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A Review of Bilateral Matching Theory and Its Applications in Financial Markets

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Abstract. In modern financial markets, the matching efficiency among market participants is crucial to market stability and efficiency. Bilateral matching theory, as an important theoretical framework, provides scientific methods and tools for solving complex matching problems. This article aims to systematically review the development process of the bilateral matching theory, analyze its current application and challenges in the financial market, and explore future research directions. Through a comprehensive literature review, this study finds that although the bilateral matching theory has been widely applied in financial fields such as venture capital, bank loans, and the securities market, it still faces major challenges in practice, such as data privacy, model adaptability, and regulatory constraints. Research shows that the application of big data analysis, artificial intelligence and international cooperation can enhance the application efficiency of this theory, thereby strengthening market efficiency and competitiveness. Future research should focus on overcoming these challenges to fully unleash the potential of bilateral matching theory in financial markets.

Keywords: Bilateral Matching Theory, Financial Markets, Matching Efficiency, Big Data, Artificial Intelligence

1. Introduction

In modern financial markets, matching efficiency among market participants plays a pivotal role in ensuring market stability and operational efficiency. Whether it is venture capital, bank credit or the securities market, an effective matching mechanism can significantly improve the efficiency of resource allocation, reduce transaction costs and enhance market competitiveness. As a key theoretical framework, bilateral matching theory offers systematic methodologies and computational tools to address intricate matching challenges. In recent years, scholars at home and abroad have conducted extensive research on bilateral matching theory and achieved remarkable results. These research achievements not only have significant theoretical importance but also have solved a large number of complex matching problems in practice [1,2]. While theoretical research on bilateral matching theory remains limited in China, its practical applications in the financial sector, particularly in the bank card industry, have been widely adopted. However, in the actual application process, many problems and challenges are also faced, including data acquisition and processing, model dynamic adaptability, multi-party interest balancing, and regulatory compliance. This study aims to systematically review the development history of the bilateral matching theory, analyze its

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current application status and problems in the financial market, and explore future research directions. By systematically reviewing the development process of bilateral matching theory, the research results of this paper can further improve its theoretical framework and provide a solid theoretical foundation for subsequent research.

2. An overview of bilateral matching theory

2.1. Theoretical origin and development

The study of bilateral matching problems and algorithms originated in the 1960s, with early applications in marriage matching and student-school allocation. Pioneering work by Gale (Brown University) and Nobel laureate Shapley formalized the marital problem as follows: individuals rank potential partners based on preference information, with the Gale-Shapley algorithm [3] ensuring stable matches that maximize mutual satisfaction.

In 1984, Harvard University economics professor Ross, through his research on medical school students' internships, proposed new algorithms and directions that conformed to market development and combined them with the actual market to conduct specific case analyses. In 1985, he first publicly proposed the concept of bilateral matching theory in an economics paper and conducted a detailed analysis with specific examples. Subsequently, in view of the background of medical college interns doing internships in hospitals, he presented the H-R algorithm and verified the effectiveness of the algorithm through experimental research.

For the problem of roommate allocation after college students' enrollment, the Gale-Shapley algorithm is still adopted. The preferences of each student for the rest of the students are sorted, and finally the students are paired one by one to find the most suitable and stable roommates for themselves. In 1985, Gusfield gave a detailed description of the roommate allocation problem and found the optimal solution to the problem through sorting. In the same year, Irving also proposed a new solution. In 2007, Flener proposed different solution methods for the roommate matching problem [3].

In 2001, scholars such as Teo studied the bilateral matching mechanism for the transition from primary to junior high school in Singapore, identifying the best matching approach between students and schools to achieve stable outcomes and maximize overall interests.

In 2005, Roth established a mechanism for the bilateral matching of education between 9,000 students in New York City and public colleges, and 6,000 students in Boston with the TTC of public schools. The benefit situations of different circumstances under the selection mechanism were studied.

2.2. Main algorithm

2.2.1. Gale-Shapley algorithm

The Gale-Shapley algorithm, pioneered by Gale and Shapley (1962), provides a systematic solution to stable marriage problems. The algorithm's core mechanism requires participants to rank potential partners based on strict preference orders. The specific steps are as follows:

Initialization: All men and women start in an unmatched state.

Selection: Each unmatched man proposes to the woman he has not yet proposed to and who is his top choice.

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Accept or Reject: Upon receiving a proposal, each woman follows a deterministic rule: immediate acceptance if currently unmatched; if she is already matched but the current proposer is more preferred than her current spouse, she rejects her current spouse and accepts the new proposer.

Repeat: Repeat the above steps until all men and women are successfully matched.

A key theoretical guarantee of the algorithm is the production of stable matchings—configurations where no pair of participants would mutually prefer each other over their current assignments [4].

2.2.2. H-R Algorithm

The Hospital-Resident Algorithm (H-R), proposed by Alvin E. Roth, addresses the bilateral matching problem of medical interns to hospitals. It extends the Gale-Shapley algorithm to handle the many-to-one matching between hospitals and interns. The steps are as follows:

Initialization: All hospitals and interns are unmatched.

Selection: Unmatched residents sequentially apply to available hospitals on their preference lists.

Accept or Reject: Each hospital reviews applications based on its preference list and available openings. If a hospital has no openings but the current applicant is preferred over its currently matched resident, it rejects the matched resident and accepts the new applicant.

Iteration: Repeat the above steps until all interns and hospitals are successfully matched.

The H-R algorithm has been experimentally validated to demonstrate its effectiveness in producing stable matches [5].

2.2.3. Linear programming approach

Linear programming is a mathematical optimization method used to address resource allocation in bilateral matching problems. It seeks optimal solutions by constructing objective functions and constraints. In bilateral matching scenarios, linear programming can be applied as follows:

Objective Function: Define an objective function, such as maximizing overall satisfaction or minimizing total cost.

Constraints: Define constraints, such as each student being assigned to only one school and each school having a fixed number of slots.

Solution: Employ linear programming algorithms (e.g., the simplex method) to find the optimal solution to the objective function within the constraints.

Linear programming excels at handling complex bilateral matching problems, delivering precise optimal solutions. However, its computational complexity is relatively high, making it suitable for small-to-medium-sized problems. For large-scale problems, heuristic or approximate algorithms may be considered to enhance solution efficiency [6].

2.3. The expansion and application of theory

The bilateral matching theory is widely used in Western countries such as the United Kingdom and the United States. Zhang Cheng drew on its advantages, combined with the characteristics of his own country, and analyzed the employment labor market of college students in China by using the bilateral matching theory [3]. Since the 20th century, e-commerce has developed rapidly. The bilateral matching theory has been used in the problem of electronic intermediary buying and selling. Xu Xiaohui, a professor from the School of Economics and Management of Tsinghua University, believes that the matching degree of e-commerce should be measured from three aspects:

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the standardization degree of the products and services sold by the seller, the standardization degree of the products and services by the customer, and the feedback of the customer on the products. It was determined whether a product was suitable for online sales, and ultimately a stable matching result was achieved. Zhang Zhenhua et al. put the Gale-Shapley and H-R algorithm theories into practice to deal with the bilateral matching problem.

3. The application of bilateral matching theory in the financial market

3.1. The field of venture capital

Venture capital markets exhibit a classic bilateral matching paradigm between investors and startup projects/entrepreneurs. Venture capitalists and venture capitalists (or entrepreneurs) each have different pursuit goals and also have certain expectations of each other to achieve common development goals. Kahneman and Tversky's (1979) prospect theory identifies two decision-making phases: editing (reference point establishment) and evaluation (utility assessment). The former sets a reference point and compares various benefit situations with the reference point. During the evaluation stage, decision-makers value each valuation and make choices, thereby achieving a better outlook. In 2007, Sorensen adopted a quantitative analysis method to examine the bilateral matching effect between venture capitalists and venture capital projects, arguing that the bilateral matching model has a positive impact on both venture capitalists and venture capital projects. In 2009, Cao Guohua and Hu Yi believed that the cooperation between venture capitalists and venture capitalists is all aimed at seeking the greatest value, and it is very important for the two to establish a stable matching theory. Based on their own value assessment criteria, they have laid a theoretical foundation for the bilateral matching between venture capitalists and entrepreneurs. However, in the field of venture capital, due to the different degrees of information acquisition and mastery, there exists a high degree of information asymmetry between the two sides of venture capital. Venture capitalists may be lured to invest by them due to information asymmetry, and investors may also face the credibility issues of venture capitalists, which brings many challenges to bilateral matching. However, in this situation, there is a high degree of information asymmetry between the venture capitalists and the investors. Venture capitalists may be lured to invest by venture capitalists due to the information asymmetry, and investors may also face the issue of the credibility of venture capitalists. Therefore, in order to safeguard the interests of both investors and venture capitalists, investment intermediaries need to objectively evaluate the actual levels of venture capitalists and venture enterprises, and then objectively assess the actual levels of venture capitalists and venture capitalists to avoid losses to the greatest extent [7].

3.2. The field of bank credit

In 2006, Wen Sheng identified structural differences between target and non-target customer segments in China's credit market. The credit market for target customers operates relatively stably. Under this mechanism, the allocation of credit funds can better meet the preferences of market participants, making the market matching results stable. The cooperative relationship between banks and enterprises is also relatively solid, which helps banks achieve stable operation. At the same time, enterprises can also obtain relatively stable financial support, promoting their sustainable development. In contrast to the stable target segment, non-target markets exhibit volatility due to decentralized bargaining mechanisms. Its decentralized bargaining process lacks a matching program that leads to stable results, resulting in low market efficiency and a large number of

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strategic behaviors. Such instability triggers credit fund migration from non-target to target markets. Small and medium-sized enterprises and other non-target customers often face the problem of difficult financing [8]. In 2011, Zhang Jijun analyzed the reasons why small and medium-sized enterprises have difficulty obtaining loans and the actual cases of city commercial banks providing loans to small and medium-sized enterprises. He pointed out that although small and medium-sized enterprises face many difficulties in the financing process, they and banks essentially share the same goal. Both parties pursue Pareto-optimal outcomes through symbiotic financial partnerships. By providing precise financial services to small and medium-sized enterprises, banks can expand their business areas and increase their sources of income. Small and medium-sized enterprises can achieve rapid development and enhance their market competitiveness by leveraging the financial support from banks. There is a stable matching relationship between banks and loan customers. Banks can avoid loan customers with bad credit, reduce losses and achieve stable operation. For loan customers, stable matching can reduce their search and loan costs, and achieve stable operation of enterprises. These dynamics underscore bilateral matching theory's critical role in credit market optimization [9].

3.3. Applications in other areas of the financial market

In the securities market, the relationship between underwriters and issuing enterprises conforms to the application scenarios of the bilateral matching theory, as both parties need to make cooperative decisions under the condition of information asymmetry. As an intermediary, the underwriter needs to select the appropriate issuing enterprise for underwriting, and the issuing enterprise also needs to choose the appropriate underwriter to help it successfully go public. The matching process incorporates multidimensional considerations including pricing dynamics, complementary resource endowments, and aligned risk appetites. Zhang Shuhui et al. took the data of enterprises listed on the main board in China from 2010 to 2019 as the research sample to explore the matching selection of the underwriting market and the impact of stable matching on the IPO market. The study reveals that optimal underwriter-issuer pairings emerge from three-dimensional filters assessing reputation capital, operational competency, and structural compatibility. The more well-matched the underwriter is with the issuing enterprise, the more it can alleviate the problem of high underpricing in the IPO market [10].

4. Problems and challenges of the application of bilateral matching theory in financial markets

Financial bilateral matching datasets frequently contain sensitive information—including user transaction histories and proprietary pricing models—creating inherent data scarcity due to privacy regulations. For instance, in the credit sector, data requirements include the borrower's credit record, repayment capacity data, capital flow, etc. in personal credit matching. This type of data directly crosses the red line of regulations such as the Personal Information Protection Law. Financial institutions cannot collect user data that exceeds their business needs at will, nor can they use the data for model training or industry sharing without authorization. Post-acquisition data processing still presents significant challenges in normalization and feature engineering [3].

Scholars at home and abroad have conducted research on bilateral matching models and achieved a series of research results, solving a large number of matching problems in life. While academic research remains limited domestically, bilateral matching theory has gained substantial traction in China's financial sector, particularly in bank card payment systems. However, the financial market is dynamic and changing, and the bilateral matching model needs to be able to adapt to the changes in

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the market. For instance, the behavioral patterns of market participants and changes in the economic environment may all affect the matching results. Therefore, the model needs to have the ability to dynamically adjust to adapt to the constantly changing market environment. In the financial market, the bilateral matching model not only involves the interests of card-issuing institutions and cardholders, but also those of merchants, acquiring institutions and many other parties. How to balance the interests of all parties while optimizing the matching mechanism is an important challenge.

5. Conclusion

Bilateral matching theory holds broad application value across multiple sectors of financial markets, including venture capital, bank lending, and securities markets. By optimizing matching mechanisms among market participants, this theory enhances market efficiency, reduces transaction costs, and strengthens market competitiveness. However, practical implementation faces numerous challenges, such as difficulties in data acquisition and processing, dynamic adaptability of models, balancing multiple stakeholders' interests, and constraints from policy and regulatory frameworks. These issues require multifaceted efforts encompassing technological innovation, policy support, and international collaboration. Future research directions should include the following aspects: Utilizing big data analytics: Acquiring and processing market participant information more accurately can enhance the efficiency of matching. Applying artificial intelligence algorithms, such as machine learning and deep learning, to optimize matching decision-making processes. Comparing financial market applications across different countries and regions: Summarizing lessons learned to provide reference for China's financial markets. Strengthening international collaborative research: Jointly advancing the global application and development of bilateral matching theory in financial markets. Although China has conducted relatively limited research on bilateral matching theory, its application in the financial sector has already yielded notable results. Moving forward, efforts should focus on deepening research and practical implementation of bilateral matching theory. Key strategies include data privacy protection and compliance, data sharing and collaboration, dynamic model adjustment and optimization, multi-stakeholder coordination and balance, and policy support and regulatory alignment. Through international collaboration, China can integrate advanced global knowledge and technologies, promoting the widespread adoption of bilateral matching theory worldwide. This approach will inject new momentum and direction into the evolution of financial markets.

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