Two-sided Matching Theory and Its Application in E-commerce Environment

Yue Yuan[1,a,*]

[1]Hongyi School of Wuhan University, Hubei, China, 430072
a. yyue_0907@163.com
*corresponding author

Abstract: Since the turn of the 21st century, China's e-commerce has exhibited a rapid development trend of diversification and internationalization. The number of users on e-commerce platforms has increased significantly, the network infrastructure has continued to improve, the number of cross-border e-commerce transactions has risen steadily, and the two-sided matching problem inherent to it has become a topic of increasing interest. Each agent in the e-commerce market may have several attributes, and e-commerce market matches are sophisticated and multi-variant. Thus, the development of a suitable matching mechanism is crucial for the market's effective operation. This paper explores the prior literature on two-sided matching theory and its application in the e-commerce sector, combs its research progress, summarizes the advantages and disadvantages of present matching approaches, and anticipates the growth of application domains in the future.

Keywords: two-sided matching, e-commerce, electronic intermediary, multi-factor

1.   Introduction

China's e-commerce started late, but after joining the WTO in 2001, Internet building increased and economic rules relaxed. Alibaba launched Taobao and Alipay, starting e-commerce. With the "Eleventh Five-Year Plan," network infrastructure improved and netizens proliferated, making e-commerce improve in quality, refinement, and social interaction. Two-sided matching has spread throughout e-commerce as many market agents have come together across time and geography. As such, a strong matching mechanism is crucial for efficiently matching two sides of agents, and the diversity of e-commerce types also diversifies matching processes. Bilateral matching theory won the 2012 Nobel Prize in Economics. How to match two disparate market agents reliably and efficiently is the research topic. E-commerce has more information and more sophisticated agents than traditional markets. The current e-commerce market's biggest challenge is how to stabilize and optimize matching. Chinese scholars have investigated e-commerce link matching methods from its development, focusing on how to set an acceptable objective function to maximize market players' benefit. Quantitative investigations on the core matching mechanism are scarce.

This paper examines the evolution of bilateral matching theory, reviews the relevant application documents of two-sided matching theory in the field of e-commerce, summarizes the key concepts of two-sided matching theory in the field of e-commerce, and examines the benefits and drawbacks of two-sided matching theory. By studying the features of various e-commerce industries and the benefits and drawbacks of matching methods, this paper identifies the deficiencies of current

research fields and proposes potential applications for bilateral matching theory in the field of personal e-commerce.

2. Two-sided Matching Theory

Two-sided matching theory is a theory that studies how two disconnected market subjects make a match in order to attain equilibrium. The paper College Admissions and the Stability of Marriage, published by Gale and Shapley in 1962 [1], is the source of two-sided matching theory. They primarily examined how to build a stable match between men and women in the marriage market in this paper, and the delayed acceptance algorithm in the two-sided matching market is preliminarily established. Based on his research on the National Resident Matching Program, Roth proposed the concept of two-sided matching for the first time in 1985 [2]. Roth discovered that in the two-sided matching market, matching occurred between two separate groups of agents, and that a stable matching was required for a satisfactory market operation. Roth also investigated more practical uses of two-sided matching theory, such as the pairing of hospitals and interns. This field is gradually being separated into two segments as this theory develops [3]. One approach is to examine how to construct a matching mechanism and algorithm   to achieve stable or Pareto efficient matching, which is the economic orientation of Gale and Shapley's research. This faction primarily employs the Gale-Shapley algorithm (DA), the Boston algorithm (IA), and the Top Trading Cycles algorithm. The other is to conduct quantitative decision-making and analysis in two-sided matching research using tools such as multi-attribute decision analysis method, intelligent algorithm, optimization modeling method, and decision support system, and its research content focuses on the generation of two-sided matching, matching satisfaction, and other issues, and the construction of decision support system through computer technology and information technology is discussed. For correct preference ranking, various functions are frequently constructed.

3. Overview of Electronic Commerce

3.1. Definition of Electronic Commerce

Electronic commerce(e-commerce) can refer to the electronization and networking of traditional commercial services as well as intangible commodities transactions over the Internet, Intranet, and other networks, such as information services and financial products. E-commerce relies on electronic equipment and network technologies, even though its meanings vary by country and field. E-commerce has expanded beyond purchasing to include logistics and distribution. E-commerce encompasses electronic currency exchange, supply chain management, electronic trading market, online marketing, online transaction processing, EDI, inventory management, and automatic data gathering system. The UN Working Group on Simplification of International Trade Procedures defines e-commerce as conducting business activities in electronic form, including any electronic tools among suppliers, customers, governments, and other participants, such as EDI, Web technology, e-mail, etc., sharing unstructured business information, managing and completing various transactions in commercial, management, and consumption activities. E-commerce revolves around buyer-seller transactions, the Internet, and company collaboration (such as logistics companies, suppliers, payment system and platform operators).

The primary categories of electronic commerce are:

First, agent, business, customer model (ABC): Agents, merchants, and consumers construct an e-commerce platform that integrates production, operation, and consumption. Transform these three sides. Everyone help each other. You and I constitute a true community of interests.

Second, business to business model (B2B): companies trade goods and services online. E-commerce transactions are usually completed by merchants (or firms and companies) via Internet

technologies or commercial network platforms. Publishing supply and demand information, ordering and confirming orders, payment process, issuing, transferring, and receiving bills, creating distribution strategy, and monitoring distribution process.

Third, business to customer model(B2C): business-to-consumer trade. China's first e-commerce platform, Tianmao, Suning, Taobao, etc.

Fourth, customer-to-customer model (C2C): an online trading platform for buyers and sellers, such Xianyu and Mercari, where vendors can actively auction goods and customers can bid on their own goods.

Fifth, customer to business model (C2B): By pooling scattered but large purchasers, the C2B mode strengthens users' B2C position and allows them to acquire a commodity at a wholesaler's pricing.

Business to Manager, Business to Team, and Business to Government models are also used in two-sided matching theory, but the models above are the most popular.

3.2. Features of Electronic Commerce

As a new method of trade, pervasive e-commerce has introduced manufacturers, distribution businesses, consumers, and the government to a new world of network economy and digital existence.

In the meanwhile, e-commerce is quite convenient. People are no longer bound by geography in the e-commerce environment, and clients may perform complex commercial tasks in a very straightforward manner. Online banking, for instance, allows access to account balances and information queries 24 hours a day, while simultaneously enhancing the service quality of businesses to their clients.

E-commerce may standardize the workflow of transaction processing and merge manual operation and electronic information processing into an inseparable whole, which not only improves the utilization rate of human and material resources but also increases the rigor of system operation.

4. Application of Two-sided Matching Theory in Electronic Commerce

At present, the application of bilateral matching theory in the field of e-commerce mainly focuses on the parts listed in the third section, namely B2B, B2C and C2C. The agents of both sides in these areas have diversified preferences and wider choice space. The three kinds of environments will be analyzed one by one as follows.

4.1. Application in B2B E-commerce Environment

4.1.1. Matching Between Suppliers and Enterprises

Suppliers provide limitations like inventory, price, fastest delivery date, etc., while companies provide preferences in the two-sided matching problem. Companies demand suppliers with speedy delivery, competitive prices, and good inventory-to-order matching. Offline procurement usually involves a single buyer. They have limited access to suppliers, low efficiency, low purchasing volume, and difficulty negotiating lower prices, which raises costs. E-commerce platforms enable low-cost information sharing and efficient two-way matching. The platform can also consolidate orders to increase bargaining strength and save expenses.

In 2017, Zheng Wang, Peng Chen, and others proposed building an online trading platform between suppliers and buyers [4], establishing a multi-objective utility function that included commodity price and average delivery time, solving the extreme value of the function under the constraints of commodity inventory and delivery time to get the optimal procurement vector and

generate the purchase list to reduce purchase cost. This mechanism may simultaneously construct the multi-objective utility function of providers and apply weights to sum up buyers' and suppliers' utility values to optimize both parties' subjective and objective utility. In 2018, Shengnan Li proposed A Multi-property Matching Problem based on Multi-factor under E-commerce [5].

4.1.2. Matching Between Enterprises and Advertisers

Online advertising differs from offline advertising at a specified time and location. It can be used in any Internet service phase due to its inexpensive cost, high transmission speed, and large range. After short video's quick growth, several traits stand out. Quick films break up viewers' time, making it harder to refuse ads. Short video bloggers act as "advertising venues" to emphasize ads and present products in 30 seconds or less. This type of advertising diversifies product ads and completes the geometric growth of the spread range in a short time. However, diversification requires enterprises to pay different types of video bloggers, resulting in a large number of potential costs, so the product must choose bloggers who are suitable for this product, with large fans and great influence; at the same time, video bloggers are more inclined to products with good reputations and high fees.

The Delayed Acceptance algorithm solves the two-sided advertising-enterprise matching problem. Online services often feature fixed advertising places like billboards in video clips, application portal pages, game revival levels, etc. Advertisers can conduct public bidding and choose the enterprise with the highest bid. If the enterprise fails to bid, it will choose the next advertiser. This type of advertisement's demand side is the advertiser, thus the firm doesn't need to find a reliable match. If advertisers require advertising urgently, they can develop a utility function on an information sharing platform, focusing on advertisers' utility value, and produce stable matching. Businesses need video bloggers to market their products in short video. On the premise of promotion willingness, video bloggers choose the items with the highest preference order and look for the next video blogger if the products are refused. Since brief video matching is heavily influenced by subjective elements, the matching outcome of building a single utility function will vary substantially.

4.1.3. Matching Between Enterprise and E-commerce Platform

E-commerce enterprises and platforms also match each other. Enterprises desire a platform with a lot of users and a solid logistics system, whereas platforms favor enterprises with a lot of revenues because they collect fees for transactions. The key to this challenge is matching the most profitable objects as there are no limits on organizations and platforms. Knowledge service matching in cross-border e-commerce supply chains is an example. Owing to differing systems and transaction restrictions in different countries, cross-border e-commerce is prone to information gaps. Settled firms use cross-border e-commerce platforms to accrue credit in cross-border transactions, cut costs, identify target groups, and increase efficiency. All cross-border transactions involve knowledge service. Cross-border e-commerce platforms depend on an enterprise's qualifications.

Yet, the volume of transactions on cross-border e-commerce platforms is still modest, and the platforms' services are inefficient due to the blind choice of huge platforms and the waste of material and financial resources. Hence, reliable and efficient matching is crucial for supply chain smoothness and regular transaction. Establishing multi-objective utility functions can still solve this challenge. Using a five- or seven-granularity language evaluation system with triangular fuzzy numbers, Xiaoxue Zheng's matching method maximizes overall satisfaction [6].

4.1.4. Application in The Process of Price Formation

The behavior of many providers and consumers determines price in the typical market. An oligopoly or monopoly can control market prices, while a single market participant cannot. If both parties are influential, how they match and agree will determine product prices. China's coal-electricity pairing is typical. Governments once set coal prices. China introduced a "dual-track system" of coal prices after the market-oriented reform. Coal prices are entirely liberalized. Coal quality, price, availability and demand, delivery date, and other factors will affect both parties' preferences when matching two types of organizations. Enterprises share trading information on the trading platform. This mechanism impacts micro-subject transaction selection and match generation, which affects the equilibrium coal price. Micro-transaction themes are also the most sensitive in changing market conditions like coal supply and demand, coal import and export, and coal policy. They will carefully alter trading information and trading choices in diverse scenarios and reflect them to the equilibrium coal price in time to protect their interests. Two-sided matching theory could match transactions and generate coal prices. We can set up scenarios like changes in coal supply and demand, import and export of coal, resource tax reform, and environmental (carbon emission) constraints, find the main factors that affect coal prices, design scenario parameters, compare the selection and amount of matching transactions of coal and power enterprises, and compare the equilibrium price of coal in different scenarios to find a long-term and reasonable mechanism. It helps coal-fired power generation firms manage and create macro-policy, establishes long-term matching transaction relationships between coal and power enterprises, decreases transaction costs, and enhances transaction efficiency [3].

4.2. Application in B2C E-commerce Environment

In the matching problem between venture capitalists and firms, the preference of invested enterprises is relatively straightforward, focusing mostly on investment share needs, but venture capitalists have preferences for enterprise scale, founder qualification, and profitability. In the e-commerce environment, electronic intermediary, as a platform for information aggregation, assists both parties in finding a match with the highest overall perceived pleasure, thereby significantly enhancing the efficiency of decision-making. In addition to the approach for determining the multi-objective utility function [7], the approximate ideal solution is also relevant [8]. Mediators are able to specify a positive ideal solution and a negative ideal solution, compute the distance between various matches and the ideal solution, and generate a match with the shortest distance from the positive ideal solution. Compared to traditional intermediaries, the information possessed by electronic intermediaries considerably widens the choice pool of investors and businesses, improves the success rate of matching, and reduces the cost of intermediaries due to the reduced usage of human resources. In addition, because firms and investors can make public evaluations through the intermediary platform, both parties have additional reference information, which facilitates the construction of a more reliable and regret-free match [9].

4.3. Application in C2C E-commerce Environment

In online auctions, two-sided matching between consumers is most prominent. Within the budget, bidders select multiple competing products on the platform, and the auctioneer sells them to the highest bidder. The simplest Delayed Acceptance algorithm can resolve this issue.

An example would be the auction of equity. As venture capital exits the market, venture capitalists and external investors will be matched. The historical reputation and performance of both parties are crucial factors to examine. In order to solve this issue, both the Delayed Acceptance algorithm and the Top Trading Cycle mechanism are viable; that is, venture capitalists select

external investors with the highest priority, and external investors select venture capitalists with the highest priority simultaneously to form a cycle; the resulting matching is Pareto efficient and incentive compatible. But, the peculiarity of an equity auction is that the value of stock is reflected not only in the immediate valuation, but also in the future appreciation valuation. Investors must examine the several characteristics of an equity. In 2013, Junjun Zheng presented the notion of threshold that may be utilized to systematically quantify the differences between two parties in the evaluation of the value of the other party [10]. If the disparities are within the threshold, it indicates that the agents on both sides can create a stable match. This strategy significantly restricts the options available to venture capitalists and external investors and increases the precision of selection.

5.   Advantages and Potential Problems of Bilateral Matching Theory

As demonstrated by the preceding instances, the primary advantage of applying the two-sided matching theory to the field of e-commerce is that the e-commerce platform has a vast amount of information, the majority of which is public. In comparison to offline matches, the selection range is vastly extended and it is much simpler for market players to identify compatible mates. Second, with the help of the Internet and a computer, a large number of matches are changed into the solution of a function's extreme value, which significantly enhances the efficiency of matching and opens the door to numerous application possibilities. Simultaneously, the two-sided matching theory in an e-commerce environment significantly reduces labor costs in the conventional method and helps businesses improve profits. There are, however, some hidden problems. Due to the simplification of numerous matching problems as function problems, the acquired matching results are not necessarily stable and effective, and market players may not necessarily adhere to the matching findings, necessitating additional time and expense to find a traditional match. In addition, because the outcomes of some matching processes are not strategy-proof, the information on the platform cannot be entirely accurate, and the intermediate platform must apply additional regulatory procedures to assure the accuracy of the information. Yet, there is no assurance that a platform with huge amounts of information can effectively save all users' information, which is likely to lead to the problem of privacy revelation; hence, the convenience of users is likely to come at the sacrifice of some privacy.

6.   Conclusion

Looking back at the literature of domestic and foreign researchers on two-sided matching theory, the researcher can see that domestic and foreign scholars have done a lot of creative research on two-sided matching, expanding from the marital matching problem to numerous markets and two different aim orientations. Scholars focus on fast, efficient, and cheap two-sided matching in all e-commerce markets, although stability and strategy-proofness cannot be guaranteed. However, applying the extreme value solution of the function requires a lot of information, therefore the authenticity and security of this information may potentially hinder bilateral matching theory's practical use. As such, a novel matching mechanism is needed to solve the extremum problem of function quickly and efficiently in the future development of two-sided matching theory in e-commerce. The existing unified function processing approach is struggling to meet the needs of big groups of agents as e-commerce becomes more personalized and subjective. Thus, establishing a matching system that fully respects individual specialization preferences and yields consistent matching outcomes is likewise a critical issue.

References

[1] Gale D,Shapley L.College admissions and the stability of marriage [J]. *American Mathematical Monthly*, 1962, 69 (1).

[2] Roth A E.Common and conflicting interests in twosided matching markets [J]. *European Economic Review*,1985 (1).

[3] Ruyi Shi, Rui Nie, Di Wang,Chongmao Li.Application prospects of two-sided matching theory on generation of electrical coal price in e-commerce environment [J]. *Chinese Coal*, 2017, 43 (03):10-13+20.

[4] Two-sided matching method and system for B2B e-commerce supply and demand, 2017. https://www.ixueshu.com/.

[5] Shengnan Li, Quan Zhang. A Multi-property Matching Problem based on Multi-factor under E-commerce [J]. *Science&Technology Vision*, 2018, (02): 78+92.

[6] Xiaoxue Zheng,Dengfeng Li,Ying wang,Jiacai Liu.Research on two-sided matching model based on knowledge service of cross-border e-commerce supply chain [J].*Journal of modern information*, 2016, 36 (11): 43-49+54.

[7] Shuping Wan,Dengfeng Li.Multi-index two-sided matching decision-making method between venture capitalists and investment enterprises with different types of information. [J].*Chinese Journal of Management Science*, 2014, 22 (02): 40-47.

[8] Zhongxing Wang,Shuai Huang.A decision making method for trade matching of buyers and sellers in electronic commerce [J]. *Popular Science&Technology*, 2014, 16 (05): 18-22.

[9] Lanlin Wang.Analysis of two-sided matching between venture capitalists and investment enterprises in e-commerce environment [J].*Global Market Information Guide*, 2018,13.

[10] Junjun Zheng, Ping Zhang, Xiaoshi Hu. Two-sided matching and simulation of equity multi-attribute auction based on graph theory [J]. *Journal of WUT(Information&Management Engineering)*, 2013, 35 (01): 106-110.