Shill Bidding in Multi-round Online Auctions

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Abstract

The online implementation of traditional business mechanisms raises many new issues not considered in classical economic models. This partially explains why online auctions have become the most successful but also the most controversial Internet businesses in the recent years. One emerging issue is that the lack of authentication over the Internet has encouraged shill bidding, the deliberate placing of bids on the seller's behalf to artificially drive up the price of the seller's auctioned item. Private-value English auctions with shill bidding can result in a higher expected seller profit than other auction formats [1], violating the classical revenue equivalence theory. This paper analyzes shill bidding in multi-round online English auctions and proves that there is no equilibrium without shill bidding. Taking into account the seller's shills and relistings, bidders with valuations even higher than the reserve will either wait for the next round or shield their bids in the current round. Hence, it is inevitable to redesign online auctions to deal with the "shiller's curse."

1. Introduction

Online businesses face new strategic and operational challenges that are unknown in the traditional economy. Many of the challenges are due to the facts that these businesses rely heavily on Internet-based information systems to conduct business transactions and a weakness in such an information system may be exploited by dishonest business participants, affecting the financial success of its supporting e-business and/or violating the fairness commonly preserved in market transactions. When an information system is implemented for resource allocation purposes, there will always be some fraudulent players who maliciously deploy hidden actions to dishonestly increase their own utilities.

New varieties of hidden actions of online players challenge the design and implementation of information systems supporting online resource allocations. We have researched on the software reliability issues and suggested modern formal verification tools to rigorously prove the correctness of information system implementations [2]. This will help to find hidden programming bugs in a complex information system, like the trading platform eBay uses to support its huge volume of auction transactions. Before the implementation assurance, however, and more importantly, information system designers should thoroughly re-examine the traditional resource allocation mechanisms (i.e., business policies and trading rules) to verify if they are still robust against new varieties of hidden, and potentially malicious, actions of online players. To assure the viability of a business model in a new trading environment, the model itself and the design of its information system should be modeled mathematically if possible and proven not to have fatal flaws. Once a system is already programmed and put into real-world operations, it will be difficult to modify its resource allocation rules, not only because of the hassle of system updates, but also because of the cost of re-educating existing system users. Not to mention that the existing users will be reluctant to the new changes.

Take the example of online auctions. Almost all of the online auction houses take the existing auction mechanisms (English, Dutch, First-price Sealed-bid, and Second-

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price Sealed-bid) directly from economics textbooks and implement them into Internet-based auctions without considering new issues related to this new trading environment. They hardly considered what the lack of authentication and the network delay uncertainties mean and how these issues affect the auction results. In contrast, our research endeavor is to redesign traditional auction mechanisms taking into account of the emerging issues in the new trading environment. Our prior research has focused on the authentication issue and concluded that the traditional auction mechanisms have to be modified to accommodate the new weakness of the technological trading platform because this weakness leads to the loss of some properties of traditional auction models [1, 3, 4]. This paper is a continuation research on shill bidding in the multi-round context. Next, we will discuss general issues of online auctions and their security and lead to shill bidding and multi-round issues.

In the recent several years online auction sites have brought auctions to the general public. eBay, founded online in September 1995, claims itself as the world's largest online marketplace. As of September 2001, eBay has nearly 30 million registered users and is the most popular shopping site on the Internet when measured by total user minutes according to Media Metrix [5]. An auction survey has concluded that up to the year 2001, 31% of online Americans, or approximately 35 million people, participated in online auctions [6]. Unlike the many dot coms which have vanished along with the bursted bubbles in 2000 and 2001, online auction sites are among the most successful Internet businesses and are here to stay.

The success of online auction businesses, however, is accompanied by problems as well. Online auctions have attracted most of the online fraud, ranked as the number one type of Internet fraud in the past three years (1998-2000) consecutively [7]. In 1999, online auction fraud accounted for 87% of reported incidents, up from 68% in 1998. Indeed, online auctions seemed to attract fraud. Between 1998 and 1999, fraud related to online auctions soared by 76% while fraud related to other types of online transactions plummeted by 44%. In the year 2000 the volume of auction related fraud increased 23% and accounted for 78% of the reported incidents. Considering that there are millions of items listed on eBay across thousands of categories on any given day and the eBay community transacted more than $5 billion in annualized gross merchandise sales in 2000 [5], online auction transactions that involve fraud can be in a large number as well. Statistical data support this prediction. In fact, among the 35 million Americans participating in online auctions, 41% of online auction buyers reported having a problem [6]. Economists have been studying auctions for over forty years, yet no one has predicted the volume of online auctions and the variety of fraudulent behavior observed in current online practices.

Shill bidding is probably one of the most widely publicized forms of online auction fraud. Shill bidding occurs when the seller (or his agent(s)) disguises as a legitimate bidder to submit bids solely for the purpose of pushing up the sale price. Shill bidding is easier to conduct and harder to detect in the Internet environment, because the Internet provides unprecedented opportunities for the seller to create false identities under whom to submit shill bids, and hence to orchestra the entire fraud all on his own. More than once, shill bidding in e*bay has become headline news [8]. It has also been identified as one of the most common types of e-auction fraud by the Internet Fraud Complaint Center (IFCC), a partnership between the Federal Bureau of Investigation (FBI) and the National White Collar Crime Center (NW3C) [9]. In addition, the analysis of the rare coin auction market in eBay also indicated that about 10% of auction buyers had shown questionable bidding behavior; they intended to run up the bid rather than to win the auction [10]. Not to our surprise, shill bidding occurs in double auction markets as well, but in different forms. Recent fraud in the IPO markets are cases where IPO shares were allocated to investors who had agreed to purchase more shares later on at much higher prices [11]. This type of IPO fraud is essentially shill bidding: payoff were delivered in advance in exchange of future shill bids from the bidding ring members.

Shill bidding has become more and more popular in online auction markets. It is important to fight against this new form of fraud. In the economics literature, it is often discussed that market failures can be caused by two economic reasons: 1) externalities resulting in inefficient or missing markets, and, 2) asymmetric information leading to lemon markets. However, the newly emerging technology-related economic problems can also lead to certain market failures not considered before by economists. Shill bidding is one example. Without proactive control over shill bidding, buyers' trust towards the markets could deteriorate, which may result in inefficient or failed markets.

Despite its importance in the new economy, shill bidding is hardly considered in the traditional auction literature [1]. This is mainly because shill bidding was not a significant problem in physical auctions. Consequently, there was the lack of mechanisms to fight against shill bidding as well [1]. To our knowledge so far, our research is the first providing imminent and creative solutions against shill bidding.

Let us look more in details. The most studied auction model in the auction literature assumes the following: 1) Bidders have private valuations drawn independently from a single distribution (commonly referred as the IID assumption); 2) The seller interacts with the bidders directly:

there is no cost involved in entering the auction or organizing the auction, and the role of an auctioneer is simplified as non-significant; 3) Most papers also assume that the seller has a single item for sale, and the single round auction is the seller's only chance to sell this item.

But even in this simple model under all these assumptions, shill bidding can still be profitable. [1] has shown that in traditional private-value single round English auctions without an auctioneer, shill bidding can be profitable to the seller if the seller's expected profit function has multiple local maximums. When there are different types of bidders present in an auction market, such as in an art auction market, there are art dealers who intend to resell the item and art collectors who would like to complete their collections, the seller's expected profit curve will have multiple humps. The global best solution to the seller's optimal reserve varies according to the number of bidders and bidders' value distributions. A shiller (a seller with shill bidding) can start with a lower optimal reserve, then according to his observation of the auction process, reset reserve prices (multiple times if necessary) through shill bids to reach a higher optimal reserve corresponding to a higher expected profit maximum. This explains why in English auctions with shill bidding, the seller can have a higher expected profit than in sealed-bid auctions, violating the classical revenue equivalence theory.

To describe real auctions and analyze shill biddings in practice, most of the above assumptions have to be relaxed. For example, common-value auctions are more common in online English auctions than private-value auctions. The open bidding process allows bidders to observe and communicate each other's valuation and adjust their own valuations if necessary. This is one of the reasons why most of the auctioneers, sellers and bidders prefer English auctions. Intuitively, one can think that the motivation of the seller submitting shill bids is to disguise as a competing buyer and to use the shill bid to encourage a legitimate high-value buyer not only to bid up to her true valuation, but also, even beyond that, to increase her valuation accordingly. In this paper, we still only consider the earlier case where bidders have their own private valuations and their valuations do not affect each other. This means that the seller's shill bids do not affect the remaining bidders' valuations. However, in a forthcoming research, we will take into account of the common value features of many online English auctions and analyze shill bidding under this context.

In addition, the second assumption has to be relaxed as well. Auctions endure costs. They are organized by intermediaries, e.g., online auction houses like eBay. Auctioneers set up the trading environment of auction markets, that is, the technological platform for executing auction processes. Economists have ignored this aspect of auctions. They hardly have any discussion of the important roles auction intermediaries play. Nevertheless, their importance can not be neglected. For example, the various fees charged by these intermediaries can have an impact on the seller's incentives for shill bidding. Since it is almost impossible to detect and exclude shill bidding, auctioneers should choose the auction mechanisms and fee schedules that make shill bidding unprofitable. As discussed in [1], shill bidding can be made unprofitable in the private-value IID English auction model. Here, we summarize the main result – a Shill-deterrent Fee Schedule (SDFS) defined as follows:

1. The auctioneer charges the seller a listing fee: $(1-c)l(r)$ where r is the reserve price and l is a monotone increasing function $l : \mathbb{R} \mapsto \mathbb{R}$. The listing fee is paid even if the auction is not successful, i.e., there is no bid at or above the reserve price.
2. The auctioneer also charges the seller a commission fee: $(1-c)(v-r)$ where v is the final winning bid, r is the reserve, and $(1-c)$, $0 \leq c \leq 1$, is the commission rate. $(1-c)$ is chosen by the auctioneer to ensure the non-profitability of shill bidding. It depends on the bidders' value distribution in an auction market and hence varies from market to market.

The importance of the role of an auctioneer in deterring fraud remains in multi-round auctions, so is the SDFS mechanism.

Moreover, to the contrary of the third common assumption, a multi-round auction is more realistic when shill biddings is most likely to occur. If the sale item remains with the seller in case a shill bid wins, the seller can relist it in the next round of the auction, reducing the risk of the item being stuck with the seller. Again the lack of authentication over the Internet makes it possible to relist the item even under different identities if necessary. In anticipation of next round, the seller has less incentive to sell the item or truthfully disclose his reserve price at the first round. In return, the buyers, knowing the seller's strategy, have less incentive to jump into the first-round competition but to hope for a lowered reserve price in a later round.

In this paper we will create a model closer to real auctions like those in eBay. We will model multi-round auctions with a single seller, multiple bidders and an intermediary. As in single-round auctions, the intermediary charges the seller listing and commission fees to affect the seller's behavior, in particular, the seller's incentive to shill bidding. We will assume that the seller and bidders have uniform discount factors which decrease the value of the sale item and urge these auction participants to complete the transactions as soon as possible. [12] has described a multi-round auction model without shill bidding or an intermediary, and concluded that when all the bidders have some constant higher valuation than the seller, the auction will end in finite rounds and when there are a large number of bidders, the seller's reserve should be his optimal reserve. Our multi-round model extends this model but to take into account shill bidding and intermediaries.

The paper proceeds as follows. In Section 2, we discuss the complexity of multi-round online auctions and its impact on its design, implementation and execution. In Section 3, we develop a multi-round English auction model that allows for shill bidding. In Section 4, we prove that there is no equilibrium without shill bidding in multi-round English auctions and discuss the implications of this result. In the concluding remarks, we summarize the research and discuss our future research directions.

2. The complexity of multi-round online auctions

2.1. The shiller's curse

As we have demonstrated in [1] and more in this paper, real auctions are much more complicated than the classical auction models analyzed in the traditional auction literature. In multi-round auctions with shill bidding, it is no longer a dominant strategy for a bidder to simply bid up to their valuations. In either private-value or common-value auctions, if a bidder suspects that she is competing against a shill seller, she may quit bidding below her valuation hoping for a later round with lowered seller's reserve. Because if the shill seller wins the auction, he will most likely try to resell the item in a later round. Moreover, in a common-value auction, a remaining bidder's valuation generally increases if she observes that other bidders bid high for the auctioned item. However, if the remaining bidder cannot differentiate legitimate competing bids from the shill bids of the seller, she will be reluctant to increase her valuation. As a result, both in private- and common-value auctions shill bidding can actually result in "the Shiller's Curse" effect, where bidders, afraid of shill bids, would shield their bids, that is, bid lower than what they should have without considering shill bidding.

2.2. Auctions vs. negotiation

When considering shill bidding, a multi-round auction has, in fact, become a multi-stage game where sellers and bidders need to use complex strategies. The traditional classical strategy, i.e., bid up to one's valuation (especially in private-value auctions), no longer hold. This added complexity makes auctions less attractive. Traditionally, auctions have been considered as a principle way of resource allocation because economists have argued that auction is always better than negotiation [13]. One major reason for this argument is that auctions do not require bidders to have the skills of bargaining – they only need to truthfully bid up to their valuations of the sale item. The resource allocation in an auction is simply a straightforward mathematical comparison, easily to be understood by common users. Because of this simplicity, auctions can attract more bidders, which, in turn, can result in higher expected payoff for the seller. On the contrary, in negotiation, the players need to have the skills of bargaining and the resource allocation is determined by how skillful the bargainers are. This complexity makes negotiation inferior to auctions. However, in the presence of shill bidding and multiple rounds, auctions lose their simplicity and require bidders to have strategic moves unless auctions can be redesigned to be both simple and robust.

2.3. Changing valuations

The value of most goods varies in time. Perishable goods lose their value quickly. Hight-tech gadgets become obsolete in no time. On the other hand, there are goods that preserve or even increase their value, such as antiques and collectibles. Sometimes, the value of the goods is time-sensitive. The value of a birthday gift increases when the birthday is approaching and drops sharply (to the gift-giver) when the birthday is over. Birthdays vary to individuals, hence the change of valuations vary. Therefore, to model the valuation changes of perishable, collectible, and birthday-gift-like goods, different schemes of discount factors should be applied. Most existing research consider the simplest case using uniform discount factors, that is, the valuation of the good for each participant discounts to the same extent after each round. Even under this assumption, it is still complicated to determine what the optimal strategies are for sellers and bidders.

2.4. Reserve prices

[13] have shown that a simple English auction with more bidders yield higher seller expected payoff than any mechanism, i.e., any other auction format or negotiation, with fewer bidders. This means that it is always better to hold an open auction with no reserve price that attracts more bidders than negotiating with a restricted set of bidders. However, this is based on an idealized auction model. Since shill bids are the seller's secret weapons to reset his reserve prices, whether or not to set up a reserve and how to set up a reserve in each round become much more complicated in multi-round auctions.

2.5. Auctioneer competition

The multi-round auction game is coordinated by an auction intermediary, who also sets the rules of the game. To make the already complex multi-round auctions even more complicated, there can be multiple intermediaries competing with each other online, and buyers and sellers can easily switch between these intermediaries based on the auction rules and services they offer. This introduces the flow of sellers and bidders in and out an auctioneer's business and, in this case, we cannot assume the fixed numbers of sellers and bidders in a multi-round auction of the same item. We do not consider this case in this paper but it is on our research agenda.

As we have discussed briefly above, multi-round auction is complicated, not to mention that shill bidding adds more complexity. It is always a challenge to model a system closer to real-world practices. We will start simple and then carry on with increased complexity.

3. The Model

We study the auction of unique items for which buyers and sellers have private valuations drawn randomly from independent identical distributions (the IID assumption). We assume that there is only one seller. This is justified by the uniqueness of the item being sold. We assume that even if there are other sellers on the market, they do not offer substitutes for the product.

The auction is conducted in multiple rounds, each round is an open ascending-bid English auction with reserve price r_t in round t ($t = 1, 2, \ldots$). The auction is organized by an intermediary, the auctioneer, who charges sellers following the SDFS fee schedule: a listing fee based on the reserve price, and if the auction is successful, an additional commission fee, which is a function of the final sale price and the reserve price.

We assume that the seller may submit shill bids, that is, bids that the seller submits under the bidder identities for the purpose of pushing up the sale price. A shill bid may win the auction, in which case the sale item stays with the seller, but the seller still has to pay the commission fee for his winning shill bid. We assume that legitimate bidders cannot distinguish shill bids from other legitimate buyers' bids.

At the beginning of each round the seller publicly announces the reserve price, and during the auction only bids that meet the reserve can be submitted. After each round of auction if the seller did not sell his good, either because there were no bids that at least met the reserve or the seller's shill bid won, the seller can repeat the auction.

We also assume that there are n bidders initially, with random valuations drawn independently from the cumulative probability distribution F. These bidders remain in the auction for all rounds until the item is sold or the seller quits.

To analyze, let us consider two cases: with and without shill bidding. In the no shill case, the last round T is the first round with a bid that meets the reserve price. In this case, if the buyers believe that the seller does not shill bid, their best strategy is to bid up to their true valuations once someone opens the bidding.

In the shill case where the seller may submit shill bids, bidders may stop bidding before their bids reach their true valuations, hoping that the seller's shill bid will win and the item will be back on sale in the next round where they may get it at a lower price.

It is possible that this game has multiple equilibria where in one equilibrium the seller does not use shill bidding and bidders assume that the seller is honest, while in another equilibrium the seller may use shill bidding and bidders suspect it so that they sometimes skip bidding in the hope of a next round.

We will first characterize the equilibrium strategy for the seller and bidders in the no-shill-bidding case under our SDFS fee structure. Then we will see under what conditions this remains an equilibrium even with shill bidding.

To find out the equilibria, we need to calculate the expected profit of both the seller and the bidders and maximize them. This is more complicated in a multi-round auction than in a single-round auction because of the change in valuations over time. Here in this paper, we only consider the simplest case and assume that the value of the item decreases uniformly over time for both the seller and buyers. A special case of this is when there is no discount for both the seller and buyers, that is, the value of the goods stays constant. We assume that both the seller and buyers' valuations for the sale item have a uniform discount factor δ, i.e., the valuations are multiplied by δ, $0 \leq \delta \leq 1$, after each round. Assume that at round T buyer i wins with a bid v. If the initial valuation of buyer i was v_i, then the utility of buyer i is her discounted valuation minus her payment, v: $u_i = \delta^T v_i - v$.

4. No equilibria without shill bidding in multi-round auctions

Now we calculate the equilibrium strategies for the seller and buyers under the assumption that the seller does not use shill bidding.

Suppose that the reserve price is r at the current round, and the seller has decided to set the reserve to $\delta r'$ for the next round in case he does not receive any bid in the current round. r' is less than r, because, if otherwise, buyers will have no reason to bid in the next round even if they have not bid in the current round. First, we only consider pure strategies. In an equilibrium each player plays a strategy that maximizes her profit assuming that all other players play their equilibrium strategies. As a result in the equilibrium buyers play as if they know the future reserve r'.

Let us call the bidder with the highest valuation A, and let h denote her valuation, and let B be the bidder with the second highest valuation l. We assume that if a buyer's optimal strategy is not to bid in the current round, then it is also optimal for all other buyers who have lower valuations than her not to bid as well. We only consider the case where $h > r$, i.e., when A can bid profitably in the current round. This is because the $h \leq r$ case is essentially the same as the $h > r$ case; A would simply wait for the first round where the reserve of that round is below her valuation.

Although $h > r$, it does not mean that A should always bid in the current round. Bidder A needs to choose to either bid in the current round or wait to bid in the next round. By waiting, A always lose $(1-\delta)h$ utility because of her discounted valuation. Besides this loss, consider three cases: 1) if $l \geq r$, A should bid in the current round because A cannot gain anything by waiting for a later round; 2) with the probability $F^{n-1}(r')/F^{n-1}(h)$, $l \leq r'$, if A waits, A gains $(r - \delta r')$ more utility; 3) if $r' < l < r$ and A waits, A gains $(r - \delta l)$ more utility. So bidder A's expected gain by bidding in the next round is:

$$g(h,r,r',\delta) = -(1-\delta)h + \frac{F^{n-1}(r')}{F^{n-1}(h)}(r-\delta r') + \int_{r'}^{r}(r-\delta l)\frac{\mathrm{d}F^{n-1}(l)}{F^{n-1}(h)} \quad (1)$$

Integrating by parts, we get

$$g(h,r,r',\delta) = \delta\int_{r'}^{r}\frac{F^{n-1}(l)}{F^{n-1}(h)}\,\mathrm{d}l - (1-\delta)\left[h - \frac{rF^{n-1}(r)}{F^{n-1}(h)}\right]$$

Bidder A should wait for the next round if $g(h,r,r',\delta) > 0$, which is,

$$\frac{1}{\delta^{-1}-1}\int_{r'}^{r}F^{n-1}(l)\,\mathrm{d}l + rF^{n-1}(r) > hF^{n-1}(h) \quad (2)$$

To generalize, bidder A should not bid in the current round, if any later round offers higher expected profit. So we expand (2) to

$$\frac{1}{\delta^{-i}-1}\int_{r^{(i)}}^{r}F^{n-1}(l)\,\mathrm{d}l + rF^{n-1}(r) > hF^{n-1}(h)$$

for some i, where $\delta^i r^{(i)}$ is the reserve price i rounds later. Thus a bidder would bid in the current round if and only if,

$$hF^{n-1}(h) \geq rF^{n-1}(r) + \max_{i>0}\left[\frac{1}{\delta^{-i}-1}\int_{r^{(i)}}^{r}F^{n-1}(l)\,\mathrm{d}l\right]$$

Note that the left-hand side is strictly increasing in h, thus there is a unique $\underline{h}$ that a buyer should bid in the current round whenever her valuation is above $\underline{h}$. Assuming that F is continuous, $\underline{h}$ satisfies

$$\underline{h}F^{n-1}(\underline{h}) = rF^{n-1}(r) + \max_{i>0}\left[\frac{1}{\delta^{-i}-1}\int_{r^{(i)}}^{r}F^{n-1}(l)\,\mathrm{d}l\right]$$

Therefore, in a multi-round English auction, if the seller's strategy is to set the reserve at $\delta^i r_i$ at round i ($i = 0, 1, \dots$), a buyer's strategy is to bid in round i if her valuation is above $\underline{h}_i$, where

$$\underline{h}_i F^{n-1}(\underline{h}_i) = r_i F^{n-1}(r_i) + \max_{j>i}\left[\frac{1}{\delta^{i-j}-1}\int_{r_j}^{r_i}F^{n-1}(l)\,\mathrm{d}l\right]$$

From this, it follows that every time if buyers expect a later round with a lowered reserve, then $\underline{h}_i > r_i$. Intuitively, if a buyer's valuation is just slightly above the reserve price, she cannot expect much profit from the current round, therefore she would rather wait for a later round if she anticipates a lower reserve price, which is less than the current reserve discounted for the later round. Using this result, we can prove the following theorem:

Theorem 1 *In a multi-round ascending-bid auction with a uniform discount factor* $0 \leq \delta \leq 1$ *for both the seller and buyers, there is no equilibrium without shill bidding.*

PROOF. By contradiction. Suppose there is an equilibrium without shill bidding. In the equilibrium, a buyer's strategy is that in case there is a bidder who starts bidding, the buyer would bid as long as her bids are still below or equal to her valuation. But we showed above that in a multi-round ascending bid auction with a uniform discount factor a buyer would open the bid in a certain round only if her valuation is at least $\underline{h}$, $\underline{h} > r$, and r is the reserve price for that particular round. Anticipating the buyer's strategy, therefore, the seller can always submit a shill bid at or slightly below $\underline{h}$, which increases his expected profit by pushing up the payment of the bidder with the highest valuation in the case where the second highest valuation from the bidders is below $\underline{h}$. This implies that the strategy without shill bidding cannot be an equilibrium. ■

In other words, the above theorem states that if buyers expect that the seller will try to sell the good again if he does not receive any valid bid, buyers will not bid if their valuations are just slightly higher than the reserve. This creates an opportunity for shill bidding.

On eBay there are two types of auctions: one with a posted reserve (also called minimum bid), and the other with a secret reserve. In a secret reserve auction, bidders do not know the reserve, but once their bids are shown in the bidding history of the auction and labeled whether or not they are above or below the secret reserve. Theorem 1 only covers the first type of eBay auctions. But this does not mean that a secret reserve can reduce shill bidding. In fact, the seller can safely submit shill bids below his secret reserve to try to push up a bidder above the reserve who

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would have waited for a next round if the seller had not shill bid.

These results show that shill bidding is an unavoidable issue in auction design, even more so in multi-round auctions than in single-round auctions. Shill bidding can hurt buyers, who would become more cautious in their biddings. This could reduce the payments to the seller, and in turn, could create more incentives for the seller to shill bid. Therefore, the role of an auctioneer becomes increasingly important in multi-round auctions in order to stop the negative influences of fraud and avoid the downward spirals. The auctioneer can help preventing shill bidding by choosing the right fee schedules and by finding and prosecuting shill bidders.

5. Conclusion

As technology-based economic mechanisms are introduced, such as online auctions, new avenues of problems occur, impacting economic models and potentially resulting in inefficient or even failed markets. Shill bidding is one of these problems reducing the buyers' trust in online auction markets.

We prove that in a multi-round English auction with a uniform discount factor to both the seller and buyers, there is no equilibrium without shill bidding. Shill bidding is more than an emerging issue. It will be a phenomenon that will prevail and potentially result in market failures.

In complex multi-round English auction with shill bidding, we emphasize the role of the auctioneer in regulating the auction trading rules. The rules promote the honest behavior of both the seller and buyers. Within the boundaries set forth by the auctioneer, the seller and buyers can use their bargaining skills to increase their expected profits in the multi-stage auction game.

Similar to the use of corrective pricing, such as tax, to deal with the market failure problem caused by externalities, we suggest a corrective pricing by an auctioneer, such as a Shill-deterrent Fee Schedule (SDFS), to solve the shill bidding problem, reducing its damage to the auction markets.

The computational implementation of our auction rules are as simple as the implementation of eBay. Since we have assumed the existence of the lack of authentication problem over the Internet and used economic incentive design to reduce its adverse effects, we do not need to apply advanced computing schemes for this matter. We predict that the reduction of fraud like shill bidding, if proper mechanism is applied, together with the reduced cost of auction participation, can increase the liquidity of auction markets.

We will extend our model to search for the optimal strategies for the seller and buyers with shill bidding in multi-round auctions. We will also use computer simulated models to numerically approximate the best strategies for the seller and buyers. These models would allow us to study the effects of the SDFS parameters on the auction outcomes.

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