary platforms can obtain more objective returns. In addition, based on information asymmetry, transaction cost and knowledge economy theory, Gu (2022) [34] constructed an evolutionary game model of enterprises, banks and third-party intermediary platforms and a multi-party game within third-party intermediary platforms to analyze the changes in the selection strategies of the main body in the game. This study mainly analyses, under the mode of intellectual property pledge financing guarantee among enterprises, banks and third-party intermediary platforms, to strengthen the risk-sharing among banks, guarantee companies, insurance companies and so on and explore the impact of the increase of default amount and credit incentives on the cooperation of intellectual property pledge financing guarantee. Influencing factors such as the amount of default, the cost under the cooperative relationship, the ratio of risk sharing and income sharing, brand value and the matching degree of intellectual property realized transactions how to impact on the probability of cooperative choice behavior strategy of guaranteed companies, evaluation institutions and operators in the third-party intermediary platform.

5. Brief Review

At present, scholars' research on the multi-agent game in intellectual property pledge financing mainly focuses on the game between borrowers and lenders, the game between lenders and third-party intermediaries (or platforms), and the game between borrowers, lenders, and third-party intermediaries (or platforms).

In the aspect of game research between borrowers and lenders, scholars mainly discuss the game between borrowers and lenders from the perspective of loan business development, the game between borrowers and lenders from the perspective of loan risk prevention and control, the game between borrowers and lenders under the influence of government, the game between borrowers and lenders under the influence of third-party intermediaries (or platforms), the game between borrowers and lenders under the background of digital finance, and the signal game between borrowers and lenders. In the aspect of game research between lenders and third-party intermediaries (or platforms), scholars mainly discuss the game between lenders and third-party intermediaries, and the game between lenders and third-party intermediary platforms. In the aspect of game research between borrowers, lenders and third-party intermediaries (or platforms), scholars mainly discuss the game between borrowers, lenders and third-party intermediaries, and the game between borrowers, lenders and third-party intermediary platforms.

To sum up, scholars have rich research on the game between borrowers and lenders, and weak research on the game between borrowers, lenders and third-party intermediaries (or platforms). Especially when the government implements financial subsidies and interest subsidies for borrowers, financial subsidies for third-party intermediaries (or platforms), and risk compensation for lenders, there is a lack of research on the intellectual property pledge financing game with the government as an independent game subject. Therefore, future research can focus on the game between borrowers, lenders, and the government under government incentives, as well as the game between borrowers, lenders, third-party intermediaries (or platforms) and the government under government incentives.

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