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Ordering, revenue and anchoring in art auctions

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We estimate the effect of ordering by value on revenues in sequential art auctions held by Sotheby's and Christie's. We exploit a pre determined rotation of which of these two houses holds their auction first during auction week in New York City. When the house that goes first has relatively expensive paintings compared to the other house, we find that the sale premium for the week is around 21% higher relative to the mean sale premium, and the fraction of paintings sold during the week is around 11% higher. We provide evidence that this is due to an anchoring effect.

1. Introduction

■ Auctions have become an increasingly important mechanism to sell valuable goods and assets. They have long been used to sell goods such as works of art, wine, and antiques. But in the last 20 years, auctions have also been extensively used by the private sector as well as governments from all over the world to sell everything from industrial enterprises to radio spectra. Given the importance of these auctions, understanding the economics of how they are conducted is of great interest to researchers and practitioners. In some cases, only a single good is being sold, but in many cases the seller has to sell several items of heterogeneous estimated value or quality. Although the seller can use simultaneous auctions, auctions are in most cases

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conducted sequentially. So the auctioneer has to decide how to order items of heterogeneous quality.

Two examples help illustrate the problem at hand. In the case of art auctions, the art auction house has to decide how to order many items of varying estimated value: from potentially a $100 million Van Gogh to a painting worth a couple of hundred thousand dollars. In the case of the Israeli auction of oil refineries in 2006, the government decided to privatize two government-controlled refineries, one of which had a bigger capacity and was as a result more valuable. How should these auctions be sequenced? Should the valuable items be auctioned first or last? And how important for revenues is sequencing?

The theoretical literature generally predicts that the auctioneer should sell the items in a declining order. As we discuss below, rational mechanisms, especially externality effects from varying bidder strengths, and behavioral mechanisms, notably anchoring effects, can deliver this result. The empirical literature, which examines a variety of auctions, largely supports this conclusion: in most auctions, items are sold in a declining order where the more valuable items are sold first (see, e.g., Pesando and Shum, 1996, and Beggs and Graddy, 1997, for studies of art auctions and Ginsburgh, 1998, for a study of wine auctions, and Zulehner, 2009, for a study of dairy cattle auctions).

However, this empirical work is limited in that we do not know how important ordering is for revenues. Does a decreasing sequence improve revenues relative to an increasing sequence and if so by how much? Because the sequences we observe in any given auction are endogenous (and typically declining), existing empirical work cannot estimate the value of sequencing without being able to consider an alternative sequence that is increasing and seeing how it affects overall revenue. The existing empirical work implicitly assumes that the auctioneers are setting the sequences in a rational way as portrayed in models. But it could also be that they are following erroneous rules of thumb or setting declining sequences for other reasons. Ideally, we would like to be the auctioneer and try out different ordering sequences (some declining, some increasing) to gauge their effects on auction revenues.

In this work we try to do just this by using a natural experiment (in the spirit of Ashenfelter, 1978) in art auctions. We analyze the results of Impressionist and Modern painting auctions at Sotheby's and Christie's over a 26-year period (1985 – 2010) covering roughly 37,000 painting observations. These auctions take place two weeks out of the year in New York City in what is called "auction week": one in the spring and one in fall. We have a total of 52 such auction weeks in our sample. During this week, bidders fly into New York City from all around the world and stay there for the week to bid for paintings from these two houses.

The natural experiment we exploit is that Sotheby's and Christie's have a handshake agreement to alternate on which house goes first during auction week. For example, Sotheby's led the auction week in the fall of 1996 and the spring of 1997. Then Christie's led in the fall of 1997 and spring of 1998, and so forth.[1] Sotheby's and Christie's auctions will typically differ in value (sometimes one house has the stronger paintings and vice versa). Our identification strategy is then to see how the performance of the auction week (aggregating across both auction houses, the sale premium, defined as the difference between the sale price and the estimated value divided by the estimated value, and the percentage of paintings sold) varies with whether the house with the expensive set of paintings went first during the week.

Given existing theories, we expect that the revenue from a given auction week relative to total estimated value is higher when the house with the more valuable items goes first. We indeed find that in weeks when the house that goes first has relatively expensive paintings compared to the other house, the average sale premium is eight percentage points higher. This translates to about a 21% higher sale premium relative to the unconditional mean sale premium (which is 0.37). The point estimate is quite robust; even though this regression is run using only the 52 weekly observations (painting outcomes are averaged at the level of the auction week), we still obtain

[1] There are a few exceptions, which we discuss below. Our results are robust to removing these few observations.

statistically significant estimates. We also find that having the house with relatively expensive paintings go first during the auction week increases the probability that a painting sells by about 11% relative to the unconditional mean (which is 0.78). This effect is again economically and statistically significant. Thus, we conclude from our natural experiment that the order in which items are sold can have a first order effect on auction revenues.

A few additional words about our natural experiment are in order. We rely on the fact that Sotheby's and Christie's do not coordinate on the sale of their paintings as would be optimal.[2] Because they alternate in this predetermined manner, we are essentially using their rotation as the source of random assignment of sequences to auctions and seeing how the overall auction revenues (here deflated by preestimated value to control for quality) vary with the sequence. Our identification technique would work if sellers choose to use Christie's or Sotheby's regardless of their position in the auction week. This may be because of a long-term relationship that may lead sellers to forgo some profit in the short term. This can also be because sellers view a specific auction house to have a competitive advantage in marketing their specific painting. A natural concern however is whether sellers do behave in this way and what the implications are if they do not. We should note that if sellers do not behave in this way this does not necessarily create a bias. If sellers of the more expensive items always choose the auction house that goes first then we may not have the sufficient variation in our explanatory variable. Although this could have prevented us from obtaining significant results we shall show fortunately this is not the case. Moreover, it seems that to a large extent indeed bidders do not choose auction house based on its auction position.

In section 5, we formally discuss the validity of our experiment. We are particularly worried about the correlation of our ordering variable (whether the house with the more expensive paintings goes first) and total auction week size, both of which are based on appraised values. One plausible worry is that there are time trends in terms of total auction size and sale premium. During periods of art booms, the total auction week size and the sale premium are naturally higher because of enthusiasm for art, which engenders higher demand and supply. And if our ordering variable happens to be correlated with total auction week size for some reason, then we might obtain a spurious finding. Another related worry is to suppose that when total auction week size is high, it is due to appraisal errors, and hence the sale premium is likely to be low. If for some reason again our ordering variable is correlated with total auction week size, then we can again spuriously find a relationship between our ordering variable and the sale premium. The key is to be convinced that there is no or little correlation between our ordering variable and total auction size. In section 5, we show that once we control for year effects then there is no correlation between our ordering variable and total auction size. This greatly increases our confidence in our experiment.

An additional concern involves the well-known cartel agreement between Sotheby's and Christie's that lasted from 1995 until 1999 during which the two parties agreed on, among other things, raising prices by fixing sellers' commissions (see Department of Justice, 2000). Although we do not have an obvious story for why this cartel arrangement should influence how the ordering of auctions affects the outcomes of those auctions, we explore how much the inclusion of the cartel years in our data sample influence our results. We show that our empirical results are not sensitive to whether we include the years when Sotheby's and Christie's engaged in collusive behavior.

We should also note that our empirical analysis focuses on paintings auctioned in the evening (of which there are 7609 paintings in our sample). Each house has a morning and an afternoon session (which have about 29,292 paintings), but these auctions are very small in comparison to the evening auctions, which is when most bidders attend. Moreover, there is little variation in the

[2] Interviews of insiders suggest that the decision to go with a house does not depend on whether the house is going first during the week. In theory, it is fine for the purposes if this does factor into the decision. In the limit, if this were all that mattered for clients, then we would rarely see a house with the more expensive lots going last.

sizes of morning or afternoon sessions between these two houses. All the variation in size comes in the evening sessions.

We then distinguish between rational explanations, such as weak bidder effects, and a behavioral explanation due to the anchoring effect, for why auctioning off large items first increases revenues. We know that weeks in which the house with the more expensive paintings goes first have higher revenues and percentage of paintings sold than weeks in which the house with the less expensive paintings go first. We then also examine whether this difference in outcomes across these two types of weeks is being driven from the paintings sold by the house that goes first, the house that goes second or if the better outcomes are coming equally from both the houses. We show below how to exploit this decomposition to distinguish between these two types of explanations. We also link our findings to an existing anchoring test by Beggs and Graddy (2009) to provide corroborating evidence that anchoring is also driving our findings.

The article proceeds as follows. In Section 2, we discuss the various theories of optimal auction sequences and provide a review of the literature more generally. In this section, we also compare our estimates for the importance of ordering to those in the literature. In Section 3, we provide more color on our natural experiment obtained from our interview with Hugh Hildesey formerly of Sotheby's. We describe the data in Section 4 and present the results in Section 5. We conclude in Section 6. In the Appendix, we replicate findings from earlier studies that the auction houses sell off expensive items first. This is simply to show that our sample is similar to earlier studies, and that the auction houses appear to be following a sensible rule of thumb.

2. Literature review

■ The existing literature examines several reasons for how ordering by value can affect overall auction revenues. We first discuss models with only rational agents before turning to behavioral models. One strand of rational models relies on an externality of early auctioned items on late ones. To see a concrete example, let us assume that bidders are interested in obtaining at most one item. Our setup is similar to Beggs and Graddy (1997) and Elmaghraby (2003). As a result, the strength (in terms of private valuations) of the pool of bidders weakens as the auction progresses over time. In absolute terms this deterioration has a bigger effect on more valuable goods so there is incentive for the seller to sell these goods first.

Specifically, assume there are three bidders (denoted by A, B, and C) and two goods (denoted α and β). The goods are sold using a second price auction. All bidders find α to be more valuable and value β at half of their value of α. Bidders' valuations for α are given by $v_A(\alpha) = 6$, $v_B(\alpha) = 4$ and $v_C(\alpha) = 2$. Their valuations for β are given by$v_A(\beta) = 3$, $v_B(\beta) = 2$and $v_C(\beta) = 1$. For simplicity we assume that these values are commonly known. The equilibrium we describe has the feature that bidders bid up to their reservation value even if they are not expected to win.

Suppose initially that bidders are myopic, and when bidding in the first auction they do not take into account the second auction. In this case, if we sell α (the more expensive item) first, then bidder A will win it by paying B's bid, which is $v_B(\alpha) = 4$, and bidder B will win the second auction by paying $v_C(\beta) = 1$. So the total revenue is $v_B(\alpha) + v_C(\beta) = 5$. If instead we sell β first then we would get $v_B(\beta) = 2$ in the first auction and $v_C(\alpha) = 2$ in the second auction so the total revenue is $v_C(\alpha) + v_B(\beta) = 4$. In other words, we get higher revenue from auctioning the expensive item first. A closer look at the difference in revenues reveals that it equals the difference between the extent bidder B prefers α over β ($v_B(\alpha) - v_B(\beta) = 2$), as compared to bidder C ($v_C(\alpha) - v_C(\beta) = 1$). In our example, bidder B not only has higher values as compared to bidder C but also has a bigger difference between these two goods. This illustrates the externality effect (across the sale of different goods) of having weaker bidders as an auction progresses and hence the optimality of putting an expensive item first.

Consider the same example as before but bidders now take into account future auctions. Suppose that the expensive item, α, is sold first using a second price auction. Bidder A knows that if he loses this auction to bidder B then in the second auction he will face bidder C and would extract a profit of $2 = v_A(\beta) - v_C(\beta)$. Hence, this bidder will be willing to only bid $4 = v_A(\alpha) - [v_A(\beta) - v_B(\beta)]$. Using the same argument we can conclude that bidder B will submit a bid of $3 = v_B(\alpha) - [v_B(\beta) - v_C(\beta)]$. Hence, bidder A wins the first auction for a price of 3 whereas bidder B wins the second auction for a price of $1 = v_C(\beta)$ so the seller gets a total of 4. If instead the cheaper good, β, is sold first, then bidder A expects a profit of $4 = v_A(\alpha) - v_C(\alpha)$ if he competes with bidder C in the second auction and hence will prefer not to submit a bid (assuming that negative bids are not allowed). Hence, B will win this auction and pay $1 = v_C(\beta)$. In the auction of the expensive good where bidders A and C compete, bidder A wins and pays $2 = v_C(\alpha)$ so the seller extracts a total payoff of 3. Similar to the myopic case a closer look at the difference in revenues reveals that it equals the difference between the extent bidder A prefers α over β ($v_B(\alpha) - v_B(\beta) = 2$), as compared to bidder C, ($v_C(\alpha) - v_C(\beta) = 1$).[3]

One can generalize the two examples above and conclude the following: to maximize revenues the seller should sell first the expensive item. The reason why it holds in the myopic case is trivial, but as the second example reveals, under the same conditions, it holds even when bidders are nonmyopic. Our analysis was simplified by the assumption of symmetric information or more importantly that bidders knew in advance who the strongest bidder is. Nevertheless, Beggs and Graddy (1997) and Elmaghraby (2003) show that a similar conclusion holds in a model with private information.

Our examples rely on the assumption that bidders demand only one good; this is an extreme case of decreasing marginal values. The literature has considered other reasons for why in a rational model the seller should sell first the more valuable good. Notably, Benoit and Krishna (2001) study a case in which two goods are being sold to bidders who have different budgets but value the goods in a similar way. Bernhardt and Scoones (1994) obtain a similar conclusion in a model in which there is private information, but bidders do not know their value for the second item when bidding on the first one. The seller should auction first the item for which valuations are more dispersed. Similar to the example above this is likely to be the valuable good. Gale and Hausch (1994) show, in a very similar setup, that even if bidders know their values for both objects when they bid on the first object, one can still generate declining prices.

Apart from the rational models mentioned above, several behavioral explanations have also been given for this pattern. One of the most important behavioral explanations is anchoring. The seller may benefit from high initial prices that bidders may use as a reference for future auctions. Tversky and Kahnemann explore this phenomenon in a number of studies (see, r.h., Tversky and Kahnemann, 1974). There have been a number of empirical studies, using experimental and observational data, documenting anchoring effects across a wide variety of applications.[4] Evidence of anchoring has been found in art auctions. Beggs and Graddy (2009) show that there is an anchoring effect of the outcome of a previous auction sale of a given painting on its subsequent sale. A similar type of story is given in the classic work of Cassady (1967), who argues that lively bidding requires that the masterpiece goes first. The seller can then exploit the enthusiasm that competition for the masterpiece generates in the subsequent sale of the minor work. If bidders are rational, this should have no effect on their enthusiasm for later items conditional on their quality. Consistent with empirical findings, these articles show that the seller should sell the more valuable items first.

Our work is distinct from the existing empirical literature in focusing on the implications for overall revenue of different sequences and why different sequences matter. The existing literature has mostly focused on documenting that expensive items are auctioned first, and that there is a declining price-to-estimate ratio as an auction progresses. In the Appendix, we examine the

[3] Note that a similar conclusion holds even if bidder A does participate in the first auction and for example sets the price for this auction as $v_A(\beta) - [v_A(\alpha) - v_C(\alpha)]$ or even wins it.

[4] Northcraft and Neale (1987) find evidence for anchoring in the appraisal of real estate, and Nunes and Boatwright (2001) find similar evidence in the consumer goods market. Both studies use experimental research designs. Rajendran and Tellis (1994) and Greenleaf (1995) find evidence for anchoring in the behavior of consumers in grocery stores using observational evidence.

patterns of ordering of paintings within an auction and the price realizations of those paintings using our data. We find results consistent with the literature. For both the evening sessions and the morning and afternoon sessions, we find that there is a downward trend in the estimates of paintings as an auction progresses. We also find that the sale premium of paintings falls also as an auction progresses.

Interestingly, this declining price pattern holds for heterogeneous goods (Beggs and Graddy, 1997) and even for identical or homogeneous goods (Ashenfelter, 1989). The finding for homogenous goods has come to be the declining price anomaly because when bidders are risk neutral we would expect prices to follow a martingale (see Weber, 1983). A number of theories have been proposed, but this still remains to be one of the main puzzles in auction theory (see McAfee and Vincent, 1993; Ginsburgh, 1998; Ashenfelter and Genesove, 1992). One exception is Deltas and Kosmopoulou (2004), who use a natural experiment on rare books in which the books are auctioned in alphabetical order and find no declining price pattern as in auctions in which larger items are auctioned first, suggesting that ordering matters for sale premiums. But they cannot observe the counterfactual in their context where the books are auctioned by size. This is what we can do with our natural experiment.

Finally, we can use the declining price pattern found in Beggs and Graddy (1997) to get an estimate for the effect of ordering on revenue in the literature. In their Table 2 column (10), they report the mean-bid-to-estimate ratio for sold items, which is analogous to one-plus-our-sales-premium variable. They find, for instance, that most expensive paintings are placed in the third order decile group. The mean-bid-to-estimate ratio of sold paintings of this group is 1.37. The mean-bid-to-estimate ratio in the order decile group 10 is 1.25. This difference of .11 is similar in magnitude to our eight percentage point difference in the sale premiums between weeks where the house with the expensive paintings go first compared to weeks where it goes second. The order group deciles 7 – 9 have even lower mean-bid-to-estimate ratios of around 1.16, yielding even larger differences in outcomes of .21 percentage points. As such, our estimates are fairly consistent with that calibrated from estimates in the literature.

3. Institutional setting and the natural experiment

■ Through an interview of Hugh Hildesey, an auctioneer with an extensive knowledge of the history of Sotheby's, we obtained a number of facts about the Sotheby's and Christie's auctions. The handshake agreement between Sotheby's and Christie's to alternate which house leads the auction week, which takes place in New York City in the months of May and November of each year, is well known. For example, Sotheby's led the auction week in the fall of 1996 and spring of 1997, and then Christie's led in the fall of 1997 and spring of 1998. Hugh said there were a few switches in the sequence of when Sotheby's or Christie's went first because of changes in the make-up of the auctions, but by and large, the sequence between them has been alternating since. We confirmed Hugh's recollection in our data. We discuss this more below in the robustness subsection of Section 5. International buyers fly in from around the world to attend both auctions, which is typically done in about three days, with each house having about a day-and-a-half to complete their auction across morning, afternoon and evening sessions.

A few weeks before the auction week occurs, the auction houses send out a catalog of the items to be auctioned. The description usually comes with a low and high estimate of each painting, and it even includes the sequence in which the paintings will be auctioned. Hugh says that these catalogs are meticulously laid out and that they do intentionally put expensive items first. For our set of paintings: the masterpiece (the painting with the most expensive estimate) goes early at around lot #10 during an evening session. The fact that the masterpiece goes at around #10 and not #1 is so that people have time to get into the room for the bidding if they are running late. In general, the expensive items go early and filler paintings go at the end.[5] The

[5] This is not the case for all art auctions per se. For other genres, there are different conventions. It would be interesting to study why sequences vary across different types of art auctions.

TABLE 1 Characteristics of Paintings

	Mean	Minimum	Median	Maximum
Panel A: Evening Sessions				
Indicator that Painting was Sold	.78			
Sotheby's	.78			
Christie's	.78			
Low Estimate	1,452,719 [2,741,645]	400	600,000	40,000,000
Sotheby's	1,451,575 [2,727,779]	2000	600,000	40,000,000
Christie's	1,453,917 [2,756,458]	400	600,000	40,000,000
High Estimate	2,014,487 [3,823,986]	500	800,000	60,000,000
Sotheby's	2,008,682 [3,774,899]	3000	800,000	60,000,000
Christie's	2,020,565 [3,875,215]	500	800,000	60,000,000
Indicator for No Estimate	.014			
Sotheby's	.014			
Christie's	.013			
Sale Price	2,186,261 [5,345,686]	1550	775,750	106,000,000
Sotheby's	2,186,984 [5,406,387]	1550	772,500	104,000,000
Christie's	2,185,507 [5,282,533]	7475	792,000	106,000,000
Sale Premium	.52 [.85]	−.83	.29	23.18
Sotheby's	.53 [.96]	−.65	.29	23.18
Christie's	.51 [.72]	−.83	.29	7.47
Panel B: Morning and Afternoon Sessions				
Indicator that Painting was Sold	.76			
Sotheby's	.74			
Christie's	.78			
Low Estimate	88,033 [116,773]	200	50,000	3,000,000
Sotheby's	92,647 [125,064]	500	50,000	3,000,000
Christie's	83,156 [107,103]	200	40,000	2,500,000
High Estimate	120,616 [160,509]	300	70,000	4,000,000
Sotheby's	127,240 [171,497]	501	70,000	4,000,000
Christie's	113,613 [147,690]	300	60,000	3,500,000
Indicator for No Estimate	.001			
Sotheby's	.001			
Christie's	.001			
Sale Price	122,755 [175,127]	250	66,000	6,050,000
Sotheby's	127,295 [173,410]	1150	69,500	3,080,000
Christie's	118,242 [176,710]	250	62,500	6,050,000
Painting Sale Premium	.61 [.92]	−.90	.38	39.00
Sotheby's	.61 [.92]	−.88	.38	39.00
Christie's	.62 [.92]	−.90	.39	20.13

Notes: The entries are summary statistics of the characteristics of individual paintings offered for auction during the 52 auction weeks of the sample period. Standard deviations are in brackets. Panel A includes all paintings offered during evening sessions (7609 paintings). Panel B (below) includes all paintings offered during morning and afternoon sessions (29,292 paintings). For all characteristics, the table provides statistics for all paintings in the sessions and separately for paintings offered by Sotheby's and Christie's. *Indicator that Painting was Sold* is a dummy variable for whether the painting was successfully sold or not. *Low Estimate* is the lower price estimate provided by the by the auction house. *High Estimate* is the higher price estimate provided by the auction house. *Indicator for No Estimate* is a dummy variable for when the auction house provides no estimates. *Sale Price* is the selling price of the painting for those that are successfully purchased. *Sale Premium* is the sale price of paintings that were successfully sold minus the low estimate of that painting divided by the low estimate of the painting.

TABLE 2 Characteristics of Auction Weeks

	Mean	Minimum	Median	Maximum
Panel A: Evening Sessions				
Number of Sessions during Week	2.3 [0.6]	2	2	4
Number of Paintings during Week	146 [38]	70	144	259
Sotheby's	75 [25]	36	68	162
Christie's	71 [25]	31	65	185
Sum of Low Estimates during Week (millions)	210 [141]	35	180	675
Sotheby's	107 [69.5]	20.6	93.8	356
Christie's	103 [76.0]	11.5	86.5	339
Sale Premium	.38 [.19]	.04	.38	1.03
Sotheby's	.37 [.23]	.00	.36	1.12
Christie's	.38 [.19]	.05	.34	.88
Percentage of Paintings Sold	.77 [.09]	.53	.79	.90
Sotheby's	.77 [.11]	.49	.78	.95
Christie's	.77 [.10]	.49	.79	.93
Panel B: Morning and Afternoon Sessions				
Number of Sessions during Week	4.0 [0.7]	3	4	7
Number of Paintings during Week	563 [135]	300	574	984
Sotheby's	290 [62]	143	306	419
Christie's	274 [92]	87	264	598
Sum of Low Estimates during Week (millions)	49.5 [28.6]	11.7	43.7	150
Sotheby's	26.8 [15.3]	6.0	23.9	80.9
Christie's	22.7 [14.0]	5.6	19.9	69.2
Sale Premium	.47 [.17]	.12	.47	.84
Sotheby's	.46 [.19]	.08	.44	.97
Christie's	.49 [.17]	.13	.47	.79
Percentage of Paintings Sold	.76 [.07]	.51	.76	.91
Sotheby's	.74 [.09]	.43	.74	.92

(Continued)

TABLE 2 Continued

Panel B: Morning and Afternoon Sessions

	Mean	Minimum	Median	Maximum
Christie's	.78 [.06]	.57	.78	.92

Notes: The entries are summary statistics of the 52 auction weeks in the sample from 1985 to 2010. Standard deviations are in brackets. Panel A includes paintings offered during evening sessions. Panel B (next page) includes paintings offered during both morning and afternoon sessions. *Number of Sessions during Week* is a count of the number of sittings where paintings are auctioned for both auction houses during the week. *Number of Paintings during Week* is a count of the number of paintings offered for sale during all of the sessions for both auction houses during the week. Separate counts for both Sotheby's and Christie's sessions are also included. *Sum of Low Estimates during Week* is the sum of the low estimate of the sale price provided by the auction house for all the paintings offered during the week. Separate sums for both Sotheby's and Christie's sessions are also included. *Sale premium* is sum of sales price across paintings minus the sum of the low estimates divided by the sum of the low estimates for the auction week. *Percentage of Paintings Sold* is the percentage of paintings offered for sale that are sold during the auction week.

reasons he gave are akin to the unlocking the money effect of Benoit and Krishna (2001) as well as behavioral arguments of anchoring and generating excitement.

However, he does not think that clients in deciding between Sotheby's and Christie's care about who goes first during auction week. He has never heard in his 40-year career of a client deciding to go with one because of this. He believes that a more fundamental factor is which house has the better reputation in that style of art: in our case, it is Sotheby's. We also confirm this in our data, and it is this fact in conjunction with the noncoordination between the two houses that allows us to identify the effect of ordering on revenues.

A few other observations are worth mentioning in regards to our empirical analysis. First, Hugh said that virtually all the expensive items go into the evening auctions. We find this and focus in our empirical work on evening auctions as there is little variation in size between the two houses in the other sessions. The low estimate is the relevant benchmark when it comes to preestimated value because this is the reservation value of the auction house. The high estimate is simply a guess to make the owner happy; the focus of the auction is on the low estimate. Another issue is that the houses tend to not want to give printed estimates for the ultraexpensive items: these are only available upon request. We have to deal with this issue carefully in our analysis.

Finally, we provide some color on the auction process itself. The starting bid must be within close range of the reserve but below it. There are fixed price increase increments that depend on the price range. This speeds the total time of an auction which is important to keep people interested. If they have a left bid that is already on the books they might start the bidding there. The auctioneer wants to make the audience believe there is lots of interest in the work and so may add bids at times. They will never add bids once the work has reached its reserve. They will also use the word "with you" to let the audience know that there is a bidder in the room or on the phone that actually made the last bid. Even if they say "with you" it does not mean that the last price was above the reserve. If the bidding does not reach the reserve, the auctioneer will not say the word "sold" and the audience knows that the work did not sell. There can be postauction negotiations between the seller and high bidder but it is totally private and the price is not listed in the postsale price sheet.

4. Data

■ The data consists of the results of Impressionist and Modern painting auctions at Sotheby's and Christie's over a 26-year period (1985 – 2010). There are two auction periods each year (spring and fall) for a total of 52 auction periods; in our sample, exactly 26 auction weeks are started by Sotheby's and exactly 26 are started by Christie's.

In Table 1, we describe the characteristics of the paintings offered in the evening compared to the morning and afternoon sessions. We begin with the evening sessions in Panel A. During these sessions, 78% of the paintings auctioned off are sold. This percentage is identical for Sotheby's and Christie's paintings. Using the low estimate, the average preestimated value of a painting in the evening session is about \$1.45 million with a standard deviation of \$2.74 million. This measure is almost identical for the sample of Sotheby's versus Christie's paintings. Using the high estimate, the average painting is valued at \$2.01 million with a standard deviation of \$3.82 million.

Around 1.4% of the paintings in the evening sessions have no estimate. The houses do not give estimates in their catalogs for some of the most expensive paintings. We will have to be careful in treating these paintings in our analysis below. This percentage is similar for Sotheby's and Christie's. We then report the sale price, which is on average \$2.19 million with a standard deviation of \$5.35 million.

Finally, we report the summary statistics for *Sale Premium*: the sale price of the painting minus the low estimate divided by the low estimate. This will be one of our outcomes of interest in the empirical analysis. The mean is 0.52 with a standard deviation of 0.85. The maximum is 23.18, the median is 0.29 and the minimum is –0.83. There is substantial variation in terms of where the sale price goes off relative to prior estimate. We break down this figure by houses. For Sotheby's, the mean is 0.53 with a standard deviation of 0.96. For Christie's, the mean is 0.51 with a standard deviation of 0.72. So the two houses have fairly similar distributions in terms of sale price to low estimate.

In Panel B, we report the results for the morning and afternoon sessions. We quickly summarize the main points here for brevity. The morning and afternoon sessions offer paintings that are only a fraction of the value of the evening sessions. This can be seen in not only the estimates but also in the indicator for no estimate. Also, there is little difference in terms of the quality of the paintings offered between Sotheby's and Christie's. Otherwise, the qualitative patterns are quite similar to the evening sessions.

Table 2 presents some basic summary statistics about auction weeks. Again, we stratify this analysis by evening (Panel A) versus morning and afternoon sessions (Panel B). As we discussed above, all the valuable paintings go into the evening sessions; it is in the evening sessions that we see sizeable differences in terms of the value of the paintings offered by Sotheby's and Christie's. In Panel A, we see that the average number of evening sessions offered in an auction week is 2.3 with a standard deviation of 0.6. The maximum number is four evening sessions during auction week: this corresponds to each house offering two evening sessions during a busy auction week. The minimum and median is two as expected. During these evening sessions, about 146 paintings are offered with a standard deviation of 38. We then break down this figure by auction houses. Sotheby's offers about 75 paintings (on average) during an auction week with a standard deviation of 25. Christie's offers a comparable number: 71 paintings on average during auction week with a standard deviation of 25.

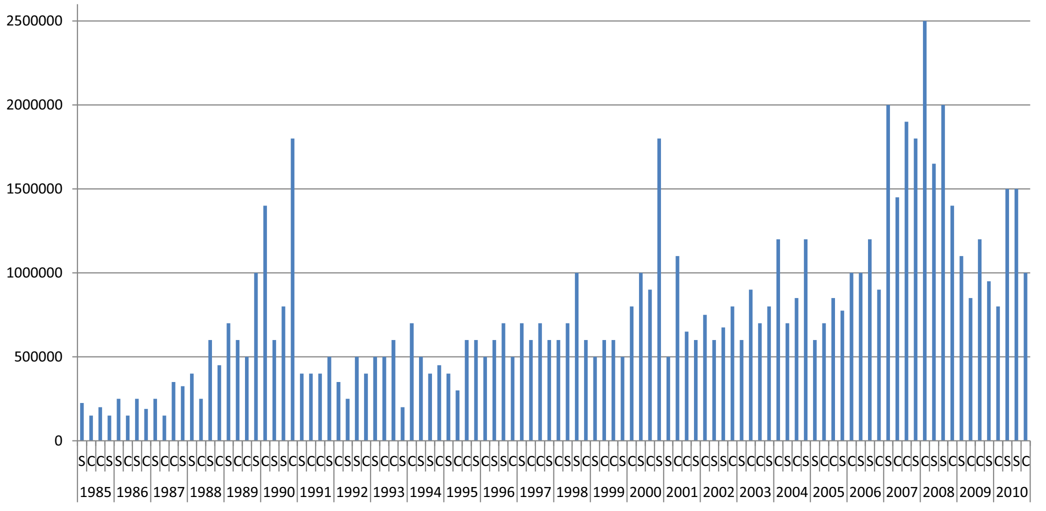
Using the low estimates for the painting (where available), we calculate the overall size of the auctions for these two houses. The average of the sum across of the value of the paintings offered by these two houses during the week is \$210 million with a standard deviation of \$141 million. On average, the total value of Sotheby's evening auctions during a week is estimated at \$107 million with a standard deviation of \$69.5 million. For Christie's, the mean is \$103 million with a standard deviation of \$76.0 million. Sotheby's has slightly more valuable paintings on average. There is also a sizeable standard deviation around these means; this suggests that there can be substantial variation in the sizes of the auctions offered by these two houses during a week. It is this difference and the alternation of who goes first during auction week that we exploit in our natural experiment.

We report the summary statistics of the *Sale Premium* for the evening sessions of the auction week, which is the sum of sales price across paintings divided by the sum of the low estimates (or equivalently, the weighted average of the sale premium by painting weighted by the low estimate of the painting). This *Sale Premium* has a mean of 0.38 with a standard deviation of 0.19. Finally,

FIGURE 1

CHARACTERISTICS OF AUCTION WEEK TILT BY AUCTION WEEK: MEDIAN LOW ESTIMATE

Notes: The entries are measures of the size of auction used to calculate *Auction Week Tilt* listed for each auction week in the sample. Within each auction week, the first listing is for the auction house that leads the auction week and the second listing is for the auction that follows. The first two columns of the year are the values for the spring auction week; the final two columns of the year are the values for the fall week. S denotes a Sotheby's auction; C denotes a Christie's auction. This figure shows the median value of the low estimate of the paintings offered by the auction house that week.



we report statistics for the *Percentage of Paintings Sold* in an auction week; the mean is 0.77 and the standard deviation is 0.09.

In Panel B of Table 2, we then report similar statistics for the morning and afternoon sessions grouped together. The total value of these auction sessions is substantially smaller than the evening sessions. There is less scope for there to be large differences in the value of the first part of the auction week compared to the second. Therefore, we expect our natural experiment to be less powerful using these sessions as it relies on important economic differences in the size of the overall auctions offered by these two houses.

5. Results

□ **Characteristics of Auction Week Tilt and the Properties of Instrument.** In this section, we discuss the properties of our principal independent variable of interest. Our basic idea is to measure how the size of the first versus the second part of the auction week affects the overall auction performance (*Sale Premium* and *Percentage of Paintings Sold*) of the paintings in the auction week. First, we need a measure of the size of paintings in the first versus the second part of the auction week. We use the following measure:

$$Auction\ Week\ Tilt = \frac{Median\ Low\ Estimate\ of\ \ Paintings\ in\ First\ Part\ of\ Week}{Sum\ of\ \ Median\ Low\ Estimate\ of\ Paintings\ In\ First\ and\ Second\ Part\ of\ Week} \quad (1)$$

We take the median of the low estimate of paintings from the house that goes first divided by the sum of the median low estimate of paintings of the house that went the first part of the week and that of the house that went during the second part of the week. So the *Auction Week Tilt* is between 0 between 1 and increases toward 1 when the house with the more valuable paintings goes first. We also use several other measures of auction size also, including means of the low estimates and different other percentiles other than the median (say the 90th percentile). We report in Figures 1 through 3 the value of the paintings for Sotheby's and Christie's broken down by

FIGURE 2

CHARACTERISTICS OF AUCTION WEEK TILT BY AUCTION WEEK: MEAN LOW ESTIMATE

Notes: The entries are measures of the size of auction used to calculate *Auction Week Tilt* listed for each auction week in the sample. Within each auction week, the first listing is for the auction house that leads the auction week and the second listing is for the auction that follows. The first two columns of the year are the values for the spring auction week; the final two columns of the year are the values for the fall week. S denotes a Sotheby's auction; C denotes a Christie's auction. This figure shows the mean value of the low estimate of the paintings offered by the auction house that week.

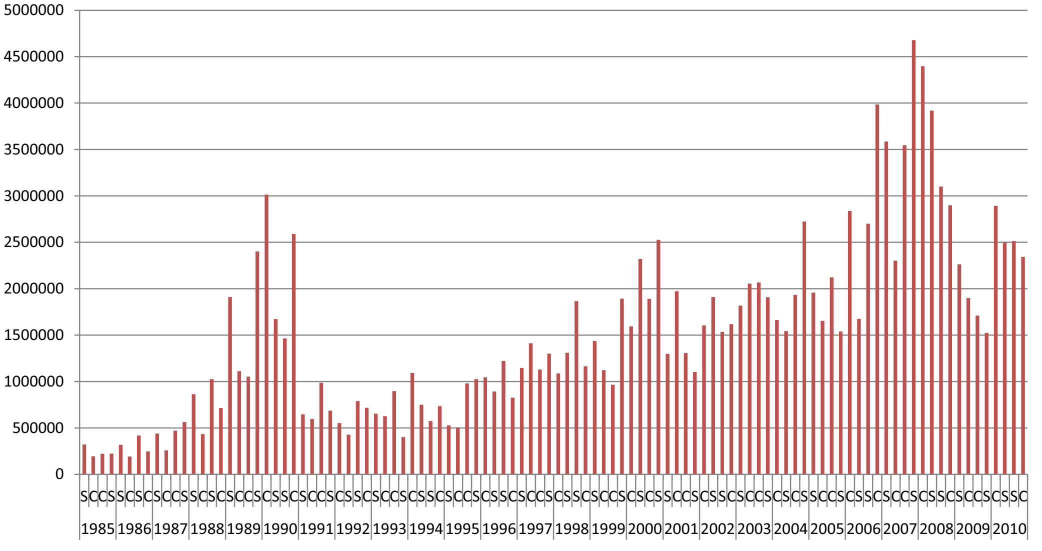


FIGURE 3

CHARACTERISTICS OF AUCTION WEEK TILT BY AUCTION WEEK: 90TH PERCENTILE LOW ESTIMATE

Notes: The entries are measures of the size of auction used to calculate *Auction Week Tilt* listed for each auction week in the sample. Within each auction week, the first listing is for the auction house that leads the auction week and the second listing is for the auction that follows. The first two columns of the year are the values for the spring auction week; the final two columns of the year are the values for the fall week. S denotes a Sotheby's auction; C denotes a Christie's auction. This figure shows the 90th percentile value of the low estimate of the paintings offered by the auction house that week.

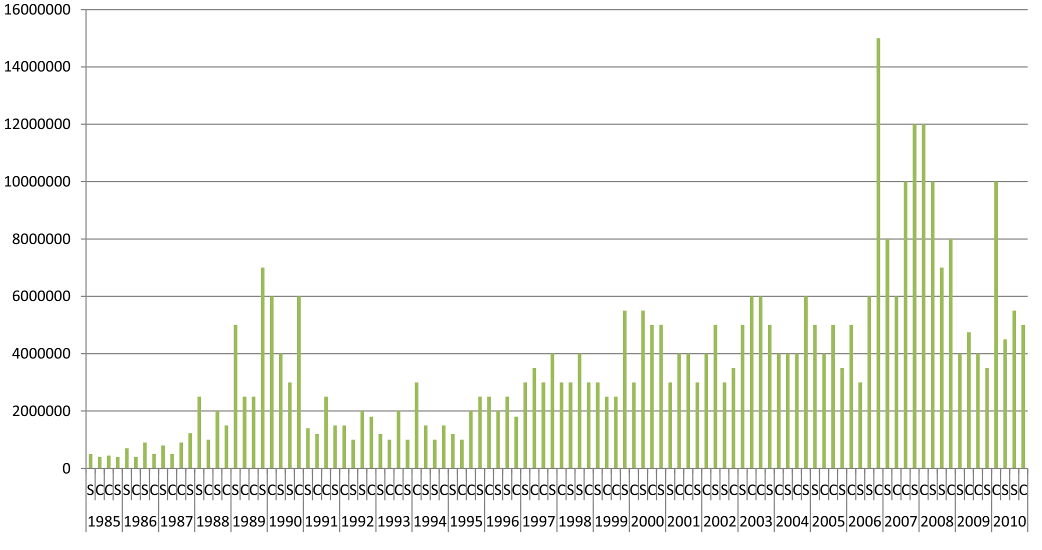


TABLE 3 Characteristics of the Auction Week Tilt

	Mean	Minimum	Median	Maximum
Median Measure	.52 [.09]	.31	.54	.75
Mean Measure	.52 [.09]	.30	.52	.69
90th Percentile Measure	.52 [.10]	.26	.54	.71

Notes: The entries are measures of the characteristics of *Auction Week Tilt* for the 52 auction weeks in the sample. Standard deviations are in brackets. Only paintings in evening sessions are included. The measures are summary statistics of the ratios of the size of the offerings of the first auction house of the auction week over the size of the offerings of both auction houses. The first ratio uses the median low estimate of the paintings offered by the first auction house divided by the median low estimate of the paintings offered by the second house. The second ratio uses the mean low estimate instead of the median, and the final ratio uses the 90th percentile of the low estimate.

auction week and by the median, mean and 90th percentile of the value of the paintings in the two houses to show what drives the variation in *Auction Week Tilt*. One can see that when one house has a higher median value of paintings in a given week than the other, the mean and 90th percentiles are also higher, consistent with the premise of our identification strategy.

We report the statistics regarding the distribution of *Auction Week Tilt* in Table 3. We focus on the evening sessions and the statistics here come from just these sessions. First, the mean of the median *Auction Week Tilt* measure is 0.52. So the auction in the first part of the week tends to be slightly larger than the second, but this difference is small and statistically insignificant. In any event, this difference is not important for our experiment. The more important thing to notice that there is substantial variation in the *Auction Week Tilt* across auction weeks, which is what allows us to conduct our natural experiment. The standard deviation is 0.09 and the difference from minimum to maximum is 0.44 (the maximum is 0.75, and minimum is 0.31). When we use the mean of the low estimates to calculate our *Auction Week Tilt* in the second row of Table 3, we find a similar outcome as when we use the median of the low estimates. This is also the case when we use the 90th percentile of the low estimates in row 3. The correlation between these three measures is quite high: 0.94 for the mean and 90th percentile, 0.54 for the median and the 90th percentile and 0.68 for the mean and median. We will run our analysis using all three of these measures but focus on the median as the benchmark case.

It is not clear whether we want to use the extent that the first part of the auction week is bigger or smaller than the second part. We might just want to use whether the first part is large compared to the second. So we also use the following alternative measure:

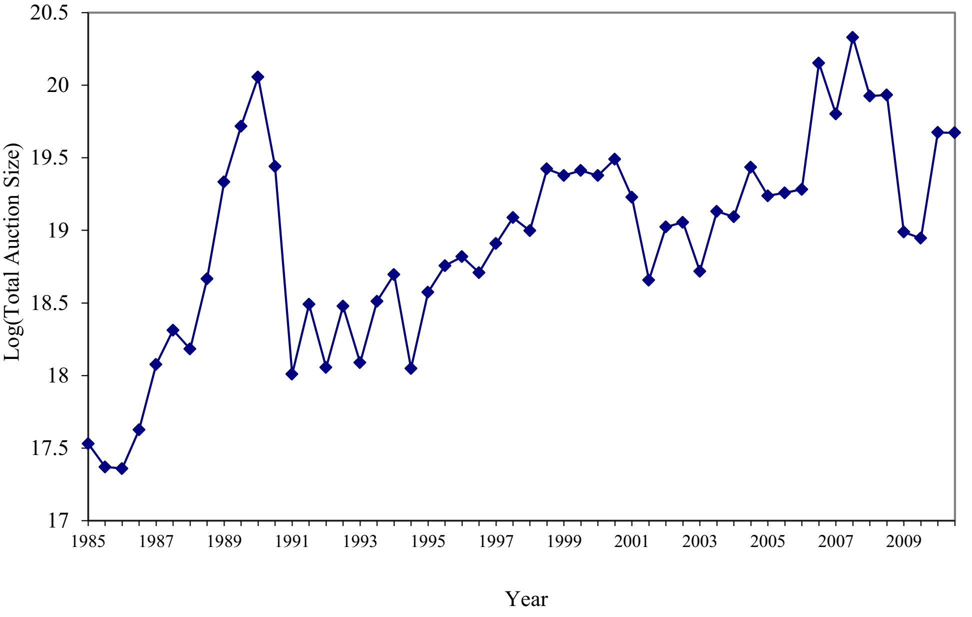
$$\textit{Indicator that Auction Week Tilt} > \textit{Average} = \begin{cases} 0, \textit{AuctionWeekTilt} < \textit{Average} \\ 1, \textit{AuctionWeekTilt} \geq \textit{Average} \end{cases} \tag{2}$$

This dummy variable equals one when the first part of the auction is greater than the sample average and zero otherwise.

We want to see how the *Auction Week Tilt* is related to the overall performance of the auction (measured in terms of the *Sale Premium* and also the *Percentage of Paintings Sold*). But as we discussed in the Introduction, we want to first convince ourselves that this measure is not correlated with other things that might explain auction performance. We are particularly worried that *Auction Week Tilt* might be related to the total size of the auction. One plausible concern is that there are time trends in total auction size and *Sale Premium*. During periods of art booms, the total auction size and *Sale Premium* are naturally higher because of enthusiasm for art, which engenders higher demand and supply. If our *Auction Week Tilt* happens to be correlated with total auction size for some reason, then we might obtain a spurious correlation between it and *Sale Premium*. Another potential concern is that there is a positive correlation between errors in appraisals (which affect *Sale Premium*) and total auction week size, which again might be correlated with ordering.

FIGURE 4

TOTAL AUCTION SIZE



To see whether we need to worry about time trends, we plot in Figures 4 through 7 *Log(Total Auction Size)* by week, the average *Sale Premium* by week, our *Auction Week Tilt* measure, and the percentage of paintings sold by week, respectively. Figure 4 shows a substantial time trend in the *Log(Total Auction Size)*. First, there is a secular trend in that total auction size has gone up over time. Second, there are periods of booms and busts: there is a big peak in the late 1980s, a period well known for high art valuations and a subsequent crash in the 1990s following the recession of the early 1990s. Similarly, there is a boom in the late 1990s coinciding with the rise of the Internet followed by a crash with the end of the Internet boom. Finally, there is a big crash at the end of the sample corresponding to the recent financial crisis.

In Figure 5, there are similar trends in the *Sale Premium*, with higher premia during the late 1980s and late 1990s and lower premium during the crashes following in 1992, 2001, and 2008. In Figure 6, we plot our *Auction Week Tilt* over time. There are less apparent time trends in our *Auction Week Tilt* than in our previous two variables, but to be careful we will include throughout our analysis controls for time trends (year effects). In Figure 7, we see that there are no apparent time trends in the *Percentage of Paintings Sold*.

To examine more closely the correlations of *Auction Week Tilt* and other characteristics that might influence the outcome of an auction, in Table 4, we regress our *Auction Week Tilt* on an *Indicator for Sotheby Leading the Auction* and *Log(Total Auction Size)* along with year effects. We include the indicator for Sotheby's leading as a way to see if our results are different from a specific auction house effect. Notice that after conditioning on year effects, there is no statistically significant correlation between *Auction Week Tilt* and these other two variables. Even though the coefficients for these variables are small, the standard errors are large because of the small number of observations. Therefore, the results of Table 4 are suggestive that *Auction Week Tilt* is not substantially correlated with other auction characteristics, but they are not definitive given this power issue.

In Table 5, we examine whether the distribution of *Auction Week Tilt* is symmetric around 0.5. We are concerned that its conditional mean is asymmetric around 0.5 (say 0.8 when it is

FIGURE 5

SALE PREMIUM

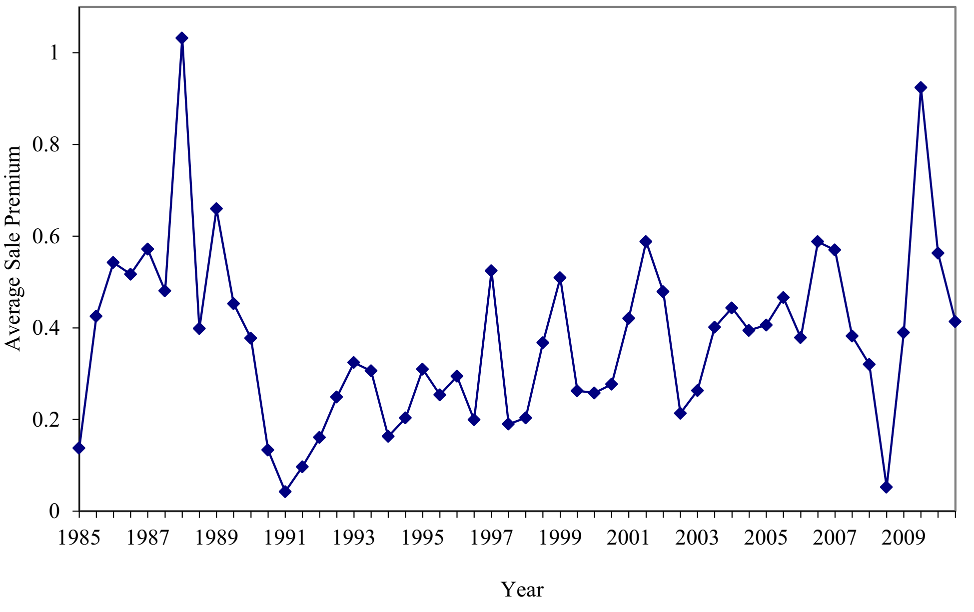
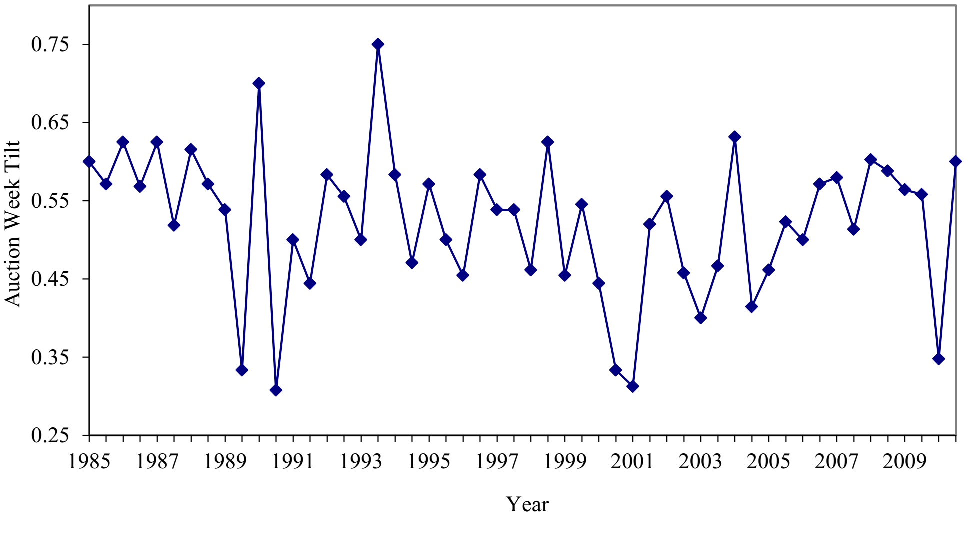


FIGURE 6

AUCTION WEEK TILT



above 0.5 and say .46 if it is below 0.5). We might worry than that only one side of the *Auction Week Tilt* is driving our results, which might be consistent with the theory but certainly may give us pause. We report the average *Auction Week Tilt* conditioned on it being greater than 0.5 and it being less than 0.5. When the *Auction Week Tilt* is greater than 0.5, the average auction size is 0.58 and when it is less than 0.5, then its average value is 0.41. Its distribution looks relatively symmetric around 0.5.

FIGURE 7

PERCENTAGE OF PAINTINGS SOLD

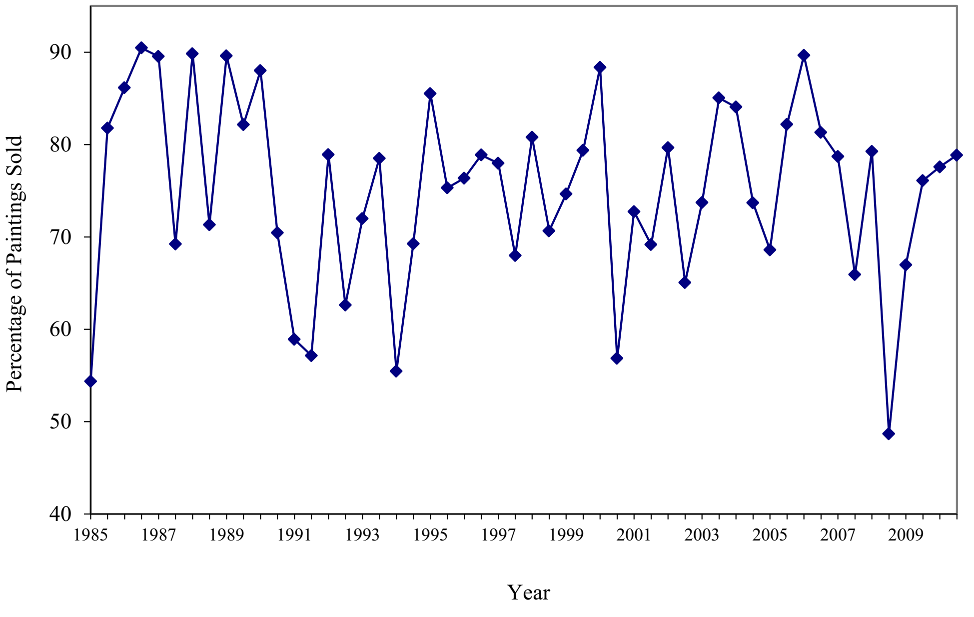


TABLE 4 The Relationship Between Auction Week Tilt and Other Auction Characteristics

	(1)	(2)	(3)
Indicator for Sotheby Leading Auction	−.008		−.005
	(.032)		(.031)
Log(Total Auction Size)		.036	.034
		(.087)	(.085)
Year Effects?	Yes	Yes	Yes
Observations	52	52	52
R^2	.40	.40	.40

Notes: The entries are coefficients of OLS regressions. Robust standard errors are in parentheses. The unit of observation is the auction week. Only paintings in evening sessions are included. The dependent variable is *Auction Week Tilt*: the median low estimate of the paintings offered by the first auction house divided by the sum of the median low estimates of the paintings offered by the two houses. The first of the two independent variables of interest is *Indicator for Sotheby Leading Auction*, which is a dummy that indicates that Sotheby's was the house that led the auction week. *Log(Total Auction Size)* log of the sum of the low estimates of entire auction week.

TABLE 5 Decomposing the Auction Week Tilt

	Auction Week Tilt > .5	Auction Week Tilt < .5
Average Auction Week Tilt	.58	.41
Log(Average Low Estimate of First Part of Auction)	13.51	13.22
Log(Average Low Estimate of Second Part of Auction)	13.16	13.55

Notes: The entries are predictions of an OLS regression of the variable of interest on an indicator that Auction Week Tilt > .5 and year effects. The prediction in the first column is the value when the indicator is on; the second column shows the value when the indicator is off. The variable of interest in the first row is the *Auction Week Tilt*. The second row is for the log of the average low estimate of the first part of an auction week. The third row is identical, but the value is for the second part of the auction week.

We also report the log of the average low estimate of the first part and the second part of the auction conditioned on the *Auction Week Tilt* being greater than 0.5 and on it being less than 0.5. The worry here is that somehow the quality of the auctions is different depending on the realization of the *Auction Week Tilt*. Again, the estimates look relatively symmetric. We feel relatively comfortable that our *Auction Week Tilt* is well behaved and move on to see how it influences overall auction outcomes.

□ **Ordering and Revenue, Estimation from Natural Experiment.** Our auction performance measures are the same as our painting performance measures except that they are aggregated up to the auction week. So, we calculate the price received on all the sold paintings relative to the low estimates of the paintings (this is the auction week *Sale Premium* of Table 2). And, we calculate the *Percentage of Paintings Sold* (also from Table 2) during the auction week. We estimate the regression model:

$$\textit{Auction Week Outcome} = \alpha + \beta_1 \textit{Auction Week Tilt} + \beta_2 \textit{Auction Week Controls} + \varepsilon \qquad (3)$$

There are three sets of controls as we discussed earlier. The first is an *Indicator for Sotheby Leading the Auction*. One might be worried that *Auction Week Tilt* might be a proxy for which auction house goes first. The relationship between *Auction Week Tilt* and the auction week outcome might be picking up this ordering effect instead of the effect we are interested in. Therefore, we control for the auction house order. Second, we also control for the *Log(Total Auction Size)*. And third, we include year effects in the specification. Because there are two auction weeks per year, we can identify the coefficients even with these relatively nonparametric controls for time trends.

The results using *Sale Premium* as the auction outcome are presented in Panel A of Table 6. Column (1) shows that there is a positive association between the *Auction Week Tilt* and the auction week outcome. The coefficient on *Auction Week Tilt* is 0.427 and precisely estimated ($t =$ 2.1). The size of the coefficient suggests that a one standard deviation increase in *Auction Week Tilt* (0.09 from Table 3) increases the price relative to low estimate of the auction week by 0.427 $\times$ 0.09 = 0.038. There are a couple of ways to interpret the economic significance of this point estimate. Note that the unconditional mean of Sale Premium is 0.38 with a standard deviation of 0.19. So a one standard deviation increase of *Auction Week Tilt* increases *Sale Premium* of the auction week by about 9% of the unconditional mean and by about 20% of the standard deviation of *Sale Premium*. Notice that the coefficients on our control variables, Indicator for *Sotheby Leading Auction* and *Log (Total Auction Size)*, are small and relatively imprecisely measured.

Column (2) is similar to column (1), except the *Indicator that Auction Week Tilt > Average* is included in the specification instead of the *Auction Week Tilt*. The coefficient on this dummy is positive (0.081) and marginally statistically significant from zero (*t*-statistic of 1.76). The coefficient indicates that having the first part of the auction larger than average relative to the second part increases the auction week *Sale Premium* by about 0.081 or about 21% of the unconditional mean and 43% of the standard deviation of *Sale Premium*.

Panel B of Table 6 shows the results using *Percentage of Paintings Sold* as the auction week outcome. In column (1), the coefficient on *Auction Week Tilt* is positive (0.390) and statistically different from zero (*t*-statistic is 2.6). A one standard deviation increase in *Auction Week Tilt* increases the *Percentage of Paintings Sold* by about 0.390 $\times$ .09 = 0.035 or about 3.5 percentage points. This is a sizeable economic effect given that the mean percentage of paintings sold is 0.77 with a standard deviation of 0.09. A one standard deviation increase in *Auction Week Tilt* increases the percentage of paintings sold by about 4.5% relative to the unconditional mean and by about 39% of the standard deviation of our left-hand-side variable.

Using the *Indicator that Auction Week Tilt > Average* instead of the *Auction Week Tilt* yields similar results. The coefficient in front of the indicator is 0.082 with a *t*-statistic of 3.9. So having a large first part of the auction relative to the second yields an increase in the percentage of paintings sold by about 11% of the unconditional mean of percentage of paintings sold and about 90% of the standard deviation of percentage of paintings sold.

TABLE 6 The Effect of Auction Week Tilt on Auction Week Outcomes

	(1)	(2)
Panel A: Dependent Variable—Sale Premium		
Auction Week Tilt	.427	
	(.202)	
Indicator of Auction Week Tilt > Average		.081
		(.046)
Indicator for Sotheby Leading Auction	−.033	−.045
	(.051)	(.051)
Log(Total Auction Size)	−.103	−.119
	(.127)	(.126)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.67	.67
Panel B: Dependent Variable— Percentage of Paintings Sold		
Auction Week Tilt	.390	
	(.151)	
Indicator of Auction Week Tilt > Average		.082
		(.021)
Indicator for Sotheby Leading Auction	−.049	−.060
	(.028)	(.026)
Log(Total Auction Size)	−.156	−.173
	(.067)	(.059)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.65	.66

Notes: The entries are coefficients of OLS regressions. Robust standard errors are in parentheses. The unit of observation is the auction week. Only paintings in evening sessions are included. There are two dependent variables. In Panel A, the dependent variable is the *Sale Premium* for the paintings sold during the week. In Panel B, the dependent variable is *Percentage of Paintings Sold* during the week. The first of the two independent variables of interest is the *Auction Week Tilt*, which is the median low estimate of the paintings offered by the first auction house divided by the sum of the median low estimates of the paintings offered by the two houses. The second independent variable of interest, *Indicator of Auction Week Tilt > Average*, is a dummy variable for if *Auction Week Tilt* is greater than the sample average. Other controls include *Indicator for Sotheby Leading Auction*, which is a dummy that indicates that Sotheby's was the house that led the auction week. *Log(Total Auction Size)* is the log of the sum of the low estimates of entire auction week.

□ **Robustness Checks.** In Tables 7 through 13, we perform a number of robustness checks to our baseline results in Table 6. In Table 7, we examine the sensitivity of the main result to different assumptions about paintings that have no estimates. In our main analysis, we do not include those paintings in the calculations. Given that they seem likely to be relatively expensive paintings, this might be a problem. To see how sensitive our results are to this issue, we assume that missing paintings have estimates that are equal to the 99th percentile of estimates of paintings that week. Table 7 compares the results using this assumption to our standard result. As can be seen, we get very similar results when we make this alternative assumption about missing estimates.

In Table 8, we examine the assumptions we use to calculate the *Auction Week Tilt*. In our main results, we compare the low estimate of the median painting in the two parts of the auction. To see how sensitive our results are to this specification, we do two other things. First, we use the mean low estimate instead of the median. Then, we use the 90th percentile instead of the median. One gets similar results when using these alternative measures. For Panel A, which uses *Sale Premium* as the dependent variable, the results tend to be somewhat larger compared to our baseline results. In Panel B where the dependent variable is the *Percentage of Paintings Sold*, the results are somewhat smaller than the baseline. But overall, our results (especially using our revenue measure) do not seem to be driven by our choice of how to specify *Auction Week Tilt*.

TABLE 7 Different Assumptions about Missing Estimates

	(1)	(2)
Panel A: Dependent Variable—Sale Premium		
Auction Week Tilt	.426	
	(.199)	
Indicator of Auction Week Tilt > Average		.099
		(.050)
Indicator for Sotheby Leading Auction	−.037	−.048
	(.051)	(.050)
Log(Total Auction Size)	−.109	−.098
	(.116)	(.092)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.68	.68
Panel B: Dependent Variable— Percentage of Paintings Sold		
Auction Week Tilt	.392	
	(.163)	
Indicator of Auction Week Tilt > Average		.085
		(.024)
Indicator for Sotheby Leading Auction	−.042	−.052
	(.025)	(.023)
Log(Total Auction Size)	−.186	−.217
	(.055)	(.053)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.71	.72

Notes: For these calculations, paintings with missing low estimates are assumed to have a low estimate equal to the 99th percentile of the distribution of low estimates that auction week. The entries are coefficients of OLS regressions. Robust standard errors are in parentheses. The unit of observation is the auction week. Only paintings in evening sessions are included. There are two dependent variables. In Panel A, the dependent variable is the *Sale Premium* for the paintings sold during the week. In Panel B, the dependent variable is *Percentage of Paintings Sold* during the week. The first of the two independent variables of interest is the *Auction Week Tilt*, which is the median low estimate of the paintings offered by the first auction house divided by the sum of the median low estimates of the paintings offered by the two houses. The second independent variable of interest, *Indicator of Auction Week Tilt > Average*, is a dummy variable for if *Auction Week Tilt* is greater than the sample average. Other controls include *Indicator for Sotheby Leading Auction*, which is a dummy that indicates that Sotheby's was the house that led the auction week. *Log(Total Auction Size)* is the log of the sum of the low estimates of entire auction week.

In Table 9, we replicate the baseline results of Table 6 for the morning and afternoon sessions grouped together. The results for *Sale Premium* are quite similar qualitatively to those obtained from the evening sessions. However, the estimates for *Percentage of Paintings Sold* are actually going the wrong way but the estimates are small and not statistically different than zero. Given our discussion above about the differences between evening sessions and the morning and afternoon sessions, it is not that surprising that the results for the morning and afternoon sessions are somewhat weaker.

We observe that the rotation pattern between Sotheby's and Christies' broke down a few times (once in the early period and once in the middle period). We asked auction insiders if they remembered why, and there was no recollection of any significant reasons. In Table 10, we show the estimates of our main specification of Table 6 when we drop the observations from the years the rotation breaks down to make sure our results are robust. The coefficients are almost identical to our main results, suggesting that they are not being driven by the anomalous periods. In Table 11, we examine if these few years when the rotation breaks down were accompanied by any observable differences in the auction weeks like aggregate value of estimates. The auction weeks during those years tend to be somewhat smaller than the rest of the sample, but again these years do not produce different results than the rest of the sample.

TABLE 8 Different Assumptions about Calculating Auction Week Tilt

	Mean Painting	90th Percentile
Panel A: Dependent Variable—Sale Premium		
Auction Week Tilt	.427	.542
	(.202)	(.236)
Indicator for Sotheby Leading Auction	−.033	−.019
	(.051)	(.049)
Log(Total Auction Size)	−.103	−.040
	(.127)	(.142)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.67	.69
Panel B: Dependent Variable— Percentage of Paintings Sold		
Auction Week Tilt	.390	.136
	(.151)	(.166)
Indicator for Sotheby Leading Auction	−.049	−.046
	(.028)	(.028)
Log(Total Auction Size)	−.156	−.131
	(.067)	(.071)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.65	.58

Notes: The entries are coefficients of OLS regressions. Robust standard errors are in parentheses. The unit of observation is the auction week. Only paintings in evening sessions are included. There are two dependent variables. In Panel A, the dependent variable is the *Sale Premium* for the paintings sold during the week. In Panel B, the dependent variable is *Percentage of Paintings Sold* during the week. In the first column, the *Auction Week Tilt* uses the mean painting instead of the median painting. In the second column, the *Auction Week Tilt* uses the 90th percentile of the distribution of low estimates.

In Table 12, we now have as our left-hand-side variable total revenue as opposed to revenue relative to estimate to check the robustness of our results and the significance is similar. We next address the cartel between Sotheby's and Christie's that lasted from 1995 until 1999 during which the two parties agreed on, among other things, raising prices by fixing sellers' commissions (see Department of Justice, 2000). One might worry that the cartel years could influence our results. So we drop the cartel years to check the robustness of our analysis. This is in Table 13. The results are very similar to not dropping the cartel years. In sum, we believe the results shown in Tables 7 through 13 indicate that a declining order by value of sale in sequential auctions substantially increases revenues.

We have also reestimated out baseline results without painting quality controls based on estimated values. In other words, we simply regress the average sale price of an auction week on our ordering variable without the total auction size controls and the deflation of price by low estimate. The point estimates are similar except that they are estimated less precisely because these quality or estimate controls help soak up a lot of the variation in price or revenues. As such, we are comfortable that our results are not driven by our painting quality controls. Finally, we have introduced auctioneer fixed effects and find that the results are similar. In Sotheby's, the auctioneer has been John Marion from the late 1960s to 1997 and then from 1997 onwards Tobias Meyer. For Christie's, there has been only one person since 1986 who is Christopher Burge.

□ **Distinguishing between Various Mechanisms.** Our main contribution up to this point has been to develop an estimate of the causal impact of ordering on auction revenues using this quasi-experiment from art auctions. In this section, we attempt to distinguish between competing explanations for why ordering matters. Our analysis revolves around the question of where the

TABLE 9 The Effect of Auction Week Tilt on Outcomes Using Morning and Afternoon Sessions

	(1)	(2)
Panel A: Dependent Variable—Sale Premium		
Auction Week Tilt	.227	
	(.142)	
Indicator of Auction Week Tilt > Average		.052
		(.029)
Indicator for Sotheby Leading Auction	−.063	−.070
	(.031)	(.030)
Log(Total Auction Size)	−.100	−.112
	(.059)	(.057)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.85	.86
Panel B: Dependent Variable— Percentage of Paintings Sold		
Auction Week Tilt	−.087	
	(.096)	
Indicator of Auction Week Tilt > Average		−.004
		(.020)
Indicator for Sotheby Leading Auction	−.010	−.009
	(.022)	(.023)
Log(Total Auction Size)	−.032	−.034
	(.033)	(.036)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.69	.68

Notes: The entries are coefficients of OLS regressions. Robust standard errors are in parentheses. The unit of observation is the auction week. Only paintings in morning and afternoon sessions are included. There are two dependent variables. In Panel A, the dependent variable is the *Sale Premium* for the paintings sold during the week. In Panel B, the dependent variable is *Percentage of Paintings Sold* during the week. The first of the two independent variables of interest is the *Auction Week Tilt*, which is the median low estimate of the paintings offered by the first auction house divided by the sum of the median low estimates of the paintings offered by the two houses. The second independent variable of interest, *Indicator of Auction Week Tilt > Average*, is a dummy variable for if *Auction Week Tilt* is greater than one half. Other controls include *Indicator for Sotheby Leading Auction*, which is a dummy that indicates that Sotheby's was the house that led the auction week. *Log(Total Auction Size)* is the log of the sum of the low estimates of entire auction week.

higher revenues or better sell rate outcomes are coming from during the weeks when the house with the more expensive painting goes first: the first house or the second house. This question is potentially informative about the nature of how ordering matters for revenues in auctions.

In rational mechanisms such as a weak bidder story, the strongest bidders who value the items the most and generate the highest sale premiums win the early items. To maximize revenues, it is better to place the most expensive items first and have them benefit from a high sale premium as opposed to less expensive items. This mechanism suggests that items auctioned in the first part of the week benefit most when expensive items come first. For instance, say the expensive items have the most dispersed valuations.[6] Having them first means that one sees the largest valuations for these big items. So comparing to a week where less expensive paintings come first, we should see big differences in the first part but less differences in the second part because the strong bidders have already been winnowed out and as such there is less dispersion in valuations later in the week.

In contrast, the anchoring effect mechanism predicts that the items which come after expensive items benefit the most because expensive items anchor later bidders at higher valuations

[6] Another related mechanism is Pitchik and Schotter (1988) who find in an experimental study of strategic behavior that bidders strategically overbid on early items to force strong bidders from bidding again on later items due to budget constraints.

TABLE 10 The Effect of Auction Week Tilt on Auction Week Outcome Drop Years Where Rotation Varies

	(1)	(2)
Panel A: Dependent Variable—Sale Premium		
Auction Week Tilt	.394	
	(.215)	
Indicator of Auction Week Tilt > Average		.077
		(.050)
Indicator for Sotheby Leading Auction	−.028	−.038
	(.049)	(.051)
Log(Total Auction Size)	−.030	−.041
	(.098)	(.098)
Year Effects?	Yes	Yes
Observations	44	44
R^2	.67	.67
Panel B: Dependent Variable— Percentage of Paintings Sold		
Auction Week Tilt	.343	
	(.169)	
Indicator of Auction Week Tilt > Average		.083
		(.023)
Indicator for Sotheby Leading Auction	−.048	−.059
	(.028)	(.026)
Log(Total Auction Size)	−.142	−.160
	(.075)	(.063)
Year Effects?	Yes	Yes
Observations	44	44
R^2	.65	.70

Notes: The entries are coefficients of OLS regressions. Robust standard errors are in parentheses. The unit of observation is the auction week. Observations from 1986, 1988, 2000 and 2004 are not included. Only paintings in evening sessions are included. There are two dependent variables. In Panel A, the dependent variable is the *Sale Premium* for the paintings sold during the week. In Panel B, the dependent variable is *Percentage of Paintings Sold* during the week. The first of the two independent variables of interest is the *Auction Week Tilt*, which is the median low estimate of the paintings offered by the first auction house divided by the sum of the median low estimates of the paintings offered by the two houses. The second independent variable of interest, *Indicator of Auction Week Tilt > Average*, is a dummy variable for if *Auction Week Tilt* is greater than the sample average. Other controls include *Indicator for Sotheby Leading Auction*, which is a dummy that indicates that Sotheby's was the house that led the auction week. *Log(Total Auction Size)* is the log of the sum of the low estimates of entire auction week.

and thereby raising the bids on later items. In other words, it is the second part of the week that benefits potentially from anchoring causing later items have much higher valuations.

To answer the question of which part of the auction week benefits from valuable paintings being auctioned first, we re-run the baseline specifications of Table 6 using as dependent variables the auction outcome of both halves of the auction week (instead of the sum of the two halves). We show in Table 14 the summary statistics for the first and second halves of the auction week. There is very little difference in the average characteristics of these two parts of the auction week.

In Table 15, the dependent variable is the sale premium. In Panel A, the dependent variable is the sale premium in the second part of the week (or the sale premium of the house that goes second). The independent variable of interest is *Auction Week Tilt* in column (1) and the *Indicator of Auction Week Tilt > Average* in column (2). The set-up is the same in Panel B except that the dependent variable is the sale premium in the first part of the auction week.

We find that outcomes are better in both cases: in other words, the week when the expensive house goes first sees revenue improvements throughout the entire week. The coefficient of interest in column (1) of Panel A is .585 and the coefficient of interest in column (1) of Panel B is .012. However, the improvement in outcomes is especially pronounced for the second part of the week. The coefficient of interest in Panel A of .585 is much larger than that of .012 in Panel B. Most of

TABLE 11 Characteristics of Auction Weeks—Rotation and Nonrotation Years

	Rotation Years	Non-Rotation Years
Number of Sessions during Week	2.3	2.3
	[0.6]	[0.5]
Number of Paintings during Week	149	133
	[41]	[8]
Sotheby's	76	67
	[26]	[12]
Christie's	73	66
	[26]	[15]
Sum of Low Estimates during Week (millions)	218	164
	[146]	[108]
Sotheby's	110	93
	[72]	[56]
Christie's	108	71
	[78]	[54]
Sale Premium	.36	.48
	[.18]	[.24]
Sotheby's	.35	.52
	[.22]	[.26]
Christie's	.37	.44
	[.19]	[.22]
Percentage of Paintings Sold	.77	.80
	[.09]	[.10]
Sotheby's	.76	.81
	[.11]	[.12]
Christie's	.77	.78
	[.10]	[.09]

Notes: The entries are summary statistics of the 52 auction weeks in the sample from 1985 to 2010. The first column shows the statistics for auction weeks in all years except 1986, 1988, 2000 and 2004. The second column shows the remaining years. Standard deviations are in brackets. The sample includes paintings offered during evening sessions. *Number of Sessions during Week* is a count of the number of sittings where paintings are auctioned for both auction houses during the week. *Number of Paintings during Week* is a count of the number of paintings offered for sale during all of the sessions for both auction houses during the week. Separate counts for both Sotheby's and Christie's sessions are also included. *Sum of Low Estimates during Week* is the sum of the low estimate of the sale price provided by the auction house for all the paintings offered during the week. Separate sums for both Sotheby's and Christie's sessions are also included. *Sale premium* is sum of sales price across paintings minus the sum of the low estimates divided by the sum of the low estimates for the auction week. *Percentage of Paintings Sold* is the percentage of paintings offered for sale that are sold during the auction week.

the higher sale premium from the auction weeks with the expensive house going first as opposed to second is due to the higher sale premium of the second part of the auction week. The same results hold when we compare column (2) for Panels A and B when we consider an alternative parameterization of our independent variable of interest. There is a bigger effect on revenue from *Auction Tilt* in the second half of the auction week. This evidence is consistent with an anchoring effect as opposed to a weak-bidder or low dispersion of valuations over time effect.

In Table 16, the dependent variable is the percentage of paintings sold. In Panel A, the dependent variable is the percentage of paintings sold in the second half of the auction week. In Panel B, the dependent variable is the percentage of paintings sold in the first half of the auction week. Comparing column (1) across the two panels, one sees that the coefficient of interest in front of *Auction Week Tilt* is .431 in the second half of auction week and .196 in the first half of the auction week. So although higher tilt means better sales outcomes in both parts of the week, it is larger in the second half, similar to the findings in Table 15. The same results hold when we compare column (2) across Panels A and B. The spread is also quite sizeable across the two panels, suggesting that the higher revenues come from the second part of the week, which is again consistent with an anchoring effect.

TABLE 12 The Effect of Auction Week Tilt on Auction Week Outcomes—Without Normalization of LHS Variable

	(1)	(2)
Auction Week Tilt	272	
	(141)	
Indicator of Auction Week Tilt > Average		39
		(24)
Indicator for Sotheby Leading Auction	−9	−15
	(24)	(25)
Log(Total Auction Size)	221	215
	(75)	(73)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.91	.90

Notes: The entries are coefficients of OLS regressions. Robust standard errors are in parentheses. The unit of observation is the auction week. Only paintings in evening sessions are included. There are two dependent variables. The dependent variable is the *Total Revenue* for the paintings sold during the week (measured in millions). The first of the two independent variables of interest is the *Auction Week Tilt*, which is the median low estimate of the paintings offered by the first auction house divided by the sum of the median low estimates of the paintings offered by the two houses. The second independent variable of interest, *Indicator of Auction Week Tilt > Average*, is a dummy variable for if *Auction Week Tilt* is greater than the sample average. Other controls include *Indicator for Sotheby Leading Auction*, which is a dummy that indicates that Sotheby's was the house that led the auction week. *Log(Total Auction Size)* is the log of the sum of the low estimates of entire auction week.

Anchoring is the often mentioned rationale for why revenues might be higher in the latter part of the auction week. But there could be other alternative explanations. It would be ideal if we could provide additional evidence linking our findings to some existing anchoring tests. To this end, we use an anchoring test developed by Beggs and Grady (2009), who examine the resale over time of the same pieces of art. Beggs and Graddy's (2009) empirical model is the following:

$$Price_{i,t} = \alpha + \beta_1 Estimated\ Price_{i,t} + \beta_2\left(Price_{i,t-1} - Estimated\ Price_{i,t}\right) + \beta_3\left(Price_{i,t-1} - Estimated\ Price_{i,t-1}\right) + \varepsilon_{i,t} \quad (4)$$

where i subscripts paintings and *t-1* is the first time the painting is observed at auction and t is the second time the painting is observed at an auction. These auctions are typically separated in time by a few years. *Price* is the outcome for the auction of the painting. *Estimated Price* is the estimated price of the painting based on its observable characteristics from a hedonic model. β_2 is the coefficient of interest; it measures the anchoring effect of the previous auction outcome at *t-1* for the painting at t. In other words, if the painting's previous price is high, a positive β_2 suggests that this previous high price anchors or increases the price that the painting sells for later. The third term measures how well the painting sold in the previous auction relative to its estimated price for that time period; this third term is a control for the painting's unobserved quality.

Instead of measuring the outcome of the sale of a painting at an auction based on its outcome during a previous sale as in Beggs and Graddy (2009), we will measure how the outcome of the second part of the auction week is affected by how well the first part of the auction week did using a similar methodology.

Our regression specification is:

$$\begin{aligned} Average\,Price_{i,2} = \alpha &+ \beta_1 Average\ Low\ Estimate_{i,2} \\ &+ \beta_2(Average\,Price_{i,1} - Average\ Low\ Estimate_{i,2}) \\ &+ \beta_3(Average\,Price_{i,1} - Average\ Low\ Estimate_{i,1}) + \varepsilon_{i,2} \end{aligned} \quad (5)$$

TABLE 13 The Effect of Auction Week Tilt on Auction Week Outcomes—No Cartel Years

	(1)	(2)
Panel A: Dependent Variable—Sale Premium		
Auction Week Tilt	.419	
	(.214)	
Indicator of Auction Week Tilt > Average		.115
		(.046)
Indicator for Sotheby Leading Auction	−.079	−.093
	(.061)	(.055)
Log(Total Auction Size)	−.126	−.155
	(.154)	(.142)
Year Effects?	Yes	Yes
Observations	42	42
R^2	.72	.74
Panel B: Dependent Variable— Percentage of Paintings Sold		
Auction Week Tilt	.385	
	(.159)	
Indicator of Auction Week Tilt > Average		.091
		(.026)
Indicator for Sotheby Leading Auction	−.059	−.072
	(.034)	(.031)
Log(Total Auction Size)	−.144	−.166
	(.074)	(.065)
Year Effects?	Yes	Yes
Observations	42	42
R^2	.66	.68

Notes: The entries are coefficients of OLS regressions. Robust standard errors are in parentheses. The unit of observation is the auction week. All observations are included except for auction weeks between the years 1995 and 1999. Only paintings in evening sessions are included. There are two dependent variables. In Panel A, the dependent variable is the *Sale Premium* for the paintings sold during the week. In Panel B, the dependent variable is *Percentage of Paintings Sold* during the week. The first of the two independent variables of interest is the *Auction Week Tilt*, which is the median low estimate of the paintings offered by the first auction house divided by the sum of the median low estimates of the paintings offered by the two houses. The second independent variable of interest, *Indicator of Auction Week Tilt > Average*, is a dummy variable for if *Auction Week Tilt* is greater than the sample average. Other controls include *Indicator for Sotheby Leading Auction*, which is a dummy that indicates that Sotheby's was the house that led the auction week. *Log(Total Auction Size)* is the log of the sum of the low estimates of entire auction week. Year effects are included in all the specifications.

where i subscripts auction week and 1 denotes the first part of the auction and 2 denotes the second part. The three right hand side terms of the model correspond to the three terms in the Beggs and Graddy (2009) specification. Once again, β_2 is the coefficient of interest; it measures the anchoring effect of the first part of the auction week on the second. The first term is our measure of the predicted price of the paintings being sold during the second part of the auction. The last term measures the price of paintings sold in the first part of the auction relative to the predicted price of those paintings: the analogous control for unobserved quality.

There are a couple of important differences between our specification and Beggs and Graddy's (2009) approach. First, we are not comparing the outcomes of the same painting over time but instead are examining the sales of different paintings at different points of an auction week. One advantage to this approach is that we are measuring an anchoring effect over a very short time period. It sometimes takes years for the same painting to be auctioned more than once, but we are always looking at outcomes within the same week. Anchoring effects are probably largest when the previous sales are more immediate. Second, instead of obtaining the predicted price of a painting using estimates from a hedonic model based on observable characteristics of that painting, we use the low estimates of the paintings. The estimates are made before the auction

TABLE 14 Summary Statistics by Part of the Auction Week

	Mean	Minimum	Median	Maximum
Sale Premium				
First Part	.38	.00	.35	1.12
	[.22]			
Second Part	.38	.05	.36	1.09
	[.22]			
Percentage of Paintings Sold				
First Part	.75			
Second Part	.79			
Total Auction Size (millions)				
First Part	104	14	82	319
	[69]			
Second Part	106	12	94	356
	[78]			

Notes: The entries are summary statistics of the 52 auction weeks in the sample from 1985 to 2010. Standard deviations are in brackets. The sample includes paintings offered during evening sessions. *Sale premium* is sum of sales price across paintings minus the sum of the low estimates divided by the sum of the low estimates for the auction week. *Percentage of Paintings Sold* is the percentage of paintings offered for sale that are sold during the auction week. *Total Auction Size* is the sum of the low estimate of all paintings.

TABLE 15 The Effect of Auction Week Tilt on Sale Premium—Second vs. First Part of the Auction Week

	(1)	(2)
Panel A: Dependent Variable—Sale Premium Second Part of Auction Week		
Auction Week Tilt	.585	
	(.263)	
Indicator of Auction Week Tilt > Average		.145
		(.049)
Indicator for Sotheby Leading Auction	.009	−.011
	(.064)	(.062)
Log(Total Auction Size)	−.050	−.084
	(.127)	(.118)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.64	.66
Panel B: Dependent Variable—Sale Premium First Part of Auction Week		
Auction Week Tilt	.012	
	(.259)	
Indicator of Auction Week Tilt > Average		.014
		(.048)
Indicator for Sotheby Leading Auction	−.032	−.034
	(.043)	(.045)
Log(Total Auction Size)	−.047	−.051
	(.137)	(.138)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.75	.75

(*Continued*)

TABLE 15 Continued

Notes: The entries are coefficients of OLS regressions. Robust standard errors are in parentheses. The unit of observation is the auction week. Only paintings in evening sessions are included. There are two dependent variables. In Panel A, the dependent variable is the *Sale Premium* for the paintings sold during the second part of the week. In Panel B, the dependent variable is the *Sale Premium* for the paintings sold during the first part of the week. The first of the two independent variables of interest is the *Auction Week Tilt*, which is the median low estimate of the paintings offered by the first auction house divided by the sum of the median low estimates of the paintings offered by the two houses. The second independent variable of interest, *Indicator of Auction Week Tilt > Average*, is a dummy variable for if *Auction Week Tilt* is greater than the sample average. Other controls include *Indicator for Sotheby Leading Auction*, which is a dummy that indicates that Sotheby's was the house that led the auction week. *Log(Total Auction Size)* is the log of the sum of the low estimates of entire auction week.

TABLE 16 The Effect of Auction Week Tilt on the Percentage of Paintings Sold— Second vs. First Part of the Auction Week

	(1)	(2)
Panel A: Dependent Variable— Percentage of Paintings Sold Second Part of Auction Week		
Auction Week Tilt	.431	
	(.191)	
Indicator of Auction Week Tilt > Average		.092
		(.030)
Indicator for Sotheby Leading Auction	−.012	−.025
	(.035)	(.033)
Log(Total Auction Size)	−.113	−.132
	(.068)	(.064)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.56	.58
Panel B: Dependent Variable— Percentage of Paintings Sold First Part of Auction Week		
Auction Week Tilt	.196	
	(.254)	
Indicator of Auction Week Tilt > Average		.049
		(.038)
Indicator for Sotheby Leading Auction	−.073	−.080
	(.038)	(.039)
Log(Total Auction Size)	−.132	−.144
	(.108)	(.105)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.63	.64

Notes: The entries are coefficients of OLS regressions. Robust standard errors are in parentheses. The unit of observation is the auction week. Only paintings in evening sessions are included. There are two dependent variables. In Panel A, the dependent variable is *Percentage of Paintings Sold* during the second part of the week. In Panel B, the dependent variable is *Percentage of Paintings Sold* during the first part of the week. The first of the two independent variables of interest is the *Auction Week Tilt*, which is the median low estimate of the paintings offered by the first auction house divided by the sum of the median low estimates of the paintings offered by the two houses. The second independent variable of interest, *Indicator of Auction Week Tilt > Average*, is a dummy variable for if *Auction Week Tilt* is greater than the sample average. Other controls include *Indicator for Sotheby Leading Auction*, which is a dummy that indicates that Sotheby's was the house that led the auction week. *Log(Total Auction Size)* is the log of the sum of the low estimates of entire auction week.

TABLE 17 Anchoring Effects

	(1)	(2)
Anchoring Effect	.703	.365
	(.359)	(.351)
Anchoring Effect × Indicator of Auction Week Tilt > Average		.812
		(.468)
Indicator of Auction Week Tilt > Average	732,097	−39,637
	(445,043)	(690,617)
Mean Low Estimate of Second Part of Auction Week	1.459	1.494
	(.097)	(.090)
Residual from First Part of Auction Week	.127	.111
	(.066)	(.065)
Indicator for Sotheby Leading Auction	390,814	285,374
	(345,404)	(338,829)
Log(Total Auction Size)	−99,856	28,588
	(847,882)	(834,022)
Year Effects?	Yes	Yes
Observations	52	52
R^2	.99	.99

Notes: The entries are coefficients of OLS regressions. Robust standard errors are in parentheses. The unit of observation is the auction week. Only paintings in evening sessions are included. The dependent variable is *Average Price of Paintings Sold* during the second part of the week. The independent variable of interest in the model shown in the first column is *Anchoring Effect*, which is the average price of paintings sold during the first part of the week minus the average low estimate of paintings offered during the second part of the week. The additional independent variable of interest in the model shown in the second column is the interaction of *Anchoring Effect* and *Indicator of Auction Week Tilt > Average*, which is a dummy variable for if *Auction Week Tilt* is greater than the sample average. Other controls include *Mean Low Estimate of Second Part of Auction Week*, the *Residual from First Part of Auction Week*, which is the mean price of paintings sold in the first part of the week minus the mean low estimate of paintings in the first part of the auction week. *Indicator for Sotheby Leading Auction* is a dummy that indicates that Sotheby's was the house that led the auction week. *Log(Total Auction Size)* is the log of the sum of the low estimates of entire auction week.

week begins, so they would not be affected by the anchoring effect of the outcomes of the first part of the auction. They are our best predictions of the price of paintings.

If anchoring effects are driving our findings, then we expect to first verify, similar to Beggs and Graddy (2009) that β_2 is positive. Moreover, one might also naturally extrapolate that anchoring effects are more important when the expensive items are auctioned first (*i.e.* when *Auction Week Tilt* is high).

In column (1) of Table 17, we show the results of our anchoring model using the outcomes of the evening sessions. As with Beggs and Graddy (2009), we find a positive and statistically significant coefficient on the anchoring term. The coefficient is very similar in magnitude to what they also obtain using their sample of Impressionistic and Modern paintings. The magnitude of the coefficient implies that a one standard deviation increase in the difference between the price of paintings sold in the first part of the auction week and the estimates of the second part of the week increase the price of paintings sold in the second part of the week by about 11%.

With this evidence about the importance of anchoring, we then examine how the magnitude of anchoring varies with the *Auction Week Tilt*. We ask whether the anchoring effect is stronger during auction weeks when the more valuable paintings are auctioned first. To answer this, we slightly modify our anchoring regression specification. We add an interaction term of the anchoring term with the *Indicator that Auction Week Tilt > Average* variable. The coefficient on the interaction term shows whether there is a differential anchoring effect during auction weeks when the *Auction Week Tilt* is high.

Column (2) of Table 2 shows the results of the model that includes this interaction term. The coefficient on the interaction term is positive and statistically significant at the 10 percent level. It is large; the anchoring effect during auction weeks with a high *Auction Week Tilt* is about three times larger than the effect during auction weeks with a small tilt. These results suggest that anchoring is an important aspect of the story of why the ordering of paintings across auctions within an auction week has important implications for the outcomes of those auctions.

6. Conclusion

■ We estimate the effect of ordering by value on revenues in sequential auctions using data from art auctions of Impressionist and Modern paintings by Sotheby's and Christies' from 1985 to 2010. Sotheby's and Christie's agreed years ago to alternate who holds their auction first during auction week in New York City. Because most of the same buyers attend both auctions, we use this predetermined rotation as a natural experiment to identify the effect of ordering on revenues. We find that total value of the two auctions during auction week as well as painting sell rates are significantly higher when the house with the most expensive paintings goes first during the week. We then attempt to identify the mechanism behind why ordering matters and we develop a test using our natural experiment that finds in favor of the anchoring effect.

Appendix

The premise of our article is that art auction houses tend to auction expensive items first. So we quickly confirm this here in this appendix just to note that our sample is similar to earlier studies and that the auction houses seem to be undertaking a sensible rule of thumb, namely that within an auction session, expensive items tend to go first. There is little new in this subsection other than to verify their results using a substantially larger sample. Our sample is more comprehensive in terms of coverage of paintings within a session and in terms of the length of our sample period. This set of empirical exercises focuses on how painting characteristics, such as value or size (low estimate), price minus low estimate divided by low estimate (percentage sale mark-up), and whether or not it is sold, depend on the painting's location in an auction.

The first task is then is to come up with a measure of where a painting is located within a session. The measure we use is:

$$Location\ within\ Auction\ Session = \frac{Lot\ Number\ of\ Painting}{Highest\ Lot\ Number\ of\ Session} \tag{6}$$

Lot Number of Painting is the order rank of the painting within the auction session (say item #10) and *Highest Lot Number of Session* is how many items are being auctioned off in that session (say item #50, which is the last item). Therefore *Location within Auction Session* is a number between 0 and 1, with the final painting of the session having the value of 1. The first painting of the session is a number close to zero but not exactly zero. This is a way of standardizing sessions with different numbers of items auctioned. Beggs and Graddy (1997) adopt a slightly different measure of location. They simply use the lot number (e.g. 1, 2, 3, ...) and include a full set of auction session dummies. In the end, it does not really matter which approach is used. The economic and statistical significance from our methodology are similar to theirs.

The regression specification we use to check the Beggs and Graddy (1997) result is the following:

$$Painting\ Outcome = \alpha + \beta_1 Location\ within\ Auction\ Session + \varepsilon \tag{7}$$

We use three different dependent variables. The first is the low estimate of the painting from the auction house. The second is sale price minus the low estimate relative to low estimate (percentage mark-up) defined before. The third is a dummy for whether the painting sells or not. We have also included set of auction session dummies as in Beggs and Graddy (1997) but these controls do not change our results in the slightest given the way we have defined *Location Within Auction Session*. Standard errors are clustered at the auction week.

The results are in Appendix Table A. We first report the results for the evening sessions in Panel A. Column (1) shows the results when the outcome is the low estimate. The coefficient on *Location within Auction Session* is negative and statistically significant from zero. This suggests that, within an auction session, the paintings with higher estimates are placed early in the session. The size of the coefficient indicates that when comparing a painting at the beginning of the auction session and painting in the exact middle of the auction session or when comparing the exact middle of the session to the end (the difference in the scores is 0.5) the low estimate of the later painting is on average about \$287,000 lower (or 0.5 times –574,947) than the earlier painting. This effect is statistically significant with a *t*-statistic of about 5.1. From Table 1 Panel A, we see that the mean low estimate of all painting is \$1.45 million so going from the first in the auction to the middle of the auction generates a movement that is about 20% (\$287,000 divided by \$1.45 million) of the mean, which is an economically significant effect.

Column (2) shows the results when the outcome is the painting sale price minus the low estimate relative to low estimate. The coefficient on *Location within Auction Session* is negative and statistically significant from zero, indicating that paintings later in the auction session sell for lower prices relative to the auction estimate. The size of the coefficient (–0.28 with a *t*-statistic of near 4.7) suggests that when comparing a painting at the beginning of the auction session and painting in the exact middle of the auction session, the price relative to estimate of the later painting is about 0.14 (again

0.5 × –0.28) lower than the earlier painting. From Table 1 the mean sale premium is 0.52. So this effect is about 27% of the mean of the distribution of the sale price relative to estimate, which is again a sizeable economic effect.

Column (3) shows the results when the outcome is whether the painting sells or not. The coefficient on *Location within Auction Session* is again negative and statistically different from zero, indicating that paintings placed later in the session are less likely to sell. The coefficient (–0.14 with a *t*-statistic of around 7) suggests that when comparing a painting at the beginning of the session and a painting in the middle, the painting in the middle is about 7 percentage points less likely to be sold (around 9% of the average probability of a painting being sold, which is 0.78).

In Panel B, we report the results for the morning and afternoon sessions grouped together. For brevity, we omit the specific discussions that we did for Panel A. The upshot is that the qualitative patterns are quite similar to the evening sessions. This is comforting in that the results from Panel A also hold up for the morning and afternoon sessions. Moreover, notice that the economic and statistical significance magnitudes are somewhat smaller (though still significant in all cases) than for the evening sessions, reflecting the fact that there is less variation in terms of the value of the paintings within an auction session. In contrast to the evening sessions, which could have significant differences in terms of value between paintings auctioned in the beginning versus the end, there is less variation in the morning and afternoon sessions. These findings are also a justification for why we will for the most part focus on the outcomes from the evening auctions.

Appendix Table A: The Relationship Between the Location of the Painting Within An Auction Session and the Auction Outcome

	Low Estimate	Sale Premium	Sell Indicator
Panel A: Evening Sessions			
Location within Auction Session	−574,947	−.28	−.14
	(112,369)	(.06)	(.02)
Observations	7506	5849	7609
R^2	.004	.009	.009
Panel B: Morning and Afternoon Sessions			
Location within Auction Session	−27,746	−.07	−.02
	(4436)	(.03)	(.01)
Observations	29260	22142	29292
R^2	.005	.001	.000

Notes: The entries are coefficients of OLS regressions. Standard errors clustered at the auction week level are in parentheses. Panel A includes paintings offered during evening sessions. Panel B includes paintings offered during morning and afternoon sessions. There are three different dependent variables. First, *Low Estimate* is the lower estimate of the sale price provided by the auction house. Second, *Sale Premium* is the sale price of paintings that were successfully sold minus the low estimate of that painting divided by the low estimate of the painting. Third, *Sell Indicator* is a dummy variable indicating that the painting was successfully purchased. The independent variable of interest is *Location within Auction Session*. It is the lot number (order rank) of the painting within the auction session divided by the maximum lot number of the session.

References

Ashenfelter, O. "Estimating the Effect of Training Programs on Earnings." *Review of Economics and Statistics*, Vol. 60 (1978), pp. 47–57.

Ashenfelter, O. "How Auctions Work for Wine and Art." *Journal of Economic Perspectives*, Vol. 3 (1989), pp. 23–36.

Ashenfelter, O. and Genesove, D. "Testing for Price Anomalies in Real-Estate Auctions." *The American Economic Review (Papers and Proceedings*), Vol. 80 (1992), pp. 501–505.

Beggs, A. and Graddy, K. "Declining Values and the Afternoon Effect: Evidence from Art Auctions." *RAND Journal of Economics*, Vol. 28 (1997), pp. 544–565.

Beggs, A. and Graddy, K. "Anchoring Effects: Evidence from Art Auctions." *American Economic Review*, Vol. 99 (2009), pp. 1027–1039.

Benoît, J.P. and Krishna, V. "Multiple-Object Auctions with Budget Constrained Bidders." *Review of Economic Studies*, Vol. 68 (2001), pp. 155–179.

Bernhardt, D. and Scoones, D. "A Note on Sequential Auctions." *American Economic Review* Vol. 84 (1994), pp. 653–657.

Cassady, R. *Auctions and Auctioneering*. Berkeley, CA: University of California Press, 1967.

Deltas, G. and Kosmopoulou, G. "Catalogue vs Order-of-Sale Effects in Sequential Auctions: Theory and Evidence." *The Economic Journal*, Vol. 114 (2004), pp. 28–54.

Department of Justice "Sotheby's and Former Top Executive Agree to Plead Guilty to Price Fixing on Commissions Charged to Sellers at Auction." Press Release, 2000, http://www.justice.gov/atr/public/press_releases/2000/6639.htm

ELMAGHRABY W. "The Importance of Ordering in Sequential Auctions." *Management Science*, Vol. 49 (2003), pp. 673–682.

GALE, I. AND HAUSCH, D. "Bottom-Fishing and Declining Prices in Sequential Auctions." *Games and Economic Behavior* Vol. 7 (1994), pp. 318–331.

GINSBURGH, V. "Absentee Bidders and the Declining Price Anomaly in Wine Auctions." *Journal of Political Economy*, Vol. 106 (1998), pp. 1302–1322.

GREENLEAF, E. "The Impact of Reference Price Effects on the Profitability of Price Promotions." *Marketing Science*, Vol. 14 (1995), pp. 82–104.

MCAFEE, R. P., and VINCENT, D. "The Declining Price Anomaly." *Journal of Economic Theory*, Vol. 60 (1993), pp. 191–212.

NORTHCRAFT, G. AND NEALE, M. "Expert, Amateurs, and Real Estate: An Anchoring-and-Adjustment Perspective on Property Pricing Decisions." *Organizational Behavior and Human Decision Processes*, Vol. 39 (1987), pp. 84–97.

NUNES, J. AND BOATWRIGHT, P. "Incidental Prices and Their Effect on Consumer Willingness to Pay." *Journal of Marketing Research*, Vol. 41 (2004), pp. 457–466.

PESANDO, J. AND SHUM, P. "Price Anomalies at Auction: Evidence from the Market for Modern Prints." In V. Ginsburgh, ed., *Economics of the Arts*. New York: North Holland, 1996.

PITCHIK, C. AND SCHOTTER, A. "Perfect Equilibria in Budget-Constrained Sequential Auctions: An Experimental Study." *RAND Journal of Economics*, Vol. 19 (1988), pp. 363–388.

RAJENDRAN, K. AND TELLIS, G. "Contextual and Temporal Components of Reference Price." *Journal of Marketing*, Vol. 58 (1994), pp. 22–34.

TVERSKY, A. AND KAHNEMAN, D. "Judgment under Uncertainty: Heuristics and Biases." *Science* Vol. 185 (174), pp. 1124–1130.

WEBER, R. "Multiple-Object Auctions." In R. Engelbrecht-Wiggans, M. Shubik, and R.M. Stark, eds., *Auctions, Bidding and Contracting: Uses and Theory*. New York: New York University Press, 1983.

ZULEHNER, C. "Bidding Behavior in Sequential Cattle Auctions." *International Journal of Industrial Organization*, Vol. 27 (2009), pp. 33–42.