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Online Auction Fraud: An Empirical Analysis of Shill-bidding Practice

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1. Introduction

Improved technology and the astronomical growth of the internet have added an entirely new dimension to the business environment. E-commerce provides access to global markets even for small firms, offers consumers an array of products and services that would have been unthinkable before the advent of the internet and does so at relatively low costs. It is not uncommon, however, for the implementation of a technological analog of an existing system or process to produce unintended and unexpected results. In this instance, the internet with its anonymity, geographical ambiguity and asynchronous nature may facilitate new, costly types of fraud that were much more difficult to perpetrate in the traditional business environment (Spinello 2006). Reported cases of internet fraud are increasing at an alarming rate, while solutions to the problem have been difficult for firms and regulators to identify and implement (IC3 2005, Waldmeir 2001, Weckert 2000).

Internet auction fraud is the most frequent type of internet fraud by a great margin (IC3 2005: 62.7% vs. 6.8% for credit card fraud). Further, there is some evidence that the rate of fraud on internet auctions exceeds that found in more traditional auction transactions (Bajari and Hortaçsu 2004). As in other internet applications, the replication of physical auctions in the online environment may have increased the potential for malfeasance as a result of specific characteristics of online transactions. The ability for one person to operate under multiple "identities" that cannot be clearly recognized as the same physical person by other parties to a transaction, as well as the difficulty in tracing internet transactions to physical locations, and the

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fact that legal processes have lagged behind technological developments all have the potential to be contributing factors (Spinello 2006).

Shill bidding is one of the most frequently studied types of internet auction fraud. eBay, the leading online auction house, defines shill bidding as "bidding that artificially increases an item's price or apparent desirability, or bidding by individuals with a level of access to the seller's item information not available to the general Community" (eBay 2007). Shill bidding is illegal in many jurisdictions and is expressly prohibited on eBay. Shill bidding is harmful to buyers, because they end up paying artificially inflated prices for items. In addition, it indirectly harms other sellers by making it incorrectly appear that there is a stronger demand for one seller's product than that of the competition. Perhaps most importantly, shill bidding harms the entire community by undermining trust in the online marketplace (eBay 2007).

Because fraud, including shill bidding, attempts to hide amidst legitimate transactions, one of the key strategies to fight fraud is to unmask it by educating the community about the incidence, characteristics, and strategies of deceit. When fraud becomes easily recognized, it can be swiftly prosecuted and will be quickly abandoned by the perpetrators. Publicly available descriptive knowledge about fraud encourages appropriate responses from governmental regulators and administrators of auction web sites and also helps auction participants avoid entering into transactions with fraudulent sellers. Identifying shill bidding has proven to be a difficult task, requiring the use of a variety of approaches to triangulate on evidence of its incidence and parameters.

This paper investigates shill bidding auction fraud in a sample of eBay transactions. It systematically assembles and reports evidence for the following research questions: How often does shill bidding happen on eBay? Do hobby sellers more commonly perpetrate shill bidding

than professional sellers? What are the shill bidding strategies used and what purpose do they serve? The paper contributes to the research by illustrating one of only a very few potential models for actually identifying shill bidding in online auctions: our five-stage shill bidding identification algorithm. Further, we demonstrate how this model can be used to add to the very small amount of empirical evidence with regard to the occurrence of shill bidding, characteristics of perpetrators, and shill strategies currently used on eBay.

The next section provides background information about auction theory and shill bidding as well as hypothesis development. Following, we provide our methodology and results. Finally, we discuss the implications of our results.

2. Background

Well before internet auction sites such as eBay began to be widely used, a significant research stream with respect to auctions in general had been developed. Beginning with Vickrey's (1969) seminal paper, auctions have been modeled as non-cooperative games. The "non-cooperative" nature of the model resulted in an assumption of no collusion among bidders or between a bidder and the seller (Vickrey 1961), with the result that the potential for fraud was often ignored. Later papers dropped this restriction and began to include the possibility of some types of fraud in their models.

The results of interest to this paper from the analytical auction paradigm fall into three general categories: the impact of the seller on the auction, the behavior of buyers and the assumptions and results with respect to potential fraud. Until quite recently, competition was only modeled among buyers (Riley and Samuelson 1981). Sellers were assumed to be monopolistic and to behave passively during the auction (Milgrom 1981). Thus, the only role

played by sellers was to set the rules of the auction in order to maximize their revenues and (in some models) to set the reserve price.

Buyers in analytical models are generally assumed to have independent preferences. Myerson (1981) makes a distinction between preference uncertainty (each bidder's lack of knowledge about the personal preferences held by other bidders with respect to the object and thus the amount they will bid) and quality uncertainty (the unknown quality of the object). In a model that only includes preference uncertainty, the bid of any one potential buyer carries no information content to other bidders, since they value the object according to their own individual utility functions. However, under quality uncertainty, a high bid may cause other bidders to revalue their bid upward based on the assumption that the high bidder has superior information about the quality of the object. The assumption of independent preferences allows for greater simplicity and tractability of models (Riley and Sameulson 1981, Vickrey 1961) and has thus typically been applied.

In the past, most models simply excluded by assumption a possibility that auctions may be open to any type of fraud (Milgrom and Weber 1982). When the potential for fraud was recognized, assumptions about the difficulty of the fraud (Chen and Tauman 2006) or the ease of implementing administrative means to prevent the fraud (Vickrey 1961) may have been valid in traditional auctions, but are no longer valid in the online environment. For example, bidders who wish to collude do not have to meet in person as they may have before, and can easily communicate and strategize outside the auction forum while the auction is progressing.

2.1 Shill Bidding

Recently, a number of analytical papers have been published about shill bidding in online auctions. In order for shill bidding to be included as a significant issue in the analytical auction

literature, the context of the auction must be modeled as more complex than has typically been the case. One of the primary motives that has been assumed for placing a shill bid is to fraudulently communicate information to the buyers about the quality of the object (Wang et al. 2002, Chakraborty and Kosmopoulou 2004). However, the usual assumption of private values precludes the bid of one potential buyer from impacting the valuations of the other bidders. Thus, the assumption must be changed to one of common values among bidders (bidders hold valuations based on a distribution around some "true" market value). Further, multiple rounds provide a more plausible setting than the typically assumed one round with all bidders placing their bids at the same time, since it is necessary for the genuine bidders to see the shill bid, revise their valuations and place higher bids (Wang et al. 2002).

In these more complex settings, it can be shown that sellers can increase their revenue, but not necessarily their profits by shill bidding (Ma et al. 2004). However, absent the information content of the bid itself, a shill bid might have an effect no different than a silent reserve (Chakraborty and Kosmopoulou 2004) or a "dynamic resetting of the reserve" (Ma et al. 2004). One further potential effect of a shill bid relates to the dominant strategy derived in the simpler settings of bid shaving (placing a bid below one's true valuation as a response to quality uncertainty) and the finding that it decreases as more buyers enter the auction. Based on this result, a shill bid may cause bids to increase slightly simply from the assumed increase in the number of buyers (Porter and Shoham 2005).

While auctioneers were largely ignored in earlier works, they have been included in the shill bidding investigations with interesting results. For example, it has been proposed that a fee schedule comprised of a combination of commissions and listing fees would discourage shill bidding and that the current fee schedule of many on line auction sites actually encourages shill

bidding (Ma et al. 2004). Further, while sellers may increase their revenue by engaging in shill bidding, they will not profit from it in the long term, since buyers in the same environment reduce their bids (shown analytically by Chakroborty and Kosmopoulou 2004) and verified in an experimental setting by Kosmoupoulou and De Silva (2007), and the seller incurs the risk of entering the winning bid and thus being required to pay a commission on an item that was not truly sold. Sellers are, in fact, generally better off if some market mechanism can be implemented that limits the ability of all sellers to shill bid. However, the auctioneer that collects commissions can be shown to benefit from shill bidding on the part of sellers at the expense of both buyers and sellers (Chakraborty and Kosmopoulou 2004).

2.2 Application of Auction Theory to Internet Auctions

Much of the theoretical literature was written before internet auction sites such as eBay became well known. Later studies based on the paradigm tend to continue in much the same way—at most relaxing one or two assumptions. Some researchers have expressed concern that the "rarefied assumptions" (Pinker at al. 2003) and "elegant and powerful theorems" (Bapna et al. 2003) of classical auction theory do not hold in the case of internet auctions. For example, in the analytical papers, buyers are all assumed to employ the same strategy. Empirical papers about internet auctions have identified a number of different strategies, such as withholding one's bid until the last minute, bidding often by adding only the minimum increment to the most recent bid, or using a proxy bidder and one's true valuation. Any or all of these strategies may be employed during the same auction (Bapna et al. 2003). Thus, depending on the bidder strategy, eBay auctions may resemble a sealed bid (only the auctioneer knows the bids entered by each bidder) second price auction as suggested by some researchers (Anwar et al. 2006, Bansal and Garg 2005) if most bidders use the proxy bidder. However, if more bidders in a particular auction

prefer to wait and respond to new bids (called a participating strategy) the auction more closely resembles an open English first price auction (bids are public and the winner pays the amount of her bid). Realistically, no one type of auction can be assumed to always typify an online auction. There is ample evidence that bidders do NOT always appear to behave rationally (Barbaro 2006) and that bidding strategies may change in response to observed, suspected or known strategies of other market participants (Barbaro 2006, Kosmopoulou 2007). Thus, while the analytical papers have produced interesting and helpful results, it remains to empirically examine the actual practice of shill bidding in live auctions.

2.3 Identifying Shill Bidding

Empirical studies of shill bidding are, obviously, hampered by the difficulty of identifying fraudulent transactions. The authors were able to find only two other models that have been used in online auctions. These two models differ from each other and from the model used in this paper. However, the basic method is the same in all three papers (including this one): identify characteristics of an auction that would be expected to differ with and without shill bidding and then look for actual auctions that display a preponderance of these characteristics. Neither of those models, like this one, can make a claim of being able to identify shill bidding with absolute certainty. All three look for suspicious transactions that MAY indicate shill bidding.

Kauffman and Wood (2005) investigate reserve price shilling (use of shill bidding to set an unofficial reserve price, avoiding listing fees that would relate to an officially set reserve). This model successfully identifies cases that would arouse suspicions of shill bidding, but the range of prices within which the model is valid is relatively small ($375 under a fairly low probability of winning with a shill bid and lower than that otherwise) and the model is restricted

to reserve price shilling and thus cannot be used to identify other types. In a sample of rare coin auctions, Kauffman and Wood (2005) find that over 25% of the auctions included a premium bid, which was their leading indicator for a shill transaction. They further find that the final price may be positively impacted by reserve price shilling.

Trevathan and Read (2005) proposed a more general model of shill bidding based on 6 criteria: the shill ID has bid exclusively on auctions of the focal seller, the shill bid frequently, the shill has few or no winnings, the shill bid shortly after a legitimate bid was posted, the shill bid only one increment above the existing bid and the shill did not bid near the end of the auction. These criteria are then weighted according to the authors' assessment of their importance to produce a shill score which, when high, indicates a suspicious transaction. This model has been tested on experimental data and eBay transactions of three sellers.

Our model takes the same starting point as the Trevathan and Read model—a bidder ID that seems more interested in one seller than would be the case for an independent buyer. From that point, however, the items that are used to investigate further are different. The Trevathan and Read (2005) model relies more on process (observations concerning the behavior of the suspected shill bidder during the auction) while our model relies more on characteristics of the suspected shill bidder that can be investigated during or after the auction. See the appendix for a detailed description of our shill bidding identification algorithm.

2.4 Hypotheses development

While the reservations expressed by some researchers relative to the validity of classical auction theory in the internet context cannot be ignored, the results from the analytical literature provide a starting point for hypothesis development. Thus, those results, coupled with some empirical findings and with basic logic, are used to provide a basis for our hypotheses. Our first

two hypotheses relate to identifying circumstances in which shill bidding is more likely to occur. The other two hypotheses relate to items that should be investigated further, once the suspicion of shill bidding has been aroused.

2.4.1 Professional sellers and the use of shill bidding

Our first test of circumstances in which shill bidding is more likely relates to the difference between a professional seller and a hobby seller. We deemed the seller to be a "professional" seller if the eBay listing contained the name and attributes of a business (e.g. Kernan Honda, 554 S Easton Rd., Dowtown, PA, 888-850-0187 ext.1216, info@kernanhonda.com) or the seller had developed an eBay store, as indicated by the icon on the listing page (e.g.  **Gifts 4 Everyone** **).**

The results of Chakraborty and Kosmopoulou (2004) show that if a seller can make a credible claim of honest dealing, buyers will not feel the need to protect themselves from the potential of shill bidding and will bid more aggressively. Professional sellers are more likely than others to be able to make such a claim, since many have names that the ordinary consumer recognizes. This reduces the uncertainty for the buyer (Kauffman and Wood 2005), which should have the effect of increasing the price (Myerson 1981). Further, firms are beginning to recognize that ethical conduct in internet transactions is important and to implement codes of conduct specifically related to such activities (eBay 2008). A policy of no shill bidding is likely to be part of such a code of conduct.

Finally, legal implications would impact a professional seller more than a hobby seller. Shill bidding is illegal and clearly violates eBay rules. Thus, a seller that uses shill bidding, if caught, may be liable for damages, including prosecution due to breach of contract and misrepresentation of the value of the product sold, financial loss incurred to meet the terms of the

transaction that may eventually be required, and even punitive damages or fines. Professional sellers are more likely than other sellers to understand these issues and to have "deep pockets" and thus be at greater risk for such losses.

On the basis of these considerations we make the following hypothesis:

H1: Professional sellers are less likely than others to employ shill bidding.

2.4.2 Product price and likelihood of shill bidding

While classical theory states that, with sufficient bidders, the auction price should approach the market price, this applies only to average prices. Variability in price may be caused by a variety of factors, including auction format (Vickrey 1961)and the number of similar products being offered (Bansal 2005) and the day of the week on which the auction ends (Kauffman and Wood 2006). Thus, any particular seller may find that bidders are not offering the price she believes to be the appropriate market price. The temptation to shill bid in order to bring the price in line with expectations thus exists.

Chakraborty and Kosmopoulou (2004) find that sellers should only shill bid when the potential increment to the price is very significant, since choosing to do so has costs in terms of higher commissions and the chance of failing to sell the item to a bona fide bidder. Thus, the return on using a shill ID, *ceteris paribus*, is higher with more expensive products, which have higher minimum bid increments on eBay.

In addition, there is more uncertainty about the market price with a more expensive item (Bajari et al. 2004). The added uncertainty should, in theory, induce bidders to offer less than their true valuations (Myerson 1981), resulting in a lower than optimal final selling price. While discounts related to internet selling have been found to be less in terms of a percentage for more expensive items (Pinker et al. 2003), the amount may be significant in dollar terms. In addition,

it has been shown that the buyers of more expensive items expect a bigger discount when purchasing on an internet auction site relative to the price posted in online catalogs (Kauffman et al. 2006). Thus, sellers of more expensive items, facing the possibility of lower than desired prices, may be impelled to attempt to shill bid in order to increase the price.

At the same time, the use of shill IDs in expensive product categories is subject to a higher degree of detection risk. The number of auctions is fewer, as is the number of bidders, and thus transparency is higher in the expensive product categories. This results from a comparably lower supply (e.g. thousands of cars vs. tens of thousand of bottles of perfume per day). In addition, expensive product categories are the focus of a higher level of eBay policing, and elicit heightened vigilance on the part of bidders. However, since the payoff is correspondingly higher, we make the following hypothesis:

H2: The more expensive the product, the more likely the seller will use shill bidding.

It should be noted that this hypothesis does not relate to price within category. That is, we do not test if the same item which sells for a higher price than others is a potential shill transaction. The interest here is in product categories: are sellers of more expensive items more likely to shill than sellers of less expensive items (cars as compared to bottles of perfume)?

2.4.3 Shill IDs are unlikely to be those of an experienced buyer or seller

This hypothesis relates to a variable which, while it cannot of itself be used to identify shill bidding, may be of secondary interest once suspicion of shill bidding is aroused.

There is strong evidence that sellers diligently protect their feedback scores, since they are quite likely to retaliate against a buyer who posts a negative comment (Bajari et al. 2004). Sellers want to secure and maintain a high feedback score in order to attract more buyers and decrease buyer uncertainty, thereby potentially increasing the price. Therefore, a seller that has decided to

shill bid would not use her usual seller ID, but would create an alternative ID. Attaining an alternate ID is quite easy for a buyer: eBay requires only very basic self-reported information and does little verification.

Not only will sellers who shill bid use an alternative ID, but they are likely to have many. Having only one shill ID would increase the risk of detection; a long history of mutual participation would provide strong evidence of shill bidding. For example, an investigator that found only two instances of a particular user ID bidding on the same seller's auctions might not be suspicious. However, a user ID established 6 month ago that shows 35 instances of mutual participation does provide evidence of potential shill bidding. Thus, it is reasonable to expect that a seller that places shill bids on his auctions on a regular basis will have more than one auxiliary user ID, each one of which he would only use for a short period of time. Thus, shill IDs will look liked inexperienced eBay users based on very low feedback scores.

H3: A shill bidding ID is likely to have a low reputation feedback score.

2.4.4 Shill bidding strategies

Like the preceding hypothesis, our test of strategies will provide evidence that can be used only after some suspicion of shill bidding has already been aroused. Our observations of eBay trade as well as descriptions of shill bidding practices made by security practitioners (Albert 2002) suggest that opportunistic sellers may use at least two strategies simultaneously or separately. We call the first strategy *bid encouragement* (Nikitkov et al. 2008) and the second strategy is similar to what Kauffman and Wood (WP) call *competitive bidding*.

The bid encouragement strategy responds to the evidence of herding behavior that has been noted to take place on internet auction sites (Dholakiaa et al. 2002, Kauffman and Wood 2006). Bidders seem reluctant to bid on an item if someone else has not already bid. In addition,

many auctions on eBay begin with unrealistically low prices (e.g., $1 for a new car). A bid encouragement shill bid takes advantage of eBay's permission to withdraw bids any time before the final 24 hours of the auction. A seller that places a bid on her own item "early in the game" may produce two important results. First, the bid creates interest around the offered product by signaling to potential buyers that the item is desired and valuable. Second, these early bids increase the final value of the true bids. It should be noted that this strategy is different from a reserve price shill bid (Kauffman and Wood 2006), which is entered in order to establish an unofficial reserve price.

A competitive bidding strategy may be initiated by a seller to take advantage of a buyer who has too clearly communicated his desire to purchase the item. The seller will shill bid close to the end of the auction, forcing the value up to the highest amount the bidder is willing to pay. Such strategically placed shill bids "stretch" genuine bidders in that they are forced to bid one or more increments more than they may have originally planned. If the genuine bidder has used eBay's proxy bidder, the competitive bidding strategy can force the price up to the bidder's reserve price (a practice Barbaro and Bracht (2006) have labeled "squeezing").

With respect to the application of the two strategies we expect to see the *competitive bidding* strategy more often in expensive product categories and the *bid encouragement* strategy in less expensive product categories. Auctions for expensive products that start with an unrealistically low amount will not require any encouragement to bidders since they represent an opportunity for huge savings. More commonly than not, there will be bids placed on such an auction. For these auctions, shill bids may only be used to ensure that the auction reaches the final price desired by the seller. On the contrary, auctions for low-ticket items, even when opened with a $1 initial bidding price, do not always attract bidders. Thus, sellers of low-ticket

items may attempt to use the *bid encouragement* strategy in order to distinguish their offers from others. It is questionable whether the sellers of low-ticket items would use the *competitive bidding* strategy since the pay-off may be relatively small when measured against the risk. These deliberations lead us to advance the following hypotheses:

H4.1: The more expensive the product, the more likely the seller will use the "bid stretching" strategy.

H4.2 The less expensive the product, the more likely the seller will use the "bid encouragement" strategy.

3. Research Method

3.1 Shill Bidding Identification

We identify transactions that may be instances of shill bidding using an algorithm that relies on analysis of several independent pieces of information, which, taken together, confirm (or refute) that the seller used secondary IDs to place shill bids. The algorithm involves evaluation of a) the frequency of association between the focal seller ID and the bidder ID, b) the homogeneity of products for which bids were placed, c) the amount of bidding activity with non-focal sellers, d) the heterogeneity of products for which bids were place with non-focal sellers, and e) the timing of the bids with reference to one of the strategic patterns (see Diagram 1 for a visual representation of the algorithm and Appendix 1 for a detailed explanation of the method employed). Analysis of this information, taken as a whole, facilitates identification of cases in which the data-pattern indicates potential shill-bidding practices. It is necessary to employ data from multiple auctions and to examine the data from a variety of viewpoints, exercising professional judgment, in order to identify cases of shill bidding.

3.2 Sample Selection

Thousands of auctions are completed on eBay every day, so we restricted our data collection to three specific products, which were chosen to vary as to price and eBay category listing. These products can also be expected to appeal to different types of customers and to be offered by different sellers. In the eBay Motors category we selected Toyota Prius, in the Computer and Networking category we used Toshiba laptops with 17 inch screens and in Health and Beauty we chose Polo Black 4.2 ounces. For each product, we examined ALL auctions that were completed during the 31 days prior to the date of data collection (May 8, June 1 and June 8 respectively). After eliminating private auctions (no access to data), listings in fixed-price format, and actions with zero bids, the resulting sample contains 186 usable observations. See Table 1 for sample descriptive statistics.

4. Data Analysis and Findings

4.1 Shill bidding and professional sellers

Our final sample includes 186 auctions. Of these, 68 were listed by professional sellers and 118 by non-professional sellers (see Table 2). Our shill bidding identification algorithm suggests that 37 auctions involved shill bidding. Of these, 21 were auctions run by professional sellers and 16 were auctions run by non-professional sellers. Table 3 contains a joint test of the first three hypotheses. As can be seen, the coefficient for professional sellers is highly significant, indicating that hobby sellers are less likely to shill bid than those that label themselves as professionals.

Our findings lead us to reject hypothesis one. We find that professional sellers are quite likely to use shill bidding. Anecdotal evidence obtained as we collected our sample suggests that professional sellers may be the “leaders” in the use of shill bidding. For example, one of the

sellers with the highest number of shill bids is an online outlet of a well known electronics store. For this seller, we detected three auxiliary user IDs that were used to place bids on 193, 181, and 31 auctions respectively within the 31 day period. In practical terms, this seller used shill bids in virtually every online auction sale. Professional sellers also accounted for the highest rate of shill bidding in the car and perfume samples.

This result runs counter to our expectations. One potential explanation is that professional sellers have a stronger idea of the market price of the item and feel "justified" in taking actions that will result in that price being achieved. They may be less willing than hobby sellers to see the item sell at a substantial discount below what they believe to be the correct price. Alternatively, professional sellers may know the system better than others and be more aware of the likelihood of being discovered by actual bidders. They may feel more confidence in their ability to increase their profits by taking actions such as shill bidding, whereas hobby sellers may be reluctant to use the technique, fearing some sort of negative consequences.

4.2 Product price and likelihood of shill bidding

The nature of the inquiry for this hypothesis is such that we are not attempting to establish a link between an additional dollar in price and the likelihood of shill bidding, but rather seeking to draw a conclusion that would serve market participants as guidance (e.g., "I should be more careful about shill bidding if I bid on an expensive product"). We believe using the product category variable where differences in price between the categories are strictly ordinal serves well to establish such a result.

Product category is significant in the analysis in Table 3 at the .05 level. While the analysis in Table 3 suggests that professionals are more likely than hobby sellers to shill bid across all product categories (the interaction was not significant and was dropped from the

model), the Cochrane's Q test that is reported in Table 2 shows that the distribution is not the same in each category. We analyzed the data separately for each type of seller, using a dummy variable analysis rather than an ordinal variable for price category. This analysis was prompted by observations of the data that show the changes for the professional sellers might not be ordinal. The results are reported in Table 4. As can be seen, professional sellers may shill more in the computer category and less in the car category than in perfumes, but the effect does not attain statistical significance. Among hobby sellers, significantly more shilling takes place in the lower priced products. This corresponds to our speculation earlier that hobby sellers may be more timid than professional sellers and may shill less in higher priced categories fearing easier detection and more severe consequences.

4.3 Shill bidding and user ID tenure

Our sample includes 44 unique user IDs used for shill bidding in the three categories (autos, computers, and perfumes). We recorded the reputation feedback score for each identity. This score provides the best available estimate of the number of transactions completed by the user ID. We constructed a histogram of feedback scores (see Figure 2). This histogram shows that 73% (32) of shill IDs in our sample have a feedback score below 70 and only 27% (12) are above 100. The reputation feedback scores are not normally distributed. The distribution of scores suggests that shill bidding IDs are likely to have a feedback score lower than 100. The evidence from Table 3 shows that, controlling for seller professionalism and product category, probability of encountering shill bidding in an auction is negatively related to the bidder's tenure; that is if tenure is sufficiently high, above 100 transactions. In reviewing the results of Table 3, the reader should remember that feedback score in this analysis is a zero or one, which explains the value of the coefficient in the table.

Our use of 100 is data driven in the absence of any theory to suggest the average score of a shill ID. There seems to be a clear break in the histogram in Figure 2. We conducted several other analyses to determine the robustness of this decision. Repeating the analysis in Table 3 using the shill ID feedback score as a continuous variable did not result in a statistically significant estimate. This is, to some degree, to be expected. The interpretation of such a result would have been that the lower the feedback score, the more likely the transaction is to be a shill transaction. We do not believe that to be likely, as it would mean that shill bidders establish a new identity nearly every time. Repeating the analysis with 50 as the cutoff point does result in a statistically significant estimate, while using 20 as the cutoff does not.

We do not wish to indicate that there is a cutoff. There is no magic number above which bidders can be certain that the competing bidder is a genuine bidder and not a shill for the seller. Our evidence does show that shill IDs are very likely to have feedback scores below 100 (although some are above) and also fairly likely to be below 50. Thus any bidder that becomes suspicious about a competing bidder should take note of the feedback level. If it is low (in the bidder's judgment) additional caution would be advisable.

We also examined the differences in the median of the reputation feedback scores within the three groups (shill IDs used in autos, computers, and perfumes). Descriptive statistics show that shill IDs used in auto auctions have a lower median (7) feedback score than shill IDs used for computers (median = 21) or perfume (median = 36) auctions (see Table 5). Between categories comparisons show that shill IDs in the "cars" category have significantly lower tenure than shill IDs in the "computers" ($p<.05$) and "perfumes" categories.

Shill IDs used in the autos category may have a lower feedback score as a result of seller precaution. The level of liability with auto auctions is substantially higher than with computer or

perfume auctions. This may lead sellers to arrange new user IDs more often in order to remain undetected. Alternatively, shill IDs in the autos category may have fewer feedbacks as an artifact of the nature of auto auctions: each seller trades fewer cars per unit of time than another seller trades computers or bottles of perfume and thus has less occasion to use the shill ID.

4.4 Product price and shill bidding strategies

In order to see whether the shill bidding strategy depends on the product price, we analyzed all the cases of shill bidding. Since a seller may use more than one shill bidding ID for a single transaction, as is often the case within our sample, we reviewed how each shill user ID was used and assigned a value of 1 to the cases of a bid encouragement strategy, a value of 2 to the cases of bid stretching strategy, and a value of 0 to the cases with no clear evidence of either strategy.

We determined the presence of shill bidding strategies in the following manner. If the shill ID was used to place one of the first three bids or was used to place multiple bids in the first half of the auction, which is indicative of deliberate refusal to use the convenient proxy bidding mechanism, we marked it as a bid-encouragement strategy. If the shill ID was used two or more times in the last 24 hours of the bidding process, we marked it as a bid stretching strategy.

The analysis from Table 3 was repeated for each strategy (see Table 6). Our analysis confirms hypothesis 4.1, but we were forced to reject hypothesis 4.2. There is no evidence that one strategy is used more than the other across product categories. We would like to note, however, that the bid encouragement strategy was used in 56% of the cases in perfumes, 67% of the cases in computers, and only 27% of the cases in cars. In addition, it can be seen that professionals are more likely than hobby sellers to use competitive bidding strategy. Since this strategy is more aggressive than the bid encouragement strategy (which is called “benign”

shilling by Trevathan and Read (2005), the result supplies further evidence that hobby sellers are a bit more timid than professional seller when it comes to using shill bidding.

5. Implications

We analyzed the occurrence of shill-bidding practice in three product categories on eBay. Our findings indicate that shill bidding is a common practice and occurs at a rate substantially higher than officially admitted by eBay administration (16 – 28% vs. 0.1% published fraud rate.) This result will be of concern to all market participants. Such a high rate of fraud has broad implications for regulators as they struggle to determine how to bring the same level of detection and enforcement to online transactions that is available in more traditional business transactions. Clearly, the current state of enforcement against shill-bidding is inadequate. Perpetrators, even those that can be expected to understand the market and the consequences of fraudulent behavior, apparently feel that the benefits of deception outweigh the risk of being caught and punished.

eBay itself should be concerned about these findings. That is clearly already the case. On eBay Motors, the history of bids page now contains information about each bidder: length of time on eBay, number of bids placed, percentage of bids with the current seller, and number of different categories in which bids have been placed. This information provides some of the same information contained in our algorithm (which provides partial third party verification of the applicability of some of the steps), thus enabling bidders to some degree to assess the potential that they are bidding against the seller. eBay has stated that it tries to detect shill bidders itself using detection software and will impose penalties, but the results of this study clearly show that such efforts must be increased.

Sellers will also find these results of interest. As more and more buyers are victims of fraud, the buying public may become apprehensive about participating in online auctions. This

may show itself as increased bid shaving (lowering of the buyers' reservation prices to protect themselves from potential fraud) or in reduced numbers of buyers and therefore reduced numbers of bidders. This, too, has the potential to lower final prices. The unfortunate result that professional sellers are more likely than others to shill bid robs honest sellers of one available mechanism that could have been used to signal one's integrity to buyers.

Perhaps more than others, buyers should take careful note of the results of this study. Conventional wisdom has suggested that buyers should protect themselves by dealing only with sellers with high feedback scores. This study indicates that tactic will not be completely or even partially effective. Professional sellers, who are *more* likely to shill bid, are also quite likely to have high feedback scores from conducting many transactions over an extended period of time. Thus, buyers will need to develop other strategies to identify and avoid unethical sellers.

It is often suggested that the most effective way to limit the incidence of online fraud is for users to become more educated and alert. Thus, we attempted to create a descriptive profile for a shill-bid perpetrator. This profile suggests that, contrary to our expectations, professional sellers are more likely to use shill bidding. In addition, the shill IDs that are used are very likely to have low feedback scores. This is particularly true for shill IDs in more expensive product categories. Any buyer who become suspicious that she may be bidding against a shill, should investigate the feedback score of opposing bidders as a means of confirming or refuting her suspicions. However, it is impractical for users to limit their participation in online auctions to those where the other bidders have substantial eBay experience. Further, bidders cannot amass the type of evidence we gathered in order to determine if the user against whom they are bidding is a shill or simply a relatively new eBayer.

We also did not find evidence that users can protect themselves by buying only a particular type of product on eBay. The finding that shill bidding is equally prevalent in all three of product categories suggests that buyers need to review the sellers' prior transactions in determining who to buy from. The belief that if the product is inexpensive then the seller would not bother to shill-bid is invalid. However, clearly the potential for material monetary damage is still higher with more expensive items.

Users should stay alert to evidence of both shill bidding strategies. The bid stretching strategy is apparently more detrimental to the buyer's interests: the seller effectively encourages the buyer to pay more than he originally rationally decided upon, or at least more than he would have had to pay had no shill bidding occurred. When bidding on high-ticket items, buyers should not make their reserve price known to the seller by either bidding on the item prior to the last 24 hours or attempting to negotiate with the seller over email. However, the bid encouragement strategy should also be taken into account. Bidders should not assume that the number of bids on an item, particularly at the beginning, indicate that the item is more valuable than others.

7. Limitations and future research

The findings of this study are limited to one online auction: eBay. While comparison between multiple online market makers is desirable and informative, other auctions have severe limitations for data gathering. It should be noted that eBay is the most popular auction site, and issues that impact eBay are quite likely to impact other internet auction sites. Solutions that are found to be effective on eBay can be assumed to be helpful, perhaps with some adaptations, on other sites.

The proposed shill-bidding identification algorithm employed in this study has limitations in its power. It follows the "presumption of innocence" and "proof beyond a reasonable doubt"

principles of common law, but may suggest incorrect classification for cases when the amount of evidence is only marginally above the threshold of recognition. However, we believe the method to be quite conservative and to be more likely to understate than overstate the incidence of shill bidding. Further, the model requires the application of professional judgment in some of the categories and in determining the overall decision.

Our test sample came from only three product categories. While the sample of products is intentionally diverse, our findings may not strictly apply to other product categories, especially those that have significant differences in business models (e.g., real estate or wholesale). Future studies may look at a wider array of products in order to verify that the results found in this study apply in other cases.

We operationalized a professional seller as one that has clearly identified a business in the listing or one that maintains an eBay store. It is possible that not all the sellers that meet these criteria are "professionals" in our sense (the attempt was to segregate those sellers that are well informed about market forces, understand the long term impact of actions and intend to engage in the market long enough that such impacts are of concern). Because most eBay sellers cannot establish a loyal clientele as do brick and mortar firms, the ways in which they communicate a good reputation to potential buyers are also different. To the extent that some of the sellers in our sample are true hobby sellers that have made their posting look like a business, there will be some noise in our data.

An interesting issue that our paper was not able to address is whether shill-bidding results in economic gains. Empirical tests for such a hypothesis would require a sample with homogeneous products: identical products under identical conditions. The sample that we analyzed included three groups of products, two of which (computers and cars) potentially have

a variety of options. As a result, we were forced to use category of product as a proxy for more or less expensive products. This precluded any estimates of the economic effect of the shill bids.

6. Conclusion

Our investigation suggests that shill bidding on eBay occurs at a rate that must be taken seriously by all involved. Our findings indicate rates from 14% to 28% depending on the product category. We also find that both professional and amateur sellers employ shill bidding, with professional sellers using the technique relatively more often. Finally, we find that in the inexpensive product categories sellers use shill bidding to encourage potential buyers to place bids. When it comes to expensive items, we find that sellers use both bid encouragement and bid stretching strategies.

Taken in total, these findings indicate that shill bidding is a significant problem in online auctions. It seems clear that for sellers who wish to engage in shill bidding the practice is relatively easy to accomplish, requiring only that they change their shill ID frequently. Sellers who use eBay as a means of making a profit rather than as an occasional hobby have been shown to be more aggressive in their use of this tactic. This may result from their knowledge that enforcement has lagged behind developments in the online environment. Rather than accepting the occasional item sold at a significant discount, these sellers may have turned to deception as a means of achieving the price they feel is the market price. They may feel that detection, with its associated consequences of loss of reputation and potential fines, is so unlikely that the risk is warranted.

Importantly, buyers cannot know for sure if they have been victims of shill bidding, even after the auction is completed. However, as studies such as this become public, buyers may become more and more suspicious. This additional source of uncertainty and risk will

undoubtedly cause online selling prices to decrease on average as predicted by the analytical auction literature. In the long run, some buyers and even some sellers may be driven out of the marketplace.

Perhaps the most disquieting finding of this study is that the common suggestion that user enforcement is the best means of encouraging ethical behavior in online auctions is clearly untenable. There is nothing in our data to suggest that users can easily, or even with great care, identify a shill bidder. Thus, the onus for detecting, preventing and imposing sanctions falls to site administrators and regulators, who are the only ones with access to the necessary volume of information. In the current environment, allowing regulators sufficient access to information would require a huge change in confidentiality agreements. In the future, this may become a necessary evil, if eBay cannot act on its own to sharply reduce the amount of shill bidding that is currently taking place.

Appendix 1 Details of the Shill-bidding Identification Algorithm

Figure 1 is a representation of the steps that were taken to categorize our transactions as involving shill bidding or not. We gathered five pieces of independent evidence from the information that is publicly available on eBay for 31 days after each transaction. A thorough evaluation of this information allowed us to identify cases in which a preponderance of the data indicates questionable practices. The algorithm requires that professional judgment be applied in a number of areas. However, when we asked two students to use the data to determine instances of shill bidding, the Cohen's Kappa agreement statistics of their decisions with the initial decisions were .978 and .871 respectively. This shows that the model is replicable with a very high degree of reliability.

Criteria 1: Frequency Count

The first criteria relates to how often a bidder placed bids on the items offered by the focal seller. Repeated mutual participation between buyer and seller pairs has been found to be relatively rare—in a five month period, only 20% of the transactions were between repeated buyer/seller pairs (Bajari et al. 2004). In our 31 day period, we would expect the incidence of repeated transactions to be even lower. Using a software robotic agent, we record all the buyers that placed bids in that seller's auctions and focus on those that participated frequently. For example, the data may indicate that the seller "argo12[1]" held 14 auctions in the last 31 days and that that five individual bidders ("sam1[1]", "rob2[1]", "bob3[1], "ted4[1]", and "jun5[1]") placed bids on the seller's auctions. Further investigation reveals that "sam1" placed only one bid across 14 auctions, "rob2", "bob3", and "jun5" placed bids on two or three of the seller's items, and "ted4" placed multiple bids on all 14 items offered by the seller. "ted4"'s repeated bids in "argo12"'s

[1] We use pseudo-names to preserve identity of the eBay users

auctions would raise suspicions of shill bidding, since "ted4", like the other bidders, has a huge array of other auctions from which to choose.

Note that frequency count does not represent the number of *bids* placed by the same userID within one auction, but the number of *auctions* by the same seller in which that buyers placed at least one bid. In the example above, "sam1" may have placed 6 bids during the course of one auction, but frequency count would be one. If "ted4" placed only one bid in each of the 14 auctions, frequency count for that userID would be 14.

During this initial step of the identification algorithm, each transaction was dismissed from further consideration or classified as suspicious based on whether frequency count exceeded the threshold of three auctions. That is, if a certain user ID was found to place bids on more than three auctions by the same seller within 31 days, we would establish an initial prediction of shill bidding and investigate the case further.

No theory was available to provide guidance in establishing our benchmark and it may thus appear arbitrary. Any forensic examination of the data would require such an initial sorting mechanism, and our choice of a benchmark was guided by experience and reasonable considerations and has deliberately been made conservatively. We are aware that cases below the benchmark may be shill bidding. In a sense, frequency count is a net, that lets the "small fish" of infrequent shill bids out, while retaining cases of glaring abuse of eBay shill-bidding policies. The potentially more serious problem of classifying a case as shill bidding when it was not, has been ameliorated since any transactions red-flagged by frequency count are then examined further using the other four criteria. During that process, observations may still be dismissed if no further evidence is found.

Criteria 2: Product List Heterogeneity

For those observations that were determined to be potential cases of shill bidding based on frequency count, we next look at product list heterogeneity. Empirical evidence shows that some bidders do "cross bid"—that is, they bid on multiple auctions of different sellers for the same product or for products that are close substitutes for each other (Anwar et al. 2004). If the buyer ID from the transaction is being used to bid on and purchase other similar items, the ID may belong to a genuine buyer. However, if the ID is being used to bid on a seemingly random list of products, many from the same seller, the initial suspicion of shill bidding is further confirmed. This pattern of bidding may indicate a concealed connection between the buyer and the seller rather than a buyer attempting to find a specific product at the best price. It would seem unlikely that a buyer, within such a short time frame, would make repeated dissimilar purchases from the same seller. Clearly, this step in the algorithm requires the use of professional judgment to determine whether the list of items is truly homogenous.

Criteria 3: Number of Bids with Other Sellers

The next step is to examine purchases made by the buyer ID from sellers other than the focal seller. The cross bidding studies suggest that a buyer bids on the auctions of many sellers, not just one (Bajari et al. 2004). Thus, if less than three bids were placed with other sellers our predication was strengthened. A second user ID that was acquired to place shill bids would be sometimes used to purchase from other sellers in order to conceal its true use. Only a very reckless shill bidder would bid *exclusively* on items of the focal seller. If the buyer ID in question was used to place many bids (more than three) on items of other sellers, we compare the strength of evidence obtained by frequency count and product list heterogeneity against bids with other sellers and most commonly would dismiss the case for the lack of convincing evidence,

unless the first and the second pieces of evidence were overwhelming (e.g. "Mark5" placed bids in 250 auctions run by "argo12" in the last 31 day and bids were placed on dissimilar products).

Criteria 4: Product List with Other Sellers

In the fourth step, the product list with other sellers was examined. Specifically, when our review suggested that the buyer placed bids with other sellers for the same type of item as that with the focal seller, we decreased the predication. This would suggest that the buyer is behaving in accordance with research findings and common sense: attempting to purchase the desired item from any seller. On the other hand, if the buyer ID was used to bid on or purchase unrelated products from other sellers, the predication was strengthened. Unless the focal seller is negligent in hiding the traces of shill bidding, we would expect him to use the buyer ID to make some purchases from other sellers in order to hide shill bidding practice—otherwise the pattern of deception would be glaring. As with criteria 2, this step requires the use of professional judgment.

Criteria 5: Strategies of shill bidding

Finally, we evaluated evidence that suggests the presence of either a bid encouragement strategy or a bid stretching strategy. Our observations of eBay trade as well as descriptions of shill bidding practices made by security practitioners (Albert 2002) suggest that opportunistic sellers may use one of these two strategies. We strengthened the predication against the case when we found a consistent pattern of "early in the game" bids that never win auctions but often participate. In addition, a pattern of bids where the use ID in questions was competing with one or more users to win the auction in the last 24 hours of the auction time, but did not place the winning bid, we deemed to be further evidence of shill bidding. If no pattern was apparent, but

the other pieces of evidence were convincing, the items remained as suspicious. However, if the other pieces of evidence were marginal and there was no pattern, the observation was dismissed.

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Figure 1: Shill bid identification algorithm (Anonymous)
See Appendix 1 for description and details.

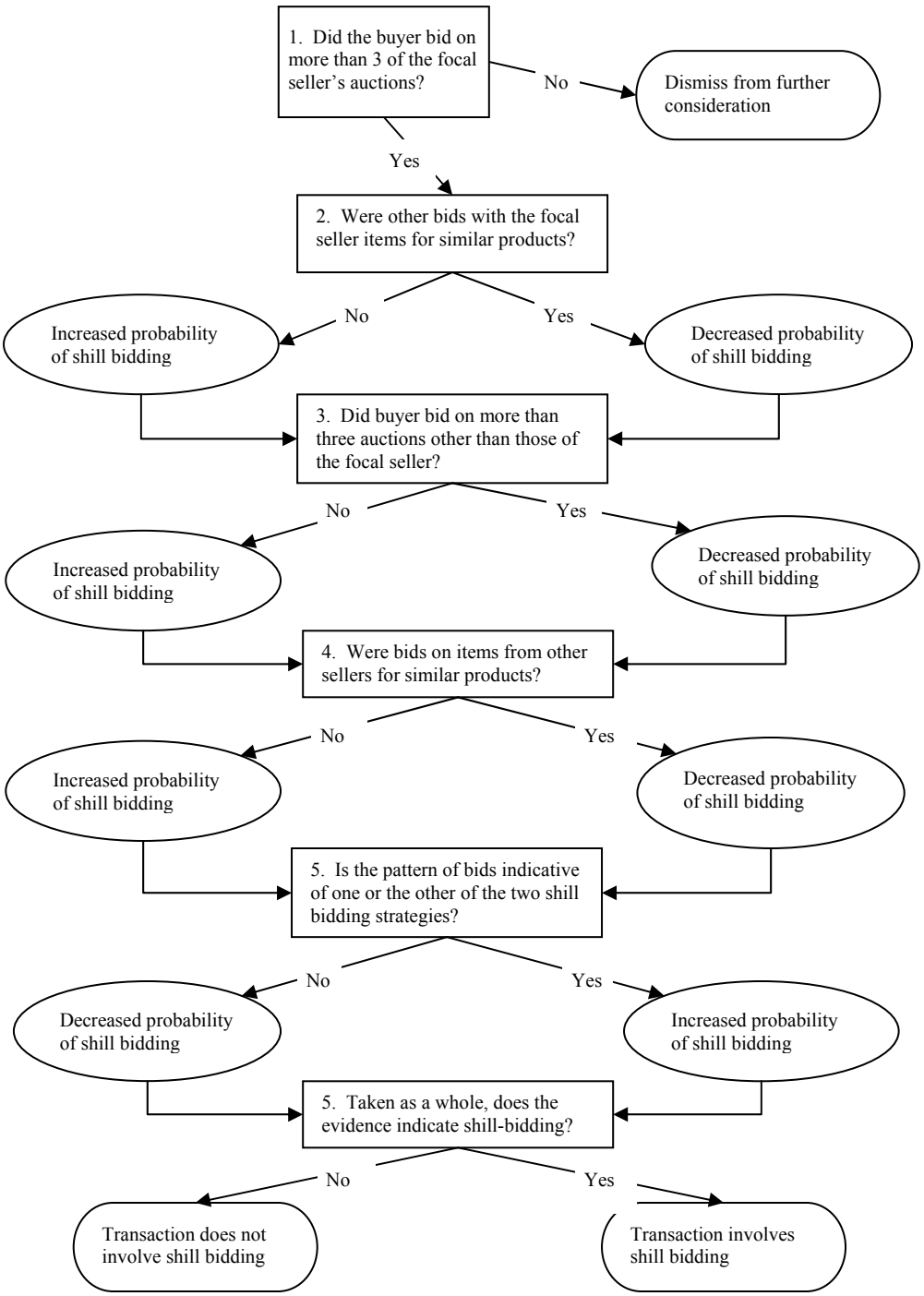

Table 1: Descriptive Statistics

	Toyota Prius	Toshiba Laptop (17" screen)	Polo Black Perfume (4.2 oz)	Total
Usable observations*	61	75	50	186
Number of transactions involving shill bids	11	12	14	37
Percentage of transactions involving shill bids	18.00%	16.00%	28.00%	19.90%
Average number of shill buyer IDs used in shill auctions	1.4	1.5	1.7	

*Usable observations include all auctions except private auctions for which no data is publicly available, listings with fixed prices and those with no bids. (Anonymous)

Table 2: Professional sellers* versus hobby sellers--descriptive statistics

	Professional sellers			**Non-professional sellers**		
Category	**Transactions**	**Shill transactions**	**%**	**Transactions**	**Shill transactions**	**%**
Cars	36	9	25%	25	2	8%
computers	8	4	50%	67	8	12%
perfumes	24	8	33%	26	6	23%
Total	68	21		118	16	

Cochran's Q test that Professional / Non-professional seller distribution is similar between the three categories shows $\chi 2(3) = 9.4$, $p = .009$

*We deemed the seller to be "professional" if the name and attributes of business were stated (e.g. Kernan Honda, 554 S Easton Rd., Dowtown, PA, 888-850-0187 ext.1216, info@kernanhonda.com) or seller had developed an eBay store, as indicated by the icon on the listing page.

Table 3: Probit analysis of the relationship of price category, seller type and bidder feedback score with shill bidding

	B	S.E.	Wald	Df	Sig.
Professional	1.040	0.261	15.91	1	0.00
Feedback Score of Shill ID	-0.000	0.000	4.052	1	0.04
Price Category	-0.319	0.164	3.779	1	0.05
Threshold	.935	0.210	19.82	1	0.00

Pseudo R-square: Cox and Snell = 0.09, Nagelkerke = 0.14, McFadden = 0.10
No shilling is the threshold.

Table 4: Probit analysis of the relationship of price category and bidder feedback score with shill bidding by seller type

Professional Sellers

	B	S.E.	Wald	Df	Sig.
Car Dummy	-0.612	0.453	1.822	1	0.18
Computer Dummy	0.583	0.553	1.111	1	0.29
Feedback Score of Shill ID	0.000	0.000	3.145	1	0.08
Threshold	0.038	0.392	0.0097	1	0.92

Pseudo R-square: Cox and Snell = 0.10, Nagelkerke = 0.14, McFadden = 0.09
No shilling is the threshold.

Non-Professional Sellers

	B	S.E.	Wald	Df	Sig.
Car Dummy	-1.174	0.524	5.008	1	0.03
Computer Dummy	-1.009	0.427	5.582	1	0.02
Feedback Score of Shill ID	0.000	0.000	3.0979	1	0.08
Threshold	0.2086	0.392	0.2825	1	0.60

Pseudo R-square: Cox and Snell = 0.07, Nagelkerke = 0.14, McFadden = 0.11
No shilling is the threshold.

Figure 2: Distribution of Reputation Feedback Scores for User IDs Used for Shill Bidding

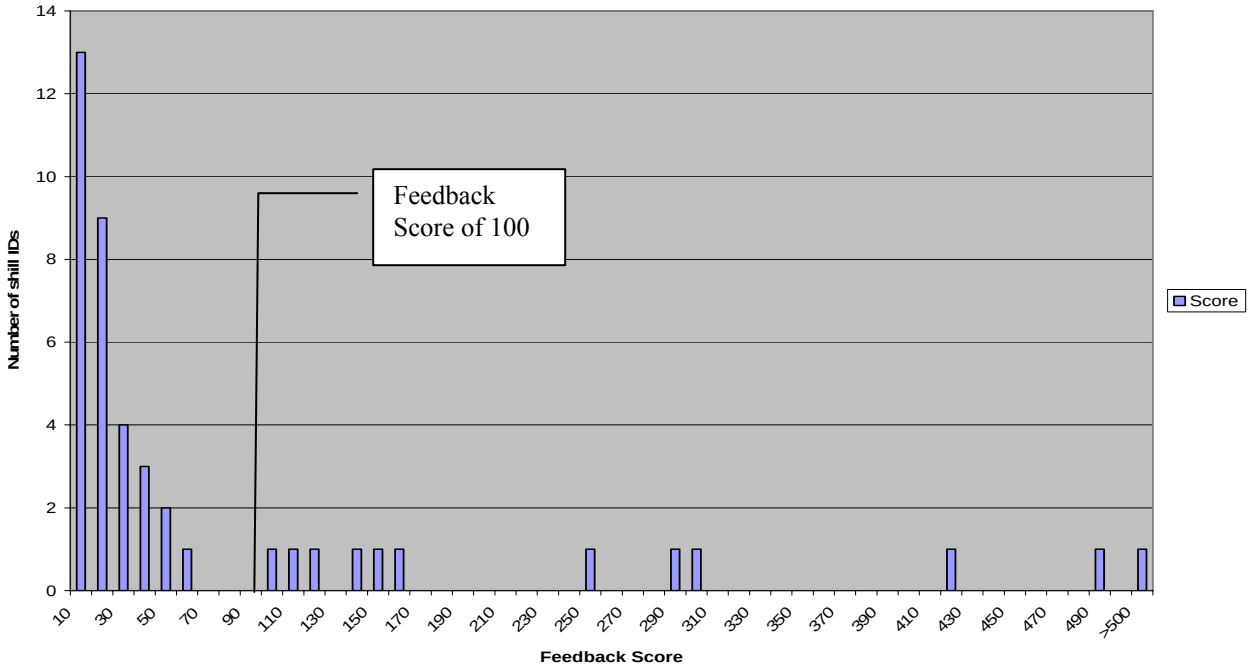

Table 5: Shill ID Feedback Score by Product Category

	N	Median	SD	Minimum	Maximum
Perfumes	20	36	131.9	1.0	798.0
Computers	15	21	134.8	0.0	414.0
Cars	9	7	9.5	0.0	29.0
Total	44				

Both the Kruskal-Wallis Test and the Median Test support a contention that the median feedback score for the shill IDs in the car category is statistically different from the other two at .004 and .019 levels of significance.

Table 6: Probit analysis of the relationship of price category, seller type and bidder feedback score with shill bidding

Bid Encouragement

	B	S.E.	Wald	df	Sig.
Professional	0.413	0.291	1.996	1	0.158
Feedback Score of Shill ID	-0.000	0.000	0.406	1	0.524
Price Category	-0.029	0.187	0.023	1	0.878
Threshold	1.405	0.250	31.494	1	0.000

Pseudo R-square: Cox and Snell = 0.014, Nagelkerke = 0.33, McFadden = 0.025
Threshold is no shilling

Competitive Bidding

	B	S.E.	Wald	df	Sig.
Professional	0.957	0.269	12.678	1	0.000
Feedback Score of Shill ID	-0.000	0.000	1.402	1	0.236
Price Category	-0.063	0.173	0.131	1	0.717
Threshold	1.370	0.238	33.087	1	0.000

Pseudo R-square: Cox and Snell = 0.04, Nagelkerke = 0.077, McFadden = 0.056
Threshold is no shilling