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# Speculation and Demand Reduction in English Clock Auctions with Resale

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## Abstract

Many auctions are followed by a resale market which occurs when the winner of the auction resells the item won to one of the participants from the original auction. The existence of such transactions may initially appear counter intuitive. However, this paper will show that active inter-bidder resale results from payoff maximizing decisions in the auction that take into account the incentives of a resale opportunity. Specifically, I examine how the existence of an inter-bidder resale opportunity impacts bidder behavior in an English clock auction, and to what extent altering the bargaining power of the final buyer and reseller in the resale market determines the strategies followed in the initial auction, in an attempt to understand the existence of these inter-bidder transactions. Theoretical and behavioral analysis is used to develop hypotheses of speculation (bidding above value) and demand reduction (bidding below value) which are directly tested in a controlled experimental setting. While value bidding is a dominant strategy in a standard English clock auction without resale, when resale is allowed, this theoretical claim is weaker. Demand reduction is observed when the bargaining power is shifted to the final buyer in resale and when the bargaining power is shifted toward the reseller, speculation is observed. The revenue achieved in the initial auction depends on the behavior observed in the auction. Regardless of bargaining power, revenue is shown to decrease below what would have been earned in an English auction without resale due to demand reduction. When the reseller has the bargaining power, and speculation is observed, this loss in revenue is somewhat mitigated by increased speculation.

**JEL Codes:** D44 C90

**Key Words:** Auctions, Resale, Demand Reduction, Speculation, Experimental Economics

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# 1 Introduction

Many different types of auctions, such as real estate auctions, auto auctions, art auctions, and auctions for raw materials, will have bidders who wish to resell as the primary motivation for participating in the auction. In most cases these bidders will be intending to resell the item to a buyer who did not participate in the auction. There are, however, cases in which resale occurs between the winner of the auction and one of the participants. The existence of these inter-bidder transactions may be something of a paradox. Why would a bidder participating in the auction ever choose to buy an item in an aftermarket, instead of attempting to win it in the initial auction?

Examples of this phenomenon can be found in “cap and trade” programs for emissions allowances, where the allowances are allocated initially by auction and there are active resale markets.<sup>1</sup> In 2004, Virginia auctioned off a percentage of their nitrogen oxide (NOx) allowances using an English clock auction. Bidders in this initial auction participated knowing that there was also an active post-auction trading market in which resale could take place.<sup>2</sup> In these cases, future sales may occur after a participant in the initial auction learns more information regarding his or his competitors’ values. However, in Burtraw et al.(2008) resale markets are explicitly modeled in experiments designed to capture market conditions for the electricity emitting sector and resale occurs even without this information revelation.

In addition to emissions allowances, the recycling industry constitutes another example of this phenomenon. This industry is comprised of waste-generating firms, waste-processing firms, and traders who buy waste to sell to the processing firms. The waste-generating firms often choose to sell their scrap material through an auction where the bidders are traders and processing firms.<sup>3</sup> Many times, these auctions only comprise the initial transaction. They are often followed by an active resale trading market of the waste won in the auction, some of which is inter-bidder resale given the presence of traders.<sup>4</sup>

Bidders who win and resell may be referred to in practice as brokers, traders, or speculators but for the purpose of this paper, bidders who participate in an auction with intentions to resell the item won in the near future will be referred to as speculators. In a general sense, speculators can be thought of as individuals who take on risk, whether large or small, for potential gain. In an auction, a speculator is a bidder who is willing to bid an amount higher than his own use

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<sup>1</sup>Emission allowances are not always auctioned off, prior attempts in Europe under the Emissions Trading Scheme were allocated freely. However, there is a movement to switch towards an auction mechanism to distribute permits.

<sup>2</sup>For more details on these auctions, see Porter et al.(2009)

<sup>3</sup>The primary industry for waste-generating firms is generally not recycling. For example, carpet producers sell scrap fiber for recycling and bottling manufacturers produce scrap plastic. It could be conjectured that they often hold auctions because of their lack of familiarity with the recycling industry and how to price their materials.

<sup>4</sup>This information is provided via a conversation with the owner of a waste trading firm. Unfortunately, gathering publically available data to substantiate this statement is difficult given the nature of trading.

value for the item with intentions of finding a buyer for the item who would be willing to pay more than his purchase price. Two types of speculation may arise in an auction format. The first is the speculator believes buyers with higher values are not participating in the auction, so he is willing to take on the risk of bidding above his use value to win the item and resell to bidders who either did not know about the auction, or chose not to participate in the auction.

The second type of speculation that could occur and explain the inter-bidder resale trading between auction participants, at least in first price auctions, is based on the premise that the speculator knows that bidders may be inclined to shade their bids from their true value. If this speculator can bid enough to win, but not enough to surpass the value of the highest bidder, then he could potentially profit by reselling the item after the auction to the losing bidder(s). This latter story though poses a puzzle in that it is unclear why this behavior might persist without bidders responding by increasing their bids to foreclose the speculators. One possibility is that if speculators are participating in an auction, then bidders with high values may gain more by intentionally shading their bid and waiting for the resale market. This relates to the notion of demand reduction in which individuals abstain from the auction and wait for the resale market, which depending on the structure of the resale market could lead to a lower price.

The traditional definition of demand reduction, in a multi-unit auction format, is bidders reducing demand by not bidding on additional items in order to reduce the price paid on other units purchased. Abstention from the auction in a single-unit auction can also be thought of as demand reducing behavior, because the opportunity exists to purchase the item in resale at a potentially reduced price. A bidder could also be thought of as demand reducing if they drop out of an auction below their value as this can still have the desired effect of decreasing the price in the resale market.

This paper will examine why the existence of an inter-bidder resale opportunity is not a paradox. It will show that inter-bidder resale results from payoff maximizing decisions within the auction that take into account the bargaining power in the resale market. Key to this analysis is the structure of bargaining power within resale, which leads to a differing mix of behaviors involving demand reduction and speculation in the auction. The baseline of analysis begins with bargaining power equally split between the final buyer and reseller in an English clock auction. This analysis is extended by altering the bargaining power of the final buyer and reseller in the resale market to determine how this impacts the strategies followed in the initial auction. Theoretical and behavioral analysis is used to develop hypotheses of speculation and demand reduction that are then directly tested in a controlled experimental setting.

The goal of the experimental design is to determine if the existence of a resale opportunity alters behavior from what is observed in an auction without resale, such that active inter-bidder resale does exist, and if active inter-bidder resale exists, is the structure of bargaining in the resale market relevant? The resale market is restricted to an automatic transfer determined from the values of the bidders, the price resulting in the auction, and the bargaining power allo-

cation to ascertain if individuals clearly understand and implement the strategic implications of resale. For this research, the use of the laboratory to examine auctions with resale will allow for the control of many factors (i.e. values, information, and the form of the resale market) to help understand the impact of resale markets and bargaining power on auction behavior.

The starting point for this analysis is the English clock auction. The dominant strategy in an English auction where resale is prohibited is that all bidders bid their value. With bidders following such a strategy, active inter-bidder resale cannot exist. Therefore, it seems even more paradoxical that active resale could exist after an English clock auction. However, when the English auction is followed by a resale market, bidders may choose to follow other strategies, such as some bidders engaging in demand reduction which could lead to inter-bidder resale.

Haile (1999) derives equilibrium outcomes for first and second price auctions, as well as English auctions, followed by a resale trade market. Haile finds that all auctions with privately known values, when followed by a resale opportunity, have the same equilibrium outcome as the auction without the resale opportunity. In the case of English auctions this is bidding one's value. Haile does not, however, claim or prove that value bidding is a unique equilibrium which leaves open the question of whether other equilibria exist that can explain inter-bidder resale in a private values framework.

One possibility, which is closer in spirit to the previous story of traders in the recycling industry, is the model developed by Garratt and Tröger (2006). They include a "speculating" bidder, whose use value is known to be zero. This bidder only exists because of the possibility of resale and only has intentions to resell in the event of winning. While they do find standard value bidding to be an equilibrium in the second price auction setting, they also find a continuum of equilibria where the speculator wins with positive profit demonstrating how the addition of resale can result in inter-bidder resale.<sup>5</sup> The primary interest of this paper is to determine if inter-bidder resale can also emerge if speculating bidders are given positive values and not restricted to a value of zero.

Garratt, Tröger and Zheng (2009) present a model that proves the existence of a tacit collusion equilibrium involving demand reduction when an English auction is followed by a resale opportunity. This equilibrium requires a public randomization device, "sunspot," which chooses the speculating bidder for the one-shot game. It is a cut-off equilibrium, where the designated speculator bids a value equal to a cut-off price. If a bidder has a value below this type, then they would bid zero, if a bidder has a value above this type, then they would bid their value. This model includes bidders who have positive values and it is shown that inter-bidder resale emerges in this scenario. The theoretical model presented in this paper sets up a similar cut-off equilibrium where the cut-off value is determined by the maximum possible value, and in that sense can be interpreted as a special case of the Garratt, Tröger and Zheng model. Specifically, I demonstrate theoretically that if resale is allowed, in addition

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<sup>5</sup>The second price auction is strategically equivalent to the English (ascending auction)

to value bidding, other equilibria also exist where a speculating bidder bids an amount high enough to induce the remaining bidders to drop out (demand reduce).

This paper will test if active resale will exist due to demand reduction and speculation, and the impact of resale bargaining power on the incentive to demand reduce and speculate. If at least one bidder chooses to demand reduce then active resale can occur. As bargaining power shifts towards the final buyer in the resale market, the expected payoff in resale is increasing and therefore the incentive to demand reduce is also increasing. The possibility of resale also encourages speculation with the intention of reselling to a bidder who is demand reducing. If a bidder believes that at least one bidder is demand reducing, then it may be possible to profitably speculate.

The possibility for demand reduction and speculation to emerge should be expected to relate to the bargaining structure of the resale market, but because value bidding is a strong attractor of behavior, it is important to understand if bidders can internalize the changing incentives of the resale market into their behavior. To examine this issue, additional theoretical analysis and a set of experimental sessions are constructed for a non-standard resale market which eliminates value bidding as an equilibrium.

Standard resale assumes that the resale surplus is the difference between the highest value and the value of the winner of the auction, or the price paid in the auction, whichever is higher. The non-standard resale market assumes that the resale surplus is the difference between the winner of the auction and the price paid in the auction. While the non-standard resale market might be seen as odd, it has some useful advantages from the perspective of experimental design. Under the non-standard resale structure, value bidding is no longer supported as a Nash equilibrium when the final buyer receives more than 50% of the resale surplus. Therefore, this set of non-standard resale sessions allows experimental control over the decision space of the subjects. It identifies whether or not subjects are internalizing the resale market bargaining changes into their behavior. For example, under the standard format when the resale market is defined as the difference between values and bidders chose to bid value, it is difficult to disentangle whether or not the subjects understood that value bidding was the equilibrium strategy to follow, or if the subjects were confused because the structure of the resale market was too much to integrate into their decisions in the auction, and simply failed to respond. Structuring a portion of the experimental design around this non-standard form of resale allows us to empirically glean the answer to the latter

The second portion of experimental sessions utilizes standard resale markets. Under standard resale markets, it is shown that value bidding and other equilibria that involve speculation and demand reduction jointly exist, so these standard sessions are used to determine if shifts in bargaining power can pull people away from value bidding towards a mix of speculation and demand reduction, assuming bidders understand the implications of resale.

Other experimental papers have addressed auctions with resale. Lange, List, and Price (2004) first conduct a field study using timber auction data from

Canada, followed by an experiment in a first-price auction setting with resale. Georganas (2007) studies an English auction with resale where the resale market was an automatic selling of the good after the auction for a price equal to the highest value drawn or an English auction, testing Haile (2003). Informational backgrounds were also changed. Georganas finds substantial deviation from value bidding and uses models of bounded rationality to explain the deviation.

The remaining sections of this paper include theoretical and behavioral predictions in section 2. The experimental design is discussed in section 3 with an analysis of the results in section 4. Section 5 concludes, including a discussion of the steps that will be taken to move forward.

## 2 Theory and Behavioral Predictions

Haile (1999) established that in a second price auction with independent private values, the symmetric Nash equilibrium strategy of bidding one's value remains an equilibrium strategy when the auction is followed by a resale market. While value bidding is an equilibrium, multiple other equilibria also exist which depend on the bargaining power allocation in the resale stage. This section will demonstrate this by presenting an additional asymmetric equilibrium, using the standard resale market structure that includes both demand reduction and speculative behavior which is particularly useful for an examination of how behavior changes with bargaining power. Following this, I will demonstrate that value bidding no longer remains an equilibrium under the non-standard resale market and conclude with behavioral predictions that generalize to both the standard and non-standard forms of resale.

### 2.1 Standard Resale

The model assumes a second price auction<sup>6</sup> followed by a resale market where the resale price is determined by the bargaining power,  $\gamma$ , held by the final buyer over the resale surplus. The resale surplus is defined as the difference between the highest value and the value of the winner, or the price paid in the auction, whichever is higher. The final buyer earns a percentage,  $\gamma$ , of this surplus and the reseller earns the remaining percentage,  $1 - \gamma$ . The reseller additionally earns the difference between their value and the auction price if the latter is less than their value. The addition of resale allows bidders another opportunity to gain the item, if they were unable to obtain the item in the initial auction. It also allows bidders the opportunity to win the item and resell for a profit, in a situation where they might have otherwise earned zero.

If a bidder exploits the presence of resale and chooses to speculate, then value bidding may no longer be a best response. As a simple example of why value bidding is no longer a best response, imagine a group of 4 bidders participating in a second price auction with values 10, 20, 30, and 40. If there is a resale

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<sup>6</sup>For modeling purposes, the second price auction is strategically equivalent to an ascending (English) auction.

market then the resale surplus is split equally by the final buyer and reseller. Under the standard value bidding equilibrium, the bidder with a value of 40 would win at a price of 30, for a payoff of 10 to the winning bidder and 0 to the remaining three bidders and resale would not occur.

Now assume instead that the first bidder with a value of 10 chooses to speculate by bidding an amount equal to 45. If the remaining three bidders anticipate the speculating behavior of the first bidder, they are all better off by demand reducing to a bid of zero allowing the speculating bidder to win the auction at a price of zero. The final buyer earns 15 which is his share of the resale surplus defined as the difference between the highest value of 40 and the value of the winning speculative bidder, 10. The reseller, selling at a price of 25 which was determined by the 50/50 surplus split, earns 25, which is the difference between the price he resold for and the price he paid in the auction. The remaining bidders are no worse off as they continue to earn zero under the demand reduction strategy. While this demonstrates the Pareto improvement of demand reduction and speculation, more work is needed to generate an equilibrium analysis.

### 2.1.1 Speculation and Demand Reduction Equilibrium

The environment consists of  $n \geq 2$  bidders participating in a second price auction followed by a resale market. Values are drawn independently from a common distribution with cumulative distribution function,  $F$ , and probability density function,  $f$ , with support over the range  $v_i \in [0, 1]$ . For what follows below, the distribution is assumed to be uniform. Each bidder knows the realization of their value,  $v_i$ , but not the realization of others' values, only the distribution that others' values are drawn from. At the end of the auction, the highest value is revealed and the resale surplus is defined as the difference between the highest value and the winner's value, or the price resulting from the auction, whichever is higher.

The resale market is assumed to take the form of a split of the resale surplus after the initial auction. If the winner of the auction does not have the highest value resale takes place. The winner of the auction becomes the reseller and the loser with the highest value becomes the final buyer in the resale market. The final buyer's share of the resale surplus is given by  $\gamma \in [0, 1]$ . Correspondingly, the reseller's share of the resale surplus is defined as  $1 - \gamma$ . The final buyer and reseller split the entire resale surplus, and the resale price is determined from this split.

An equilibrium is calculated where  $n - 1$  bidders employ a strategy where they all bid zero,  $b_i = 0$ . One bidder, the speculating bidder, chooses a bid,  $b_s$ , equal to the cut-off value,  $v_c$ , that would make a bidder with the maximum possible value indifferent between staying in the auction and demand reducing.<sup>7</sup>

**Proposition 1** *In an English clock auction with a resale opportunity and  $n$  risk neutral bidders, assuming a uniform distribution on the common support  $[0, 1]$*

<sup>7</sup>A more in-depth proof of the proposition is given in the appendix.



and  $\gamma \in [0, 1]$ , the following bidding strategy profile constitutes an equilibrium,

1. One bidder, the speculator, bids the cut-off,  $v_c = 1 - \frac{\gamma}{n}$
2. all other  $n - 1$  bidders bid zero

**Proof.** Equation (1) defines the expected payoff to a bidder choosing to demand reduce to a bid of zero, which is equal to the final buyer's share of the resale surplus that a bidder would earn in the event that he has the highest value. The resale surplus is defined as the difference between the value of the final buyer and the expected second highest value. This assumes that the winner of the auction has the second highest value, which minimizes the potential gain from resale by the final buyer.

$$(1) u_i^{eq}(v, \gamma, Y_1, \dots, Y_{n-1}) = F(v)^{n-1} \gamma E[(v - Y_{n-1}) | Y_n = v]$$

Equation (2) defines the expected payoff to a bidder choosing to bid an amount greater than the cut-off value to win the auction with certainty. The first part of equation (2) gives the expected payoff in the event the bidder has the highest value and keeps the item, where he earns his value less the price resulting from the auction. The second part of the equation gives the expected payoff in the event he becomes the reseller because another bidder has a higher value. It includes the reseller's share,  $1 - \gamma$ , of the resale surplus which is defined as the difference between the expected value of the final buyer and the value of the winning bidder. In addition to the surplus split, the reseller also earns an amount equal to the difference his value and the price paid in the auction. Equation (2) is only defined for values greater than or equal to the cut-off value,  $v_c$ , because the expected payoff for a bidder whose value is in the range  $[0, v_c)$  includes negative potential earnings which make it strictly less than the expected payoff to a bidder whose value is greater than or equal to the cut-off. As a result, we can restrict attention to the range of values where  $v \geq v_c$ .

$$(2) u_i^{dev}(v, \gamma, v_c, v_1, \dots, v_{n-1}) = F(v)^{n-1} (v - v_c) + (1 - v) \{ (1 - \gamma) E[(v_j - v) | v_j > v] + (v - v_c) \}, v \geq v_c$$

A speculator who bids an amount equal to the cut-off leaves a bidder with a value of 1 indifferent between bidding above the speculator and demand reducing to a bid of zero. Any bid by the speculator above  $v_c$  generates a strictly higher payoff for a bid of zero than deviation by a bidder with a value of 1. For bidders with values in the range  $[0, 1)$ , equation (1) is strictly greater than equation (2) rejecting any profitable deviation from a bid of zero to a bid higher than the cut-off. To demonstrate this, suppose deviation is profitable, if so then the relationship given by (3) should be non-negative.

$$(3) u_i^{dev} - u_i^{eq} \geq 0 \\ = v^{n-1} (v - 1 + \frac{\gamma}{n}) + (1 - \gamma) \frac{(1-v)^2}{2} + (1 - v) (v - 1 + \frac{\gamma}{n}) - \gamma \frac{v^n}{n}$$

=  $-\frac{1}{2nv} (v-1) (2v\gamma + nv^2 - 2nv^n + 2v^n\gamma - nv - nv\gamma + nv^2\gamma) < 0$ , which is a contradiction of the assumption.

Thus it holds that for the remaining  $n - 1$  (non-speculative) bidders, a bid of zero constitutes an equilibrium strategy. ■

In summary, the equilibrium presented above demonstrates that in addition to value bidding, strategies of speculation and demand reduction also theoretically exist when resale is possible. The equilibrium construction relies on the cut-off bid of the speculating bidder, which was calculated as the value that would make a bidder with the maximum possible value indifferent between demand reducing to a bid of zero and staying in the auction. It is worthwhile to note that  $v_c$  represents the lower bound on the bid of the speculator and the equilibrium is also supported by any bid above  $v_c$ . The speculator's bid depends critically on the bargaining power allocation, of which the derivative is decreasing,  $\frac{\partial b_s}{\partial \gamma} < 0$ . This simple property provides insight into how the bargaining power allocation changes the behavior of the speculating bidder. As the bargaining power of the final buyer increases, the amount that a speculator must bid to induce bidders to demand reduce is decreasing. Correspondingly, as the bargaining power shifts away from the final buyer to the reseller, the amount that a speculator must bid is increasing.<sup>8</sup>

However, it must be noted that directly observing the exact speculation and demand reduction equilibrium presented above or the value bidding equilibrium in a laboratory setting would be difficult. A primary source of this difficulty is the ability of subjects to coordinate. First, they must simultaneously determine what equilibrium to play, and on a second level if they choose to engage in speculation and demand reduction, they must coordinate on who would play the role of the speculator.

## 2.2 Non-standard Resale

From an empirical perspective, the existence of value bidding and speculation/demand reduction equilibria under the standard resale model makes it difficult to determine if bidders are able to understand resale opportunities and integrate these incentives into their bidding decisions. Examining the auction with a non-standard resale market provides a control treatment for this confounding situation.

The only set-up difference between the non-standard resale model and the standard resale model is that the non-standard resale surplus is now defined as the difference between the highest value and the price resulting from the auction. Consider again a second price auction for a single object with  $n$  risk neutral bidders, where each bidder draws their privately known value,  $v_i \in [\underline{v}, \bar{v}]$ , from a commonly known distribution,  $F$ , with density function,  $f$ . Each bidder

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<sup>8</sup>If  $\gamma = 0$ , the final buyer earns zero in resale, so the speculator must bid at the maximum of the value distribution, which is 1. Of course, this equilibrium also exists in an English auction without resale, but behaviorally appears more likely when resale is possible.

knows the realization of their value,  $v_i$ , but not the realization of others' values, only the distribution that others' values are drawn from. At the end of the auction, the highest value is revealed and the resale surplus is defined as the difference between the highest value and the price resulting from the auction.

**Proposition 2** *Value bidding is not an equilibrium bidding strategy when the auction is followed by a non-standard resale surplus split given*

$$\gamma > \frac{v_1 - E[Y_{n-1}|Y_n=v_1]}{v_1 - E[Y_{n-2}|Y_n=v_1]}$$

**Proof.** Assume  $n - 1$  bidders are choosing to follow the value bidding strategy,  $b(v) = v$ . To show that this strategy is not an equilibrium strategy of the game, it suffices to show that the remaining bidder can profitably deviate to a some bid other than their value. Assume that  $F$  is distributed on the support  $[0, 1]$ , and let  $Y_1, \dots, Y_{n-1}$  denote the smallest, ..., largest estimates from  $v_2, \dots, v_{n-1}$ . Let  $\gamma \in [0, 1]$  denote the final buyer's share of the resale surplus. The winner of the auction becomes the reseller in the resale market and their share of the resale surplus is defined as  $(1 - \gamma)$ . The expected payoff to the bidder who bids their value is

$$(1) u_1(v_1, Y_1, \dots, Y_{n-1}) = F(v_1)^{n-1} E[(v_1 - Y_{n-1})|Y_n = v_1]$$

The expected payoff to value bidding is the same as the expected payoff to value bidding auction without the resale opportunity because the bidder with the highest value wins the auction, and there is no resale. Inter-bidder resale only occurs when the bidder who wins the auction does not have the highest value.

Consider instead that this bidder chooses to bid zero,  $b(v) = 0$ . The expected payoff to a bidder who deviates to a bid of zero is

$$(2) u_1(v_1, \gamma, Y_1, \dots, Y_{n-2}) = F(v_1)^{n-1} \gamma E[(v_1 - Y_{n-2})|Y_n = v_1]$$

Value bidding is not an equilibrium as long as the expected payoff from deviating to a bid of zero is greater than the expected payoff of value bidding. This holds if

$$(3) \gamma > \frac{v_1 - E[Y_{n-1}|Y_n=v_1]}{v_1 - E[Y_{n-2}|Y_n=v_1]}$$

As long as the final buyer's share of the resale surplus is greater than the ratio of the payoff from value bidding to the payoff from bidding zero, then value-bidding is no longer supported as an equilibrium strategy. ■

Simply stated, the final buyer must have enough resale bargaining power to capture the share of the resale surplus that is greater than the payoff from value bidding, otherwise they would just bid value. For expositional purposes, assume

that  $F$  is a uniform distribution on the support  $[0, 1]$ . Under that assumption it can be seen that value bidding is not an equilibrium strategy if  $\gamma > \frac{1}{2}$ .

With  $n$  bidders, if  $\gamma$ , the final buyer's share of the resale surplus is greater than .5, then deviation to a bid of zero, or any bid between 0 and the expected third highest value ( $Y_{n-2}$ ), will occur if he believes all other will bid value. If  $\gamma = .5$ , then the bidder is indifferent between value bidding and deviating to a lower bid, and if  $\gamma < .5$ , all bidders will value bid, and the standard equilibrium outcome will hold. Clearly, the final buyer's share and correspondingly, the reseller's share of the resale surplus is important for bidding strategies.

### 2.3 Behavioral Predictions

Based on the formal analysis presented above, there are some particular types of behavioral deviations from standard value bidding that we may expect to see.

*Demand Reduction:* If a bidder believes they hold the highest value, they will be more likely to demand reduce (bid below value). This bidder runs the risk of not winning the auction, but if they are not the highest value, then they are no worse off than under the value-bidding equilibrium. If the bidder is able to demand reduce at a low enough value, then he can participate in the resale market for a positive surplus. The incentives to demand reduce are higher if the bidder believes they hold the highest value, and we would expect that behaviorally, this incentive to demand reduce would occur more often for higher values in the distribution versus lower values. As bargaining power is shifted to the final buyer, the incentive to demand reduce is stronger as the expected payoff from resale is increasing. This should result in a demand reduction strategy being followed by bidders for a larger range of values, moving to lower values, over what would be observed if the bargaining power was shifted in favor of the reseller.

*Speculation:* If a bidder believes they hold a value lower than the highest value in the group and they understand the incentives to demand reduce by higher valued bidders, they would hold some expectation of profit in the resale market. Given that they believe they do not have the highest value, then the incentive will be to speculate, as the only way to earn non-zero profit will be to win the auction and resell to the high value holder in resale. The incentive to speculate is higher for lower values on the value distribution, as it is more likely that another member of their bidding group has drawn a higher value. As this is an inverse relationship, we should see speculation decreasing for a bidder as his value increases. As bargaining power is shifted to the reseller in the resale market, this will increase the incentive to speculate. This should result in speculative strategies being followed for a larger range of values, moving to higher values.

If speculation and demand reduction take place, then the revenue to the seller may be different, on average, from the standard value-bidding equilibrium prediction of the second highest value. If demand reduction is dominant, then the price resulting from the auction should be lower than the auction price that would occur without a resale market. If speculation is dominant, then the price

resulting from the auction should be higher than what would occur in a similar auction without resale.

Given the above theoretical and behavioral analysis, the primary goal of the experimental design will be to test what happens to bidding strategies and revenue from the initial auction as bargaining power is shifted to and from the final buyer and reseller in the resale market. The baseline of analysis is a 50/50 split of the resale surplus. The bargaining power treatments involve shifting the share of the surplus from a 50/50 split to a 90% share for the advantaged player (final buyer or reseller) in order to make the bargaining power shifts salient and because creating an equal share of the resale surplus will serve as a useful benchmark of bargaining power to determine baseline behavior.

Shifting away from this benchmark to a higher final buyer share (lower reseller share) should exhibit a higher frequency of demand reduction. As the surplus shifts in favor of the highest value holder, the speculation distance will decrease for all values and the demand reduction distance will increase. More bidders will attempt demand reduction. The lowest values on the distribution may still speculate, but not by as much. The reasoning behind this is that the expected return on speculation decreased, while the expected return on demand reduction increased. The revenue for the initial seller in the auction should be lower under this resale split than under the 50/50 split due to demand reduction.

Shifting to a lower final buyer share (higher reseller share) should exhibit a higher frequency of speculation. As the surplus shifts in favor of the seller, the speculating distance will become closer to the demand reduction distance for all values. Also, more bidders will attempt speculation (perhaps switching from value-bidding or demand reduction), and at higher values than in the 50/50 treatment. The values on the highest end of the distribution will bid closer to values, if not their values. The reasoning behind this behavior is that the expected payoff from speculating increased. Correspondingly, the expected payoff from demand reduction decreased. The revenue for the initial seller in the auction should be higher under this resale split than under the 50/50 split or the split in favor of the final buyer due to increased speculation by bidders.

### 3 Design of Experiments

The experiments were designed to analyze bidding behavior differences in an auction as bargaining power, defined as the share of the resale surplus, is shifted between the final buyer and the reseller in the resale market. To accomplish this goal, three symmetric treatments of an English clock auction followed by an automatic non-standard resale market were created using a within subjects design, differing only in the share of the resale surplus earned by the final buyer and reseller in the resale market. A second set of three treatments, parallel in all ways to the first set of three treatments except for the form of the resale market, were also created to examine the change in behavior when the standard resale market was implemented. I will refer to these as experiment 1 and experiment 2, respectively.

The specific procedures are as follows:

Undergraduate students were recruited using ORSEE, Greiner (2004), and brought into the laboratory at Florida State University where they participated in an ascending English clock auction followed by an automatic resale market for a hypothetical good. Sixteen subjects participated in each of the 8 sessions run. Four of the 8 sessions implemented the non-standard resale market and the remaining four implemented the standard resale market. In each session, the 16 subjects were randomly divided into two groups of 8. The subjects were then randomly placed into two subgroups of 4 within each group of 8.

The experiment was programmed using Z-tree software, Fischbacher (2007). In the non-standard resale sessions (experiment 1) the subjects were given instructions which included two examples of bidding behavior. One demonstrated when automatic resale would occur and one when automatic resale wouldn't occur. In the standard resale sessions (experiment 2), subjects were given instructions which included three examples of bidding behavior. The first illustrated when resale would not occur, and the remaining two illustrated the automatic resale market when the winner's value was below the auction price and when the winner's value was above the auction price. The difference in protocol between experiments 1 and 2 was minimal to maintain parallelism. The primary difference was the additional example provided in experiment 2, which was necessary to explain the added outcome possibility in the standard resale market. In addition to the instructions, subjects participated in one unpaid practice period against three computerized bidders (robots), prior to the start of the paid periods, to become accustomed to the computer interface. After the instructions and practice period, the subjects entered into the paid phase of the experiment. They played this phase for 20 periods.

In each period, subjects randomly drew their private valuation for the hypothetical good from a uniform distribution on the range  $[0,100]$ . The maximum bid allowed was 100, which is the maximum of the value distribution. They participated in the auction through a computer interface, where they were able to see a bid clock gradually increasing from 0 in increments of 1. The subjects chose to "drop out" when the bid clock reached a price they were no longer willing to pay.

The auction ended when three bids had been placed, or when the bid clock hit 100. The winner of the auction was the last remaining subject and any ties were broken randomly by the computer program. At the conclusion of the auction, if the subject with the highest value did not win the auction, the resale market transaction automatically took place. The resale market involved an automatic transfer of the hypothetical good to the highest-valued subject. In experiment 1 (non-standard resale), the final buyer earned a share of the difference in their value and the price in the auction. The reseller earned the remaining share of this difference. In experiment 2 (standard resale), the final buyer in the resale market earned a share of the difference in their value and the value of the winner, or the price in the auction, whichever was higher. The reseller earned the remaining share of this difference and any positive difference remaining between their value and the price paid in the auction.

After the automatic resale market, in addition to being informed about their earnings, subjects were given feedback about whether or not resale occurred, the highest value, the price paid in the auction, the resale price and earnings of the resale participants.

The treatments involved varying the respective shares of the final buyer and the reseller in the resale market and these shares, defined by the treatments, were identical regardless of the form of the resale market (standard or non-standard). If the winner of the auction was the highest-valued subject, there was no resale, and the winner earned the difference between their value and the price resulting from the auction. The use of an “automatic” resale market was chosen to tightly control outcomes from the resale market to allow for careful observation of the effects from manipulating bargaining power.

The choice of bargaining power in the treatments was based on the theoretical and behavioral predictions mentioned in section 2. A 50/50 split of the resale surplus was established as the baseline treatment. The second and third treatments varied the advantage between the final buyer and the reseller from the 50/50 baseline. The bargaining advantage percentage was chosen to be 90% to ensure that subjects would understand and incorporate the shift in bargaining power into their decisions.<sup>9</sup> The three treatments are defined as follows:

#### **Experiment 1 (non-standard resale)**

*50/50 Treatment:* The final buyer in the resale market earned 50% of the difference between the highest value and the bid price in the auction. The reseller in the resale market earned the remaining 50%.

*Reseller Advantage Treatment:* The final buyer in the resale market earned 10% of the difference between the highest value and the bid price in the auction. The reseller in the resale market earned the remaining 90%.

*Final Buyer Advantage Treatment:* The final buyer in the resale market earned 90% of the difference between the highest value and the bid price in the auction. The reseller in the resale market earned the remaining 10%.

#### **Experiment 2 (standard resale)**

*50/50 Treatment:* The final buyer in the resale market earned 50% of the resale surplus, defined as the difference between their value and the maximum of the winner’s value or the price paid in the auction. The reseller in the resale market earned the remaining 50% of the resale surplus, and any remaining difference between their value and the price paid in the auction.

*Reseller Advantage Treatment:* The final buyer in the resale market earned 10% of the resale surplus, defined as the difference between their value and the maximum of the winner’s value or the price paid in the auction. The reseller

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<sup>9</sup>The percentage split,  $\gamma$ , must lie between 0 and 1. Shifting from .5 to .9 (.1) for the advantaged (disadvantaged) bargainer makes it clear to the subjects that one resale participant has a stronger (weaker) position. In particular, it is far enough from the .5 baseline to ensure that the payoffs implied by a shift in either direction (to .1 or .9) are understood. Choosing at the maximum of the distribution, 1, would confound the results.

in the resale market earned the remaining 90% of the resale surplus, and any remaining difference between their value and the price paid in the auction.

*Final Buyer Advantage Treatment:* The final buyer in the resale market earned 90% of the resale surplus, defined as the difference between their value and the maximum of the winner’s value or the price paid in the auction. The reseller in the resale market earned the remaining 10% of the resale surplus, and any remaining difference between their value and the price paid in the auction.

A within subjects design is used, using the 50/50 treatment as a baseline. Additional treatments of an English clock auction without resale were not included in the design, as prior research on English auctions without resale has replicated the result that value bidding is understood by bidders to be an equilibrium strategy and followed in the laboratory.<sup>10</sup>

In each session, the subjects participated in the 50/50 treatment for the first ten periods. After the initial 10 periods, subjects were informed of the change, given another example showing the change in rules, played another practice robot round, and either the Final Buyer Advantage treatment or the Reseller Advantage treatment was implemented. Subjects only participated in one of the “advantage” treatments, in addition to the 50/50. Average earnings of the subjects in experiment 1 were \$23.10, including the show-up fee of \$10. Average earnings of the subjects in experiment 2 were \$21.67, also including the show-up fee of \$10. There were zero bankruptcies across all sessions.

## 4 Results

Initially, I will discuss the impact of the existence of a resale opportunity on bidding behavior, using the 50/50 treatment as a baseline. Afterwards, the analysis of bidding behavior will continue but focus on the impact of shifting the bargaining power to and from the final buyer and reseller away from the 50/50 baseline and how this increases/decreases the frequency of speculation and demand reduction. Revenue and efficiency results will be examined in the final sections. Results from experiment 1 (non-standard resale) and experiment 2 (standard resale) will be explicitly noted.

### 4.1 Bidding Behavior

#### 4.1.1 Non-standard Resale (experiment 1)

The primary result derived in the non-standard resale theoretical analysis showed that value bidding was not an equilibrium strategy when the English auction is followed by a split of the resale surplus. Figure 1 shows the scatterplot of drop out bids plotted against values for the observable bids in the 50/50 treatment. The 45-degree line is included to show where an exit point (bid) equals value. All

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<sup>10</sup>See Alsemgeest et al. (1998) and Kagel et al. (1987) for previous experimental results on English auctions.



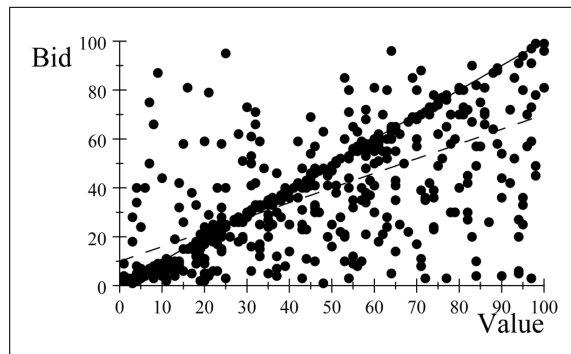


Figure 1: 50/50 (Baseline) Treatment - Experiment 1

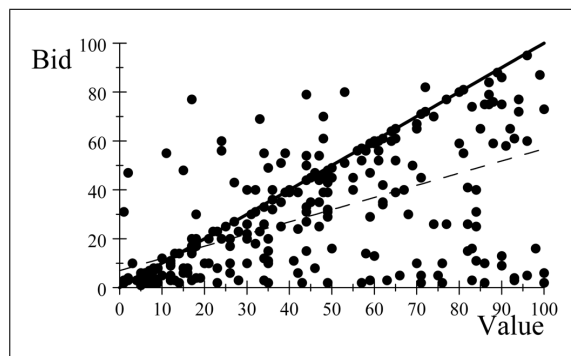


Figure 2: Final Buyer Advantage Treatment - Experiment 1

points above this line indicate speculative behavior (exiting the auction above value), and all points below this line indicate demand reduction behavior (exiting below value). Regression lines from Table 1, Model 2, are also included to demonstrate that the treatment effect is captured by regression analysis. Bidding below, above, and at value are all commonly observed, however, it appears as if value bidding and bidding below value occurs with more frequency than speculation.

Prior research on English auctions without resale, for example Alsemgeest et al. (1998) and Kagel et al. (1987), has given consistent results that value bidding is understood by bidders to be an equilibrium strategy and followed in the laboratory. These results would show a clustering of bids around the 45-degree line. It is a striking result that the addition of a simple resale market does lead to substantial deviations from value bidding in the direction of speculation and demand reduction.

The Final Buyer Advantage treatment shifted bargaining power away from the 50/50 split to a 90% share for the final buyer and a 10% share for the

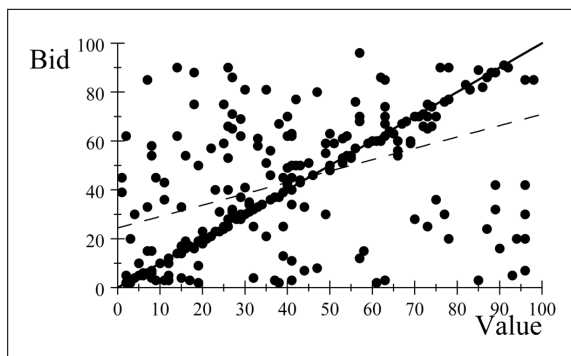


Figure 3: Reseller Advantage Treatment - Experiment 1

reseller. It was predicted that this shift would increase the incentive to demand reduce, and this strategy would be followed more frequently than in the 50/50 treatment. Figure 2 exhibits the scatterplot of drop out bids plotted against values for the Final Buyer Advantage treatment. Comparing the scatterplots for the 50/50 treatment to the Final Buyer Advantage treatment, there is a clear movement of bids away from speculating and bidding at value to bidding below value.

It should be noted that while demand reducing appears to be the predominant strategy, not all bidders are following it. A few bidders are still pursuing speculative strategies and value bidding. This was also predicted, behaviorally. If a bidder believes that the majority of bidders in his group are demand reducing and also believes that he does not hold the highest value, it is a better response for this bidder, given his beliefs, to speculate. This incentive decreases as his value increases, which would explain the majority of the speculative behavior in the middle to lower range of the value distribution.

The Reseller Advantage treatment shifted bargaining power away from the 50/50 split to a 10% share for the final buyer and a 90% share for the reseller. It was predicted that this shift would increase the incentive to speculate, and this behavior would occur more frequently than in the 50/50 treatment. Figure 3 exhibits the scatterplot of drop out bids plotted against values for the Reseller Advantage treatment. Compared to the baseline 50/50 treatment, we see a clear shift in bidding behavior towards speculation.

The predominant strategy followed by the subjects is bidding above value, but a few bidders continue to demand reduce, despite the reduced incentives for final buyers in the resale market. A few of the exit points are near the top of the distribution, meaning the winning bidder had intentions of bidding at the top of the distribution. Although demand reduction does exist, most bidders are choosing to speculate or to bid value.

It appears that the subjects are factoring in the incentive effects of the shift in bargaining power in the resale surplus split into their bidding strategies.

Bid	Model 1		Model 2		Model 3	
	Estimate	p-value	Estimate	p-value	Estimate	p-value
Constant	13.197 (2.568)	< 0.001	10.841 (2.485)	< 0.001	9.668 (2.721)	0.001
Value	0.551 (0.052)	< 0.001	0.602 (0.053)	< 0.001	0.600 (0.053)	< 0.001
Final Buyer Adv.	-8.180 (1.900)	< 0.001	-3.758 (3.595)	0.300	-2.185 (3.928)	0.580
Reseller Adv.	8.600 (2.346)	0.001	13.323 (4.601)	0.005	17.174 (4.797)	0.001
Final Buyer Adv. x Value			-0.097 (0.088)	0.272	-0.094 (0.088)	0.287
Reseller Adv. x Value			-0.107 (0.093)	0.255	-0.109 (0.093)	0.246
Time-Block 2 (last half 50/50)					2.571 (1.896)	0.180
Time-Block 4 (last half treatment)					-0.691 (2.276)	0.762
Time-Block 4 X Reseller Adv					-3.470 (3.572)	0.335
Obs (Groups)	960(64)		960(64)		960(64)	
$R^2$	0.32		0.32		0.32	

Table 1: Panel fixed effects for bidding in all Treatments (Experiment 1). Robust standard errors are in parentheses.

They are choosing to speculate by bidding above value with higher frequency in the Reseller Advantage treatment and they are choosing to demand reduce by bidding below value with higher frequency in the Final Buyer Advantage treatment.

Several panel fixed effects models,<sup>11</sup> seen in Table 1, are utilized to analyze bidding behavior between the 50/50, Reseller Advantage, and Final Buyer Advantage treatments in more depth leading to the first result. The first model directly tests for a treatment effect on bidding. The second model extends the first by analyzing the interaction of a bidder's value and the treatment applied to test the behavioral hypothesis that the amount of speculation and demand reduction depends on your relative position on the value distribution. The third model was included to test for any learning effects.

*Result 1: The addition of the resale market does induce non-value bidding behavior and bidders are able to integrate the resale market into their initial bidding decisions. As bargaining power shifts in favor of the final buyer, more bidders are choosing to demand reduce. As bargaining power shifts in favor of the reseller, more bidders are choosing to speculate.*

<sup>11</sup>Random effects models were also tested along with the Hausman test to test for significant differences in the coefficients estimated with both fixed and random effects (null is that the coefficients are the same). The resulting p-values of the tests were significant for all specifications, therefore fixed effects are used.

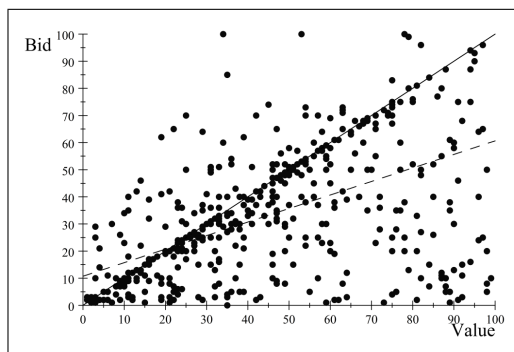


Figure 4: 50/50 (Baseline) Treatment - Experiment 2

All three models demonstrate a positive intercept with a slope less than 1 for the 50/50, Buyer Advantage, and Reseller Advantage treatments. Bidders are bidding above their value (speculating) at low values and bidding below their value (demand reducing) at higher values. The advantage treatments exhibit non-value bidding behavior, but the direction of bargaining power, towards the reseller or the final buyer, impacts if speculation or demand reduction is observed more often. In all three models, the Reseller Advantage treatment resulted in a significant positive intercept shift of the bid. The Final Buyer Advantage treatment effect also remains constant throughout all three specifications, in the predicted negative direction, but this coefficient loses significance in models 2 and 3. Model 1, in its simplest form confirms that as bargaining power moves to the final buyer in the advantage treatment, that subjects lower their bids. It also confirms the hypothesis of the Reseller Advantage treatment that bidders will increase their bids as bargaining power moves in favor of the seller.

#### 4.1.2 Standard Resale (experiment 2)

The results of experiment 1 substantiate the claim that subjects are able to respond to the incentives given by the resale opportunity, which establishes the implementation of the standard resale market as a real test of what happens when the bargaining power is altered.

The primary result derived in the standard resale theoretical analysis showed that value bidding was not the only equilibrium strategy when the English auction is followed by a split of the resale surplus. In particular, it was shown that multiple equilibria exist where one bidder bids a cut-off amount which depends on the bargaining power allocation, and the remaining bidders bid zero. The question addressed by these results is, under standard resale markets do shifts in bargaining power pull people away from value bidding? If bidders fail to respond to the shifts in bargaining power, the previous results confirm that the reason isn't an inability to understand the incentives.

Figure 4 shows the scatterplot of drop out bids plotted against values for

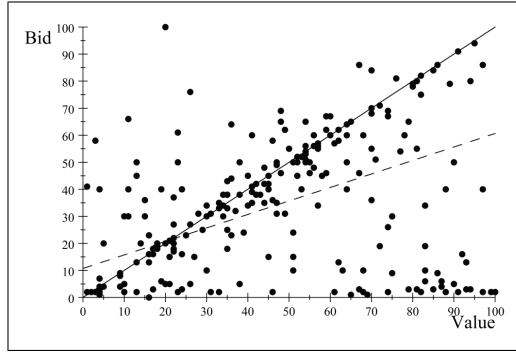


Figure 5: Final Buyer Advantage Treatment - Experiment 2

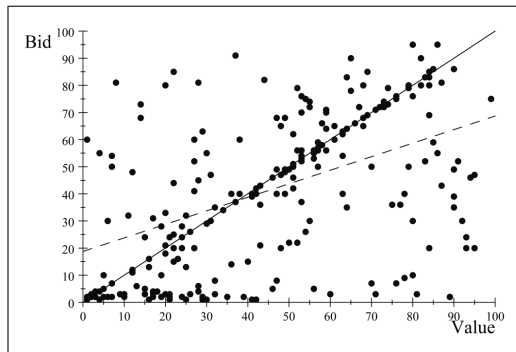


Figure 6: Reseller Advantage Treatment - Experiment 2

the observable bids in the 50/50 baseline treatment. Figures 5 and 6 are the scatterplots for the Final Buyer Advantage and Reseller Advantage treatments, respectively. Again, the 45-degree line is included to show where an exit point (bid) equals value, along with regression lines from Table 2, Model 1.

As before, the Final Buyer Advantage treatment shifted bargaining power to a 90% share for the final buyer and a 10% share for the reseller. It is clear that bidding below value has the highest relative frequency in the Final Buyer Advantage treatment. In comparison to the scatterplot for the 50/50 treatment it appears that for the upper values in the distribution there is a downward movement of bids, however it is unclear if bidding below value is followed more aggressively overall in response to the shift in bargaining power.

The Reseller Advantage treatment shifted bargaining power to a 10% share for the final buyer and a 90% share for the reseller. Focusing only on bids that are above value, the bid amount of the speculative bids in the Reseller Advantage treatment appears to exceed the bid amount of the speculative bids in the both the 50/50 and final buyer treatments. Theoretically this was to be expected as the bid that a speculator must make to induce bidders to demand reduce is increasing with the bargaining power of the speculator. However, the large number of speculating bids is also evidence that the problem of coordination on the speculating bidder persists.

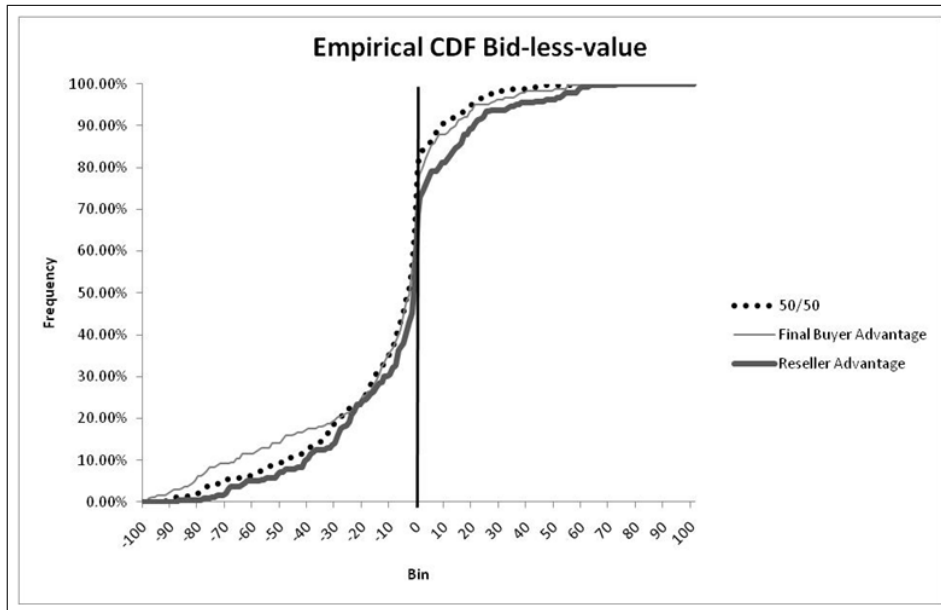


Figure 7: Empirical CDF bid-less-value (Experiment 2)

As a summary view of bidding behavior across treatments, Figure 7 graphs the empirical cumulative distribution of the difference between bid and value

Bid	Model 1		Model 2		Model 3	
	Estimate	p-value	Estimate	p-value	Estimate	p-value
Constant	10.732 (2.310)	< 0.001	8.904 (2.412)	< 0.001	8.942 (2.862)	0.003
Value	0.499 (0.047)	< 0.001	0.540 (0.054)	< 0.001	0.540 (.054)	< 0.001
Final Buyer Adv.	-1.972 (2.138)	0.360	8.056 (3.671)	0.032	6.074 (3.931)	0.127
Reseller Adv.	8.030 (2.464)	0.002	5.315 (3.827)	0.170	5.018 (4.432)	0.262
Final Buyer Adv. x Value			-0.217 (0.089)	0.017	-0.214 (0.088)	0.019
Reseller Adv. x Value			0.058 (0.076)	0.449	0.059 (0.076)	0.441
Time-Block 2 (last half 50/50)					-0.056 (2.207)	0.980
Time-Block 4 (last half treatment)					0.438 (2.928)	0.881
Time-Block 4 X Final Buyer Adv					3.122 (3.745)	0.408
Obs (Groups)	960(64)		960(64)		960(64)	
$R^2$	0.23		0.24		0.24	

Table 2: Panel fixed effects for bidding in all Treatments (Experiment 2). Robust standard errors are in parentheses.

as a summary way to view differences across treatments. In all treatments, the frequency of bid deviation from value is high, both above value and below value. The treatments appear to follow the behavioral predictions of shifts in bargaining power.

The frequency of bidding under value is much higher in the Final Buyer Advantage treatment, and the frequency of bidding above value is higher in the Reseller Advantage treatment. The 50/50 treatment appears to be more similarly distributed to the Reseller Advantage treatment for the demand reduction region (negative domain), switching roles in the speculation region (positive domain) by displaying a similar distribution to the Final Buyer Advantage treatment. Demand reduction behavior does occur in the Reseller Advantage treatment, but it does not occur with as much intensity as in the Final Buyer Advantage treatment for larger deviations in the negative domain.

Speculative behavior occurs in all treatments, but appears more strongly in the Reseller Advantage treatment and for greater deviations in the positive domain. It appears from Figure 7 that the subjects are factoring in the incentive effects of the shift in bargaining power into their bidding strategies. They are choosing to speculate by bidding above value with higher frequency in the Reseller Advantage treatment and they are choosing to demand reduce by bidding below value with higher frequency in the Final Buyer Advantage.

Panel fixed effects models, seen in Table 2, are again utilized to analyze bidding behavior between the 50/50, Reseller Advantage, and Final Buyer Advantage treatments for the standard resale market.

*Result 2: The addition of the standard resale market does induce non-value bidding behavior.*

Models 1-3 all demonstrate a positive intercept with a slope less than 1 for the 50/50, Buyer Advantage, and Reseller Advantage treatments. Bidders are bidding above their value (speculating) at low values and bidding below their value (demand reducing) at higher values.

*Result 3: As bargaining power shifts in favor of the reseller, more bidders are choosing to speculate. In the 50/50 split and as bargaining power shifts in favor of the final buyer more bidders are choosing to demand reduce, but demand reduction is not observed significantly more in the buyer advantage treatment than in the 50/50 treatment.*

Model 1 confirms that as bargaining power moves to the reseller in the advantage treatment subjects increase their bids. The negative coefficient on the Final Buyer Advantage treatment directionally confirms the hypothesis that bids decrease as bargaining power moves to the final buyer but this result is not significant. This does not imply that demand reduction does not take place, only that the amount by which subjects lower their bids is not significantly different from the 50/50 treatment where a large amount of demand reduction already occurs.

A positive coefficient on the Reseller Advantage treatment indicates that as the bargaining power is shifted in favor of the seller in the resale market, bidders respond by increasing their bid. The Reseller Advantage treatment resulted in a positive intercept shift of the bid, but this result is only significant in Model 1. The Final Buyer Advantage treatment effect gains significance in Model 2 with a positive intercept shift. While this appears counter to the hypothesis presented above, it is important to note that in this model the interaction of value and the Final Buyer Advantage treatment is also significant and negative. This significant slope shift demonstrates that there is demand reduction, but the amount that a bid is lowered by depends on the value. Bids are decreasing as values increase. The positive increase in the intercept shift indicates that at lower values there is speculation. This confirms the behavioral hypothesis for the Final Buyer Advantage treatment that the relative location of value is important in determining which strategy might be followed.

Speculation and demand reduction are observed in all treatments. On average, in Model 2 subjects bid around 54% of their value in the 50/50 treatment. The slope shift ( $\text{Value} \times \text{Adv. Treatment}$ ) is negative and significant for the Final Buyer Advantage treatment, which lowers the slope to approximately .32. The slope shift in the Reseller Advantage treatment is positive, but not significant in either Model 2 or Model 3 where it is examined. All treatments show a positive intercept, across Models 1-3. This implies that at low values, all treatments have speculation. As values increase, because the slope estimate on value is less than 1, eventually, demand reduction is predicted for higher values.



<i>Treatment</i>	<i>50/50</i>	<i>Final Buyer Advantage</i>	<i>Reseller Advantage</i>
Total Resale Outcomes	0.41	0.65	0.38
Successful Speculators (Auction Price > Winner's Value & Resale Surplus > 0)	0.08	0.15	0.08
Unsuccessful Speculators (Auction Price > Winner's Value & Resale Surplus <= 0)	0.03	0.10	0.10
Demand Reduction (Auction Price ≤ Winner's Value & Resale Surplus > 0)	0.29	0.40	0.20

Table 3: Relative frequency of resale outcomes of total number of auctions (resale and no resale), by treatment - Experiment 2

The experimental design creates an environment where inter-bidder resale is not a certain outcome. If the individual with the highest value wins the auction, there is no resale, and the outcome and payoffs are the same as the standard English clock auction without resale. Therefore, speculating, as a strategy, is only successful when the speculator is able to resell for a positive surplus amount. This in turn, is only possible when an individual within the group decides to follow the demand reduction strategy.

Demand reduction, on the other hand, does not always depend on the strategic decisions of others in a bidding group. This makes it possible to have all bidders demand reducing. However, if one individual in the group decides to follow a speculating strategy, it is possible that a demand reducer is paying an amount equal to their value and is therefore no better off than under a value bidding strategy. Define a successful speculator to be a bidder that wins the auction at a price greater than their value and successfully resells to another bidder for a positive amount, in other words, the resale surplus is positive.<sup>12</sup> Analogously, define successful demand reduction to be the case where positive surplus is split in the resale market, without speculation.

To determine how altering the bargaining power helps or hurts these strategies and impacts the existence of inter-bidder resale, Table 3 examines the relative frequency of successful speculators and demand reduction by treatment.

Resale occurs in all treatments with the highest number of resale outcomes, 65% of all auctions, occurring in the Final Buyer Advantage treatment. As the bargaining power is shifted in favor of the final buyer, it is clear that resale outcomes occur with higher frequency. As the bargaining power moves from the 50/50 treatment to the Reseller Advantage treatment (in favor of the reseller) the resale frequency falls, but the difference is not substantial.

It has been shown that the Reseller Advantage treatment has the highest frequency of speculation and the lowest frequency of demand reduction. Therefore, despite the large amount of speculative behavior, only 8% of speculators

<sup>12</sup>Recall that the resale surplus is defined as the difference between the highest value in the group and the value of the winner or the price paid in the auction, whichever is higher. In this case, the speculator bids an amount greater than their value, so the resale surplus is simply defined as the difference between the highest value in the group and the price paid in the auction, given resale occurs.

<i>All Bidders n = 64</i>	<i>50/50</i>	<i>Final Buyer Advantage</i>	<i>Reseller Advantage</i>
Demand Reducers	29	12	10
Speculators	5	2	3
Value Bidders	6	6	5
Multiple Strategies	24	12	14
<i>Non-Switchers n = 41</i>	<i>50/50</i>	<i>Final Buyer Advantage</i>	<i>Reseller Advantage</i>
Demand Reducers	18	10	8
Speculators	2	0	2
Value Bidders	3	2	1
Multiple Strategies	18	9	9

Table 4: Bidding Types

were successful, 10% were unsuccessful.<sup>13</sup> Speculators have the highest success rate in the Final Buyer Advantage treatment, obtaining a positive outcome in 15% of the auctions.

Demand reduction outcomes occur with the highest frequency in the Final Buyer Advantage treatment (40%) and second highest in the 50/50 (29%) treatment. This result is expected given the high rate of demand reduction in both of these treatments. The Reseller Advantage treatment had a smaller frequency of demand reduction outcomes than both the 50/50 and Final Buyer Advantage treatments which again is expected given the high rate of speculation and lowered rate of demand reduction observed in this treatment.

All of the data presented, regardless of the form of resale, demonstrate that coordination on a particular equilibrium outcome was a difficult task. A natural follow-up is to determine whether or not individuals follow one particular strategy or if they mix between strategies. To examine behavior on an individual level, bidders were categorized based on their mean deviation (bid less value), minimum deviation, and maximum deviation.<sup>14</sup> The four categories include: demand reducers, speculators, value bidders, and bidders who used a combination of speculation, demand reduction, and value bidding (multiple strategies). The top level of Table 4 presents the number of bidders in each type for all bidders, by treatment. The lower level presents the number of bidders in each type for the non-switchers. A bidder was labeled as a non-switcher if their strategy type remained constant between the 50/50 and advantage treatment.

The most numerous types of bidders are demand reducers and multiple strat-

<sup>13</sup>A speculator is defined as unsuccessful if the price resulting from the auction is greater than or equal to the highest value in the group, and the winner of the auction is not the high value holder.

<sup>14</sup>Demand reducers were bidders with a negative mean deviation and the maximum deviation never exceeded zero. Speculators were bidders with a positive mean deviation and minimum deviation never less than zero. Bidders categorized as value bidders were bidders with small mean deviation (typically +/- 3, or less) with a max/min deviation never exceeding 10. The final category, multiple strategies, consisted of all uncategorized bidders who had a min/max deviation that spanned both positive and negative domains.

<i>Treatment</i>	<i>50/50</i>	<i>Final Buyer Advantage</i>	<i>Reseller Advantage</i>
Average Efficiency (Standard Deviation)	0.90 (0.176)	0.78 (0.241)	0.90 (0.164)

Table 5: Efficiency results by treatment - Experiment 2

egy bidders, regardless of whether all bidders are taken into account or only the non-switchers. The non-switchers represented the majority of bidders as approximately 64% maintained a consistent type between the 50/50 and advantage treatment. This consistency does not imply that subjects do not mix. On the contrary, the large number of multiple strategy bidders (approximately 44% of non-switchers) gives evidence that subjects do mix strategies, and mix with consistency. Consistent value bidders and speculators also exist, although not to as great of an extent as demand reducers and multiple strategy players.

## 4.2 Efficiency and Revenue (standard resale)

Examining the bidding behavior above naturally suggests the question of what happens to revenue when resale is applied. These results will focus on the revenue and efficiency results of the standard resale market, as the non-standard resale market was primarily used to isolate bidder understanding of resale and is not likely to emerge in a setting outside of the laboratory.

Efficiency is measured as the value generated by the auction divided by the maximum value the auction could have achieved,  $\frac{V}{V^*}$ . It is important to note that this definition of efficiency applies to both the initial auction, and to the final allocation in resale, but this analysis of efficiency only focuses on the efficiency in the initial auction. By construction, overall efficiency will always be 1 due to the resale market. As another way of characterizing outcomes from the auction, we can look at the efficiency generated by that initial allocation.

The purpose is to examine the efficiency of the initial auction given that there is a resale opportunity. The standard efficiency of an English auction without a resale opportunity obtained from previous experimental results has resulted in high efficiency rates.<sup>15</sup> The efficiency results of experiment 2 are presented in Table 5, by treatment. The addition of resale has lowered overall efficiency across treatments compared to previous experimental results of English clock auctions without resale. For example, in Alsemgeest et al. from (1998), they report that for the single unit English clock auction, 100% of the periods achieved full allocative efficiency of 1, where the highest bidder obtained the item. The importance of the efficiency results presented in this paper is that the highest valued bidder is winning less often when resale is allowed.

*Result 4: Average efficiency at the auction allocation is approximately the*

<sup>15</sup>High efficiency is close to 1. See Coppinger et al.(1980) for an example of experimental results of an English auction without resale.

	<i>Average Revenue</i>	$V_{(2)}$	<i>Price Deviation</i>
50/50	48.36 (15.049)	61.41 (18.847)	-13.05 (13.217)
Final Buyer Advantage	49.67 (15.947)	59.52 (18.173)	-9.85 (17.158)
Reseller Advantage	58.66 (15.563)	60.95 (17.513)	-2.29 (15.525)

Table 6: Average revenue and deviation from predicted price in auction without resale for experiment 2. (standard deviation)

*same in the 50/50 treatment and the Reseller Advantage treatment, while efficiency falls in the Final Buyer Advantage treatment.*

Examining the lowered efficiency rates in the initial auction draws attention to the question of what happens to the initial revenue earned in the auction. As can be seen in Table 6, the addition of the resale market lowers revenue across all treatments from the expected revenue without resale. The amount of deviation depends on the structure of bargaining power in the resale market. Price deviation is measured as the difference between what was obtained in the auction with resale given various bargaining structures and the expected revenue,  $V_{(2)}$ , obtainable in a standard English auction without resale.<sup>16</sup>

As bargaining power is shifted away from the reseller, revenue drops for the initial seller but not in a consistent manner as the 50/50 treatment generates a stronger price deviation than the Final Buyer Advantage treatment. Across all treatments, bidders are demand reducing and effectively splitting revenue that would have been earned by the initial auction seller in the resale market. As bargaining power is shifted away from the reseller, the incentives to demand reduce become stronger, and more bidders are demand reducing. As a result, the probability of a demand reduction outcome is higher and revenue suffers.

The 50/50 treatment shows that with resale, the initial auction seller would earn approximately 78% of what he would have earned in the comparable auction without resale.<sup>17</sup> In the Final Buyer Advantage treatment, revenue is 83% of what would have been expected in an auction where resale was not possible. As bargaining power is shifted to the reseller in the resale market the revenue earned by the initial auction seller is approximately 96% of the revenue the auction could have earned without resale. The increased speculation due to the incentives created in the resale market creates competition that increased the revenue to the initial seller, but not enough to offset the demand reduction behavior that lowers revenue.<sup>18</sup>

<sup>16</sup>The predicted price in an English clock auction without resale is the second highest value.

<sup>17</sup>As noted previously, in an experimental English auction without resale, bidders typically follow “bid your value” strategies, where the predicted revenue is equal to the second highest value. Empirically, because the subjects follow the value bidding strategies, the revenue is generally close to predicted revenue, see Coppinger et al.(1980).

<sup>18</sup>The revenue results for experiment 1 (non-standard resale) indicate that under the Final Buyer Advantage treatment the auction would earn approximately 82% of what would have

Revenue	Model 1		Model 2		Model 3	
	Estimate	p-value	Estimate	p-value	Estimate	p-value
Constant	15.451 (7.013)	0.063	14.590 (8.781)	0.141	8.376 (10.393)	0.447
V1		< 0.001	0.023 (0.132)	0.864	-0.025 (0.120)	0.838
V2	0.333 (0.090)	0.008	0.308 (0.146)	0.073	0.485 (0.141)	0.011
V3	0.298 (0.082)	0.008	0.224 (0.121)	0.106	0.291 (0.075)	0.006
V4			0.165 (0.150)	0.308		
Final Buyer Advantage	-0.754 (1.521)	0.635	-1.091 (1.500)	0.491	24.686 (17.612)	0.204
Reseller Advantage	12.054 (3.399)	0.009	12.300 (2.921)	0.004	-0.871 (20.735)	0.968
V1 × Final Buyer Adv.					-0.257 (.194)	0.228
V1 × Reseller Adv.					0.560 (0.218)	0.004
V2 × Final Buyer Adv.					-0.082 (0.107)	0.467
V2 × Reseller Adv.					-0.527 (0.137)	0.006
Obs (Groups)	160(8)		160(8)		160(8)	
$R^2$	0.30		0.30		.32	

Table 7: Panel fixed effects for revenue in all treatments, experiment 2. Robust standard errors are in parentheses.

Revenue results for the 50/50, Reseller Advantage, and Final Buyer Advantage treatments are examined in more detail through panel fixed effects analysis in Table 7. The first and second models directly test the impact of the treatment on revenue. The third model analyzes the addition of the interaction of the highest and second highest values with the treatment on revenue.

*Result 5: Revenue from the initial auction is highest under the Reseller Advantage treatment, where the reseller has the bargaining power.*

Models 1 and 2 both show a strong intercept increase of approximately 12 in the Reseller Advantage treatment. Increasing the bargaining power of the reseller, in Model 1, raises revenue by approximately 78% over what is obtained in the 50/50 treatment. In the Reseller Advantage treatment, more speculation exists and less demand reduction. The competition between speculating bids translates into higher auction prices which raises revenue. It is clear from these results that if the bargaining power lies with the potential reseller in an auction,

been possible in the comparable auction without resale. In the 50/50 treatment, revenue is 89% of what would have been expected and the Reseller Advantage treatment resulted in a 5% increase in revenue over the predicted revenue without resale.

then the initial seller in the auction will benefit as the increased amount of speculation leads to higher revenue.

*Result 5: Auction revenue is approximately the same between the Final Buyer Advantage treatment and the 50/50 treatment.*

Models 1 and 2 also show a negative intercept change for the Final Buyer Advantage treatment, but this effect is not significant. In both treatments, demand reduction was the most frequently followed strategy, with the 50/50 treatment having slightly higher rates. Revenue from the initial auction in both treatments is lower which is a direct result of demand reduction. However, it does not appear that bidders reacted as strongly to the final buyer advantage treatment as they responded to the bargaining shift in favor of the reseller. The high demand reduction rates already observed in the 50/50 treatment do not leave much room for a substantial shift as the bargaining power of the final buyer increases.

Interestingly but not unexpectedly, in Models 1 and 3, the third highest value, V3, is positive and significantly impacts revenue in the 50/50 treatment. Without resale, we would expect only the second highest value, V2, to have the strongest influence on revenue because most bidders follow value bidding strategies. When value bidding is the strategy played in the English auction, the bidder with the highest value wins, but pays a price (revenue for the auction) equal to the second highest bid. However, when the third highest value has significant influence over the resulting price, it indicates that a bidder is demand reducing and the price resulting is the third highest value instead of the second.

Overall, these results indicate that the initial seller in the auction will earn less revenue due to the presence of resale and the loss in earnings will increase if the bargaining split is 50/50 between the final buyer and reseller or if the final buyer has a higher bargaining advantage. If the reseller has the bargaining power, this can mitigate some of the revenue loss associated with demand reduction due to increased speculation and value bidding behavior.

## 5 Conclusion

This paper analyzes the impact of the existence of inter-bidder resale and bargaining power within the resale market on bidding behavior and revenue for an English clock auction. The primary result is that it is clear that the addition of a resale market opportunity to the standard English auction does indeed alter the behavior from value bidding in the initial auction. Bidders are able to, and do internalize resale market outcomes into their bidding decisions in the initial auction. Understanding that bidders are able to formulate and implement the strategic implications of resale, at a basic level, is useful to the auctions with resale literature and in practice. When an auction is held, the initial seller should be aware of any resale opportunities, as this would impact the expected revenue they would hope to obtain, due to the altered behavior from a standard English auction without resale.

Theoretically, this paper demonstrated that in addition to value bidding, multiple equilibria exist that include speculation and demand reduction as strategies. The particular equilibrium analyzed in this paper required coordination on one speculating bidder, while the remaining bidders demand reduced. The selection of the "speculating bidder" is a difficult coordination problem, which is compounded by the second coordination problem of which equilibrium to play. The strategy that achieved the highest frequency of play was demand reduction, followed by speculation and then value bidding. It is clear from these results and not surprising that bidders were not able to "choose" which bidder would speculate and also not surprising that they were not able to explicitly coordinate on one equilibrium to play. This implies that some form of mixed strategy equilibrium analysis might more accurately describe behavior when a resale market is present and the ability to signal intentions or communicate is not possible.

Behaviorally, this paper hypothesized on how shifts in the bargaining power allocation of the resale market would impact bidder behavior in the initial auction, provided bidders understand the resale incentives. If bargaining power lies with the reseller, there is an incentive to speculate and if bargaining power lies with the final buyer, there is an incentive to demand reduce. To test whether or not bidders understand the implications of resale, a subset of the experimental sessions implemented a non-standard form of resale which eliminated value bidding as an equilibrium outcome. The results for the non-standard resale market strongly indicate that bidders do understand the implications of shifts in bargaining power and integrate these incentives into their initial bidding decisions.

Moving forward from these results, additional sessions with a standard resale market were conducted to determine if bidders still responded to shifts in bargaining power and moved away from value bidding, which exists as an equilibrium outcome (in addition to others) when English auctions are followed by the standard resale market. The results for the standard resale market are not as strong as the results for the non-standard resale market, but the latter establish that the failure to respond is not indicative of an inability to understand the incentives. However, while not as strong, the directional results for the standard resale experiments do appear to mimic the results found under the non-standard resale format suggesting some consistency in the response of bidding behavior to resale incentives.

The standard resale market sessions were used to examine the impact of resale on revenue. If the bargaining power lies with the reseller in the resale market, there is an incentive to speculate. While there is an increased incentive to speculate, demand reduction is still observed which provides an environment for successful speculation. Demand reduction lowers revenue, but the incentive to speculate mitigates, to a certain extent, the loss in revenue that occurs from demand reduction. It appears that the relative mix of demand reduction and speculation is key. If demand reduction is dominant, then revenue will decrease. If speculation is dominant, it should increase revenue. For example, if an auction is held in an industry with a large amount of lower valued bidders, and resale is allowed, it is possible that the majority of the bidders will engage in

speculation and this will actually increase revenue for the initial seller. This is important for the recycling industry, or any industry inhabited by a large number of traders. These traders are primarily participating in the auction with intentions of reselling, and therefore should exhibit speculative behavior. An attempt to restrict any potential resale, such as excluding traders from the auction, could potentially lower the revenue achieved in the auction.

Across all sessions, but particularly when the bargaining power lies with the final buyer in the resale market or if there is a 50/50 split, there is an incentive to demand reduce. Again we see a mixture of behavior between demand reduction and speculation. Despite the increased incentives to demand reduce, speculation is still observed, although to a lesser degree than demand reduction. Demand reduction behavior leads to lower revenues than what would be expected in the same auction without resale opportunities. Demand reduction is observed in this scenario because the demand reducing bidder is trying to obtain a lower price for the good, which can happen in this single-unit format only because of resale. If an initial seller observes that all of the bidders are final users of the good (i.e. not traders) who might not want to engage in speculation, it might benefit the initial seller to try to minimize resale. Of course the initial seller, unless they are a government entity, cannot limit resale outside of the auction, but the initial seller does have choice over the format of the auction used which could minimize the impact of resale.

The English clock auction, in particular, appears to be susceptible to successful demand reduction due to its sequential nature. Alsemgeest et al.(1998) suggest that the ability to collude is enhanced by the clock auction and Burtraw et al.(2008) also find that successful demand reduction in multi-unit auctions was more pronounced in clock auctions than in the sealed-bid formats. This relates to the current research in that bidders are using the resale market as a way to demand reduce in the single-unit auction. If it is the sequential nature of the English clock auction that facilitates demand reduction, then it could be conjectured that a sealed-bid format would be a better choice for the initial seller to minimize resale by making it more difficult for bidders to demand reduce. However, this is an untested conjecture.

It is important to note that one of the treatments in the experimental design of Burtraw et al.(2008) included a spot market for resale after the auction. There was active resale trade in this spot market. This fact, along with the observation of demand reduction during the auction suggests that the results of this paper are robust to alternative specifications of resale.

Moving forward, it is important to examine if these results are robust to other auction institutions, for example a sealed-bid format. Another direction of future research should determine what types of industry structures lead to a differing bargaining structures in resale. For future experimental research, in addition to testing the robustness of these results in alternative auction formats, the next step would be to endogenize bargaining in the resale market, and allow bidders to communicate prior to the auction.



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## 7 Appendix

### 7.1 In-depth proof of Proposition 1

#### Proposition 3

**Proof.** The speculating bidder does not wish to deviate from a bid equal to the cut-off,  $v_c$ , because the only bid which changes the expected payoff of this bidder is a bid of zero. A bid of zero results in a tie for the winner of the auction and assuming that in the event of a tie a bidder wins the auction with probability  $\rho < 1$ , bidding zero lowers the expected payoff of the speculating bidder. Therefore, a bid of  $v_c$  constitutes an equilibrium strategy for the speculating bidder. The next section will examine the strategies of the bidders who are choosing to demand reduce at a bid of zero.

Suppose bidder  $i$  deviates from a bid of zero to any bid below the cut-off value,  $v_c$ , the bid of the speculating bidder. He would still lose the auction to the speculating bidder and this deviation would only change his expected payoff in the event that the speculating bidder's value is below the price resulting from the auction. In this case, bidder  $i$  sets a new auction price equal to his bid which lowers the resale surplus, leading to a lower expected payoff than would occur under a bid of zero. Therefore, to prove that the strategy constitutes an equilibrium, it suffices to show that deviation to a bid equal to or greater than the cut-off value does not increase a bidder's expected payoff from a bid of zero.

Equation (1) defines the expected payoff to a bidder choosing to demand reduce to a bid of zero, which is equal to the final buyer's share of the resale surplus that a bidder would earn in the event that he has the highest value. The resale surplus is defined as the difference between the value of the final buyer and the expected second highest value. This assumes that the winner of the auction has the second highest value, which minimizes the potential gain from resale by the final buyer.

$$(1) u_i^{eq}(v, \gamma, Y_1, \dots, Y_{n-1}) = F(v)^{n-1} \gamma E[(v - Y_{n-1}) | Y_n = v]$$

Equation (2) defines the expected payoff to a bidder choosing to bid an amount greater than the cut-off value to win the auction with certainty. The first part of equation (2) gives the expected payoff in the event the bidder has the highest value and keeps the item, where he earns his value less the price resulting from the auction. The second part of the equation gives the expected payoff in the event he becomes the reseller because another bidder has a higher value. It includes the reseller's share,  $1 - \gamma$ , of the resale surplus which is defined as the difference between the expected value of the final buyer and the value of the winning bidder. In addition to the surplus split, the reseller also earns an amount equal to the difference his value and the price paid in the auction. Equation (2) is only defined for values greater than or equal to the cut-off value,  $v_c$ , because the expected payoff for a bidder whose value is in the range  $[0, v_c)$  includes negative potential earnings which make it strictly less than the expected payoff to a bidder whose value is greater than or equal to the cut-off. As a result, we can restrict attention to the range of values where  $v \geq v_c$ .

$$(2) u_i^{dev}(v, \gamma, v_c, v_1, \dots, v_{n-1}) = F(v)^{n-1}(v - v_c) + (1 - v) \{(1 - \gamma)E[(v_j - v)|v_j > v] + (v - v_c)\}, v \geq v_c$$

Equation (3) defines the expected payoff to a bidder choosing to bid an amount equal to the cut-off value. Again, this equation is only defined for values greater than or equal to the cut-off value,  $v_c$ , by the same argument presented for equation (2). If bidder  $i$  deviates to a bid equal to the cut-off value,  $v_c$ , he ties with the speculating bidder, and wins the auction with probability  $\rho$ . He loses the auction with probability  $1 - \rho$ , and only earns profit if he has the highest value and shares the surplus with the winner of the auction. The resale surplus in equation (3) utilizes the price resulting from the auction,  $v_c$ , as this is the maximum surplus possible in resale for the losing bidder if they become the final buyer.

$$(3) u_i^{b=v_c}(v, \gamma, v_c, v_1, \dots, v_{n-1}) = (1 - \rho)(F(v)^{n-1}\gamma(v - v_c)) + \rho(F(v)^{n-1}(v - v_c) + (1 - v) \{(1 - \gamma)E[(v_j - v)|v_j > v] + (v - v_c)\}), v \geq v_c$$

A bid equal to the cut-off does not generate an expected payoff greater than that of a bid greater than the cut-off. To see this, note that the expected payoff from winning the auction in equation (3) is identical to that of equation (2), but is weighted by the probability of winning,  $\rho$ , which is less than 1. Thus, for the expected payoff given by equation (3) to exceed the expected payoff given by equation (2), the expected payoff from losing the auction must exceed the payoff from winning the auction, which it does not. Therefore, to prove deviation from a bid of zero is not profitable, a comparison of the expected profit for a bid greater than the cut-off to the expected profit of a bid of zero is sufficient.

The bid of the speculator,  $b_s$ , is defined as the cut-off value which would make a bidder with the highest possible valuation,  $v = 1$ , indifferent between demand reducing to a bid of zero and winning the auction by deviating to a bid

higher than that of the speculator. It is obtained by equating equations (1) and (2). The cut-off value, given by equation (3), is the minimum bid that must be placed by the speculating bidder.

$$(3) \quad b_s = 1 - \frac{\gamma}{n} = v_c$$

A speculator who bids an amount equal to the cut-off leaves a bidder with a value of 1 indifferent between bidding above the speculator and demand reducing to a bid of zero. Any bid by the speculator above  $v_c$  generates a strictly higher payoff for a bid of zero than deviation by a bidder with a value of 1. For bidders with values in the range  $[0, 1)$ , equation (1) is strictly greater than equation (2) rejecting any profitable deviation from a bid of zero to a bid higher than the cut-off. To demonstrate this, suppose deviation is profitable, if so then the relationship given by (4) should be non-negative.

$$(4) \quad u_i^{dev} - u_i^{eq} \geq 0$$

$$= v^{n-1}(v - 1 + \frac{\gamma}{n}) + (1 - \gamma)\frac{(1-v)^2}{2} + (1 - v)(v - 1 + \frac{\gamma}{n}) - \gamma\frac{v^n}{n}$$

$$= -\frac{1}{2nv}(v - 1)(2v\gamma + nv^2 - 2nv^n + 2v^n\gamma - nv - nv\gamma + nv^2\gamma) < 0,$$

which is a contradiction of the assumption.

Thus it holds that for the remaining  $n - 1$  bidders, a bid of zero constitutes an equilibrium strategy. ■