

Comparative Study of Double Auction Markets under Different Auction Rules

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Abstract: As an important market mechanism, double auctions are widely applied in complex markets such as finance and energy. The design of auction rules significantly impacts market efficiency, fairness, and resource allocation. This paper focuses on two typical auction rules: uniform pricing and discriminatory pricing. It compares and analyzes their characteristics and market performance from price discovery efficiency, resource allocation efficiency, and market transparency perspectives. This paper uses the German electricity market and the Shanghai license plate auction to validate the theoretical analysis as case studies. Through an in-depth analysis of these two markets, this study demonstrates the applicability and limitations of uniform pricing and discriminatory pricing under different market environments. The results show that uniform pricing, with its single equilibrium price, improves market transparency and fairness, making it suitable for markets that prioritize price stability and efficiency. In contrast, discriminatory pricing caters to individualized needs through differentiated pricing but may face challenges in transparency and fairness due to strategic behaviors and price dispersion. This study provides theoretical support and practical insights for optimizing rule design in double auction markets.

Keywords: Double auction, uniform price auction, discriminatory price auction, market rule design, resource allocation efficiency.

1. Introduction

As an important market mechanism, double auctions are widely applied in complex markets such as finance and energy. At their core, double auctions determine transaction prices and quantities by dynamically matching bids submitted by both buyers and sellers by market rules. Compared to single-sided auctions, double auctions are more flexible and better reflect the preferences of both supply and demand sides. This makes them particularly suitable for high-frequency trading and scenarios with high demands for resource allocation. Therefore, the performance of double auction markets under different auction rules has become a critical research topic that significantly affects market efficiency and fairness.

In the context of double auction mechanisms, uniform pricing, and discriminatory pricing are two typical transaction rules. Uniform pricing determines transactions through a single equilibrium price, characterized by price consistency and market transparency. For instance, the German electricity market employs uniform pricing to achieve high levels of market transparency and fairness [1]. In contrast, discriminatory pricing determines transactions based on individual bids, reflecting price

flexibility and differentiation. The Shanghai license plate auction adopts discriminatory pricing, which caters to diverse needs through differentiated pricing. However, price dispersion and strategic behaviors limit its transparency and fairness [2].

This paper focuses on the rule design and market performance of uniform pricing and discriminatory pricing in double auction markets. By examining real-world case studies, it explores the specific applications and differences of these two mechanisms in price discovery, market efficiency, and resource allocation. The study aims to provide theoretical support and practical insights for optimizing rule design in double auction markets.

2. Fundamentals of Double Auction Mechanisms and Rule Design

Double auctions, as a trading model that facilitates direct interaction between buyers and sellers in market environments, determine transaction prices and quantities through bids simultaneously submitted by both sides and matched by market mechanisms. Unlike single-sided auctions, the core of double auctions lies in the dynamic interaction and matching between supply and demand, making them particularly suitable for complex markets where direct transactions between buyers and sellers are required, such as financial and energy markets [3].

As a market mechanism, double auctions dynamically match supply and demand through buyers' bids, which represent the highest willingness to pay, and sellers' bids, which represent the lowest willingness to accept. This process ensures efficient resource allocation and price discovery [4]. The system ranks buyers' bids from high to low and sellers' bids from low to high, determining the equilibrium price at the intersection of the supply and demand curves. This equilibrium price is used to match orders and finalize transaction prices. Additionally, double auctions allow real-time bid adjustments, further enhancing supply-demand balance and improving the efficiency of resource allocation in the market.

Rule design plays a critical role in double auctions, directly influencing market efficiency and fairness. The core rules include the price priority principle and the time priority principle. The price priority principle states that orders with higher buyer bids or lower seller bids are prioritized for transactions. The time priority principle specifies that, in the case of identical bids, earlier submitted orders are processed first [1]. The determination of transaction prices is the central aspect of rule design. Currently, two typical mechanisms are widely used: uniform pricing and discriminatory pricing. These two mechanisms differ significantly in terms of market efficiency, incentive effects, and fairness, and will be discussed in detail in subsequent sections.

Compared to single-sided auctions, double auctions have distinct advantages in several aspects. Their ability to dynamically match supply and demand curves allows them to more accurately reflect market equilibrium points, thereby improving resource allocation efficiency [5]. At the same time, double auctions enhance price discovery by integrating buyers' demand and sellers' supply intentions, resulting in market prices that are closer to true market values. Thanks to their flexibility and adaptability, double auctions are also widely applied in complex markets requiring high-frequency trading, such as electricity markets and financial securities, effectively meeting the high demands of these markets for trading mechanisms [6].

3. Core Models of Auction Mechanisms: Uniform Pricing and Discriminatory Pricing

In the double auction mechanism, the determination of transaction prices is the core of market rule design. Uniform Price Auctions (UPA) and Discriminatory Price Auctions (DPA) are two of the most common transaction rules, widely applied in complex trading environments such as financial and energy markets [2]. Uniform Price Auctions execute all orders at a single clearing price, emphasizing price consistency and market transparency. In contrast, Discriminatory Price Auctions settle

transactions based on individual bids submitted by participants, highlighting price flexibility and differentiation [7]. This section focuses on the rule characteristics of these two mechanisms, providing a foundation for subsequent comparative analyses in terms of price discovery efficiency, market transparency, and resource allocation.

3.1. The Mechanism and Characteristics of Uniform Price Auctions

Uniform Price Auctions are a specific transaction rule within the double auction framework, characterized by all matched orders being executed at the same price. This price, referred to as the clearing price, is determined by the intersection of the supply and demand curves in the market. Compared with the general framework of double auctions, Uniform Price Auctions retain the fundamental mechanisms of simultaneous bid submission, market matching, and dynamic adjustments but differ significantly in the method of determining transaction prices.

The distinct characteristics of Uniform Price Auctions are reflected in three key aspects: price consistency, incentive compatibility, and market transparency. Price consistency is one of its core features. Regardless of how high a buyer's bid is or how low a seller's offer is, if transaction conditions are met, all orders are executed at the clearing price. Specifically, buyers only need to bid higher than the clearing price to complete transactions and pay the clearing price, while sellers only need to bid lower than the clearing price to sell and receive the clearing price. This mechanism ensures that all participants in a transaction are subject to a unified price.

Uniform Price Auctions also exhibit a high degree of incentive compatibility. Participants are encouraged to submit truthful bids because the final transaction price is determined by the overall market supply and demand, and individual bids have limited influence on the clearing price. This mechanism effectively reduces the motivation for strategic behavior, thereby improving market efficiency. Furthermore, Uniform Price Auctions provide a high level of market transparency. The clearing price, as a single market price signal, offers participants clear information about the supply-demand relationship, reducing the risk of information asymmetry and avoiding price discrimination caused by differentiated pricing.

3.2. The Mechanism and Characteristics of Discriminatory Price Auctions

Discriminatory Price Auctions are another specific transaction rule within the double auction framework, characterized by each matched order being executed at its respective bid price. In this mechanism, transaction prices are no longer unified but are directly determined by the bids submitted by buyers or sellers. Like Uniform Price Auctions, Discriminatory Price Auctions retain the fundamental mechanisms of simultaneous bid submission, market matching, and dynamic adjustments, but they differ significantly in the way transaction prices are determined.

Discriminatory Price Auctions have three notable characteristics: price differentiation, competitive incentives, and lower market transparency. Price differentiation is a defining feature of this mechanism. Under Discriminatory Price Auctions, the price of each transaction is determined by the individual bid submitted by the participant. Specifically, buyers can complete transactions as long as their bids are higher than or equal to the clearing price, but the price they pay is their submitted bid. Similarly, sellers can complete transactions if their bids are lower than or equal to the clearing price, but the price they receive is their submitted bid. As a result, transaction prices vary significantly across the market.

This mechanism also creates competitive incentives. Buyers are motivated to submit higher bids to prioritize their transactions, while sellers are encouraged to submit lower bids for the same reason. Since transaction prices are directly determined by individual bids, participants tend to adopt competitive strategies rather than relying solely on the clearing price. However, Discriminatory Price

Auctions exhibit lower market transparency. Because each transaction is executed at a different price, this mechanism fails to provide a unified and clear price signal. The presence of multiple transaction prices makes it difficult to comprehensively reflect the overall supply-demand relationship and may lead to asymmetric understandings of the market among buyers and sellers.

3.3. Comparison of Mechanisms and Characteristics

Uniform Price Auctions and Discriminatory Price Auctions each have distinct advantages. Uniform Price Auctions achieve price consistency, incentive compatibility, and market transparency through the clearing price, making them suitable for markets that prioritize fairness and resource allocation efficiency. On the other hand, Discriminatory Price Auctions are characterized by price differentiation and competitive incentives. By providing a more flexible pricing mechanism, they meet individualized needs and are better suited for diversified market environments. The choice between these two mechanisms depends on the specific objectives of the market, such as fairness, transparency, or flexibility.

4. Case Analysis: Market Performance of Double Auctions under Different Auction Rules

The performance of double auction markets differs significantly under different auction rules. Evaluating the advantages and disadvantages of auction mechanisms requires examining core indicators such as price discovery efficiency, market efficiency, resource allocation, and price volatility. This section analyzes the specific performance of Uniform Price Auctions and Discriminatory Price Auctions based on case studies of the German electricity market and the Shanghai license plate auction.

4.1. Uniform Price Auctions: The Case of the German Electricity Market

Uniform Price Auctions execute all matched orders at a single clearing price, ensuring price transparency and fairness. In the German electricity market, all participants transact at the clearing price, effectively avoiding unfairness caused by price differentiation. This mechanism allows market prices to more accurately reflect the supply-demand relationship and reduces price discrimination arising from differences in market power. Studies show that approximately 85% of participants in the German electricity market submit bids close to their actual generation costs, indicating that Uniform Price Auctions significantly reduce strategic bidding behavior, thereby improving overall market transparency and fairness [8].

Uniform Price Auctions exhibit high incentive compatibility, significantly reducing strategic behavior among market participants. By providing a clear clearing price signal, participants are more inclined to bid based on their true costs, thereby optimizing resource allocation efficiency. Simulation studies have demonstrated that the proportion of strategic bidding in Uniform Price Auctions is significantly lower than in other auction mechanisms. In the German electricity market, market prices are closer to participants' marginal costs, further validating the effectiveness of Uniform Price Auctions in mitigating strategic behavior [8].

In terms of price discovery efficiency and volatility, Uniform Price Auctions enhance price discovery by providing a clear price signal through the single clearing price. Data from the German electricity market show that the intraday auction price volatility is below 5%, significantly outperforming other market mechanisms, where price volatility typically ranges from 10% to 15%. This demonstrates the role of Uniform Price Auctions in promoting price stability [8]. Moreover, the design of a single clearing price reduces market fluctuations caused by price inconsistencies, providing participants with a more stable and transparent trading environment.

4.2. Discriminatory Price Auctions: The Case of the Shanghai License Plate Auction

Discriminatory Price Auctions allow each bidder to pay the transaction amount based on their submitted bid, reflecting price differentiation. In the Shanghai license plate auction, the final transaction price for each bidder is determined by their last submitted bid. Experimental data show that the average bid in the Shanghai license plate auction is significantly lower than that in Uniform Price Auctions, with an average difference of approximately 12 units [9]. This mechanism provides greater flexibility for bidders through differentiated pricing but may also result in resource allocation imbalances due to the dispersion of transaction prices [9].

Discriminatory Price Auctions are characterized by more pronounced strategic behavior. Studies indicate that bidders in the Shanghai license plate auction tend to conceal their private values to minimize payment costs, with initial bids generally lower than their private values. Data shows that over 79% of bidders revise their bids upwards after the initial submission [9]. This phenomenon reflects bidders' adaptability to auction rules and their ability to adjust strategies. Furthermore, the dynamic modification phase intensifies the complexity of strategic behavior, as bidders use multiple rounds of bid adjustments to maximize personal gains through low initial bids followed by gradual increases [9].

In terms of price discovery efficiency, Discriminatory Price Auctions result in a wide distribution of transaction prices. This dispersion indicates lower transparency in price signals and may cause some transaction prices to deviate from bidders' actual private values [9]. Experimental data reveal that the average transaction price in the Shanghai license plate auction is significantly lower than that in Uniform Price Auctions, further demonstrating differences in price discovery efficiency under different auction rules [8]. Although information disclosure, such as the minimum acceptable transaction price, partially mitigates price dispersion, the introduction of dynamic modification mechanisms provides bidders with greater strategic flexibility, limiting price discovery efficiency [9].

From the perspective of market revenue, Discriminatory Price Auctions demonstrate certain advantages for sellers. Experimental data show that the average seller revenue in the Discriminatory Price Auction group is 232.60, significantly higher than the 213.12 observed in the Uniform Price Auction group [8]. However, despite the flexibility for bidders to minimize payment costs through strategy adjustments during the dynamic modification phase, this mechanism may further suppress final transaction prices, resulting in seller revenues that fall below theoretical expectations for the Shanghai license plate auction [9].

4.3. Comparative Analysis: Market Performance of the Two Auction Mechanisms

The case studies of the German electricity market and the Shanghai license plate auction reveal significant differences in market performance between Uniform Price Auctions and Discriminatory Price Auctions. Uniform Price Auctions improve price transparency and fairness through the single clearing price, reduce strategic behavior, and stabilize prices, making them suitable for markets that prioritize fairness and stability. In contrast, Discriminatory Price Auctions meet individualized needs through price differentiation but exhibit lower efficiency due to price dispersion and strategic behavior, resulting in inequitable resource allocation. These findings highlight the distinct differences between the two auction mechanisms in terms of transparency, fairness, and flexibility, providing valuable practical insights for selecting appropriate auction rules in double auction markets.

5. Conclusion

This paper examines the rule design of double auction markets, providing a detailed comparison of the core characteristics and market performance of Uniform Price Auctions and Discriminatory Price Auctions. Based on case studies of the German electricity market and the Shanghai license plate

auction, the findings indicate that Uniform Price Auctions enhance market transparency and fairness through a single clearing price, effectively reducing strategic behavior. This mechanism is particularly suitable for markets that prioritize price stability and resource allocation efficiency. In contrast, Discriminatory Price Auctions meet individualized needs through differentiated pricing but may face limitations in fairness and transparency due to issues such as strategic behavior and price dispersion.

The study further demonstrates that each auction rule has its own strengths and weaknesses, and the choice between them should be determined by the specific operational objectives of the market. Uniform Price Auctions are better suited for market environments emphasizing fairness, price consistency, and transparency, while Discriminatory Price Auctions are more applicable to markets with diverse demands and higher flexibility requirements.

Despite providing theoretical insights and practical references for the selection and optimization of rules in double auction markets, this study has certain limitations. Future research could delve deeper into the following areas: first, exploring more types of auction rules, such as combinatorial auctions and hybrid auctions, to investigate their applicability in more complex market environments; second, conducting extensive empirical comparisons across different market contexts (e.g., financial markets, carbon trading markets) to verify the performance of various rules in terms of price discovery efficiency, market fairness, and transparency; and third, examining the potential applications of emerging technologies, such as blockchain and artificial intelligence, in the design and implementation of auction rules, aiming to improve the efficiency and adaptability of rule optimization.

In summary, this paper provides an in-depth comparative analysis of double auction market rules and offers recommendations for their optimization. These findings contribute theoretical support and practical insights for better meeting the operational demands of complex market environments.

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