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Art Arbitrage - Violations of the Law of One Price Created by Fine Art Auctions

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Abstract
Although fine art is becoming increasingly popular as investment, its price determination is relatively opaque. This paper expands upon the work of Pesando (1993) and Pesando and Shum (2007) concerning the law of one price in the art auction industry. By examining the sale history of silkscreen prints from Andy Warhol's 1970 series *Flowers*, this paper controls for the physical characteristics of particular artwork and seeks to determine the likelihood of sale and price differentials created by specific auction environments. This paper further examines the extent to which auction houses take into account these auction environments when setting presale price estimates, as well as how correlated these estimates are to the final realized price of a work. The results suggest that significant factors impacting likelihood of sale and final realized price for a work include the average price of the total sale it was included in—indicative of spillover effects from other works in the sale. The results also suggest that on some level, auction houses set presale estimates strategically, based on factors aside from market trends and the inherent quality and condition of the work. Larger, more established houses are likely more strategic at setting estimates—valuing lower to increase the probability of sale.

Keywords
Auctions

I. Introduction

In May of 1998, *Orange Marilyn*, one in a series of five almost identical prints by pop artist Andy Warhol sold for a record $17.3 million at auction at Sotheby's New York. Not only was this price four times the record for a Warhol piece at the time, but also more than three times the price of a slightly different *Orange Marilyn* available for sale at the same time through a private dealer. Only a few days after the sale, a slightly smaller *Orange Marilyn* sold for $3 million.[1] These disparate prices seem to be in blatant violation of the law of one price, which assumes that in the absence of transaction costs or regulatory barriers, no price differences should exist for identical goods.[2]

The private dealer market is inherently obscure, with very little information publicly available—making generalizations within the private sales market, and between the private sales and auction market almost impossible. Yet within the sensational and extravagant world of fine art auctions, similar examples of price dispersion abound. This paper seeks to study the effects of the auction environment in which works are sold on their likelihood of sale and final realized price. Unique physical characteristics of works will be controlled for by restricting the sample to silkscreen prints, which will be assumed to be identical.[3] This paper also seeks to examine the extent to which auction houses take into account the auction environments they create when setting presale price estimates, and how accurate these estimates are at predicting realized prices.

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[1] Thompson, Donald N. *The $ 12 Million Stuffed Shark: The Curious Economics of Contemporary Art and Auction Houses*. New York: Palgrave Macmillan, 2008. Print.

[2] The range of transactions costs that could occur in the art market, such as different taxing schemes or the costs of international shipping, is quite small and hence is assumed to have minimal effect on buyer behavior. All final realized prices mentioned in this paper are exclusive of taxes or shipping costs.

[3] Screen printing is a technique in which a desired image is transferred from a stencil onto a medium, such as paper, canvas, or wood.

Ultimately, it is hoped that these findings will have implications for the strategic choices made by both buyers and sellers of art, including those who seek art as an investment asset.

This paper will proceed as follows: Section II provides a general overview of the fine art auction market and the mechanics of auctions. Section III reviews relevant literature on fine art as investment, auctions, and the fine art auction market more specifically. Section IV describes the sample of prints chosen, the dataset collected, and the variables examined. Section V explains the empirical methodology utilized, while Section VI highlights econometric results. Section VII examines potential sources of error, and finally Section VIII provides concluding remarks and areas for further study.

II. Overview of Art Auctions

The Market

The fine art auction market is considered by most to be a duopoly. The oldest and most prominent auction houses are Sotheby's, founded in 1744, and Christie's, founded in 1766. Together, the two houses control almost 90% of the global secondary art market today.[45] In a tier below exist Phillips and Bonhams, both globally reaching auction houses, yet considered clearly secondary to Christie's and Sotheby's. These medium auction houses hold about 5% and 1% of the market respectively today.[6] In recent years, these two houses have been increasingly steering away from direct competition with Christie's and Sotheby's and instead seeking out niche

[4] The secondary market is comprised of works that are resold, whereas the primary market is comprised of works that are sold directly from the artist.
[5] McAndrew, Clare. TEFAF Art Market Report 2015: The Global Art Market, With a Focus on the U.S. and China. Rep. Maastricht: European Fine Art Foundation, 2015. Print.
[6] Ibid.

markets—such as ultra-contemporary art.[7] Finally, numerous small regional and local auction houses exist, each controlling less than 1% of the market.

The traditional large art auction markets are New York, London, and Paris. In the last decade, emerging markets, particularly in Asia, have rapidly become important art markets as their population of ultra high net worth individuals increases. China, in 2014, was tied with the United Kingdom as the second largest art market in the world by value, with 22% of the market—while the United States was the largest with 39% of the market. In 2011, China even briefly overtook the United States as the world's largest art market.[8] The most important and prestigious sales, largely held by the major auction houses, occur in the spring and fall months, whereas major art fairs occur in winter and summer months.

Auction Mechanics

Individuals and institutions with works they wish to sell approach, or in some cases—such as after the death of a famous or prolific collector—are approached by an auction house or auction houses. Negotiations over auction aspects as well as commission charged to the seller occur, and the seller agrees to sell through a specific auction house. Auction houses earn their revenue by charging commissions to both sellers and buyers of work. The seller's commission is negotiated on a case-by-case basis, and is usually quoted as a percentage of the hammer price, as the winning bid at auction is known. In some cases, such as with famous works or collections that have the potential of producing great media attention and attracting high profile and high net worth bidders, the seller's commission is waved and the auction house may even guarantee a

[7] Thompson, Donald N.
[8] Ibid.

minimum sale price.[9] Auction houses set fixed buyer's premiums on a sliding scale for every work sold by the house in a particular market. For example, at Christie's New York in 2014, buyer's paid a 25% premium on the first $100,000 of the hammer price, 20% on the amount from $100,001 to $2,000,000, and 12% on the amount above $2,000,000. Buyer's premiums are similar across auction houses, and have fluctuated since their introduction in 1975.[10]

Prior to 1995, Christie's and Sotheby's engaged in fierce competition for consignments through negotiating favorable seller's commissions, offering price guarantees, and other methods. This competition suddenly ended in 1995 when both houses announced fixed, nonnegotiable sliding-scale commissions. In 2000, an antitrust investigation revealed a price fixing scandal between executives of Christie's and Sotheby's. The two firms were accused of colluding to raise seller's commissions and stealing more than $400 million between 1993 and 1999.[11] In September 2001, Christie's and Sotheby's settled a class-action civil suit, agreeing to each pay a total of $256 million that could be claimed by anyone who had bought or sold from the houses since 1993. Alfred Taubman, Sotheby's Chairman of the Board at the time, served 10 months in prison in 2002.[12] Since the conclusion of the price-fixing scheme, this paper assumes that auction houses fairly compete for consignments.

Before an auction, auction houses publish glossy, visually appealing pre-sale catalogues detailing information on the works up for sale. This includes photographic reproduction of the work, its title, artist, year of creation, medium, size, and provenance—or prior ownership and sale history. In addition, auction houses publish both a low and high price estimate for the

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[9] Ibid.
[10] Horowitz, Noah. Art of the Deal: Contemporary Art in a Global Financial Market. Princeton, NJ: Princeton UP, 2011. Print.
[11] "Ex-Sotheby's Boss Convicted." *CNN*. Cable News Network, 5 Dec. 2001. Web. 31 Jan. 2014.
[12] "Christie's and Sotheby's: What an Art." *The Economist*. The Economist Newspaper, 05 Aug. 2004. Web. 31 Jan. 2014.

hammer price of the work. Auction estimates are purported by auction houses to reflect "rarity, condition, quality and provenance" and are "based on prices recently paid at auction for comparable property."[13] Works are also featured in pre-sale exhibitions, and important, highly sought after works often travel to different markets to be viewed by potential buyers.

Art auctions themselves operate as English auctions—in other words, ascending price auctions. The first work offered for sale is assigned a lot number of 1 and lot numbers ascend until the last work offered in a particular auction. Auctioneers start with low prices and call out increasingly high prices until the work is sold at the hammer price. The final price for each work and the total sale sum published in post-sale results by most auction houses is the final realized price inclusive of the hammer price and the buyer's premiums. All works offered for sale have a undisclosed reserve price, agreed upon by the seller and the auction house. If bidding does not reach the reserve price, the work will go unsold and is referred to as "bought in." Although reserve prices are never revealed, research shows that reserve prices are around 70% of the low estimate quoted by the auction house.[14] Auction houses are eager to conceal items that have failed to sell at auction. Beginning with legislation enacted in the early 1980s in New York, auction houses have been obliged to announce during the auction whether a sale has occurred.[15] However, information on sales is still difficult to garner from published post-sale auction results, as will be discussed in further detail in Section IV.

[13] "Guide to Buying & Bidding." Christie's, n.d. Web.
[14] Ashenfelter, Orley, and Kathryn Graddy. "Sale Rates and Price Movements in Art Auctions." *American Economic Review* 101.3 (2011): 212-16. Web.
[15] Ashenfelter, Orley, and Kathryn Graddy. "Auctions and the Price of Art." Journal of Economic Literature 41.3 (2003): 763-86. Web.

III. Literature Review

Ashenfelter and Graddy (2003) provide a thorough overview of the mechanics of art auctions and the business of auction houses, as well as a survey of the economic research done on the field. Unsurprisingly, much of the literature on the market is focused on the returns of art purchased as investment.

Price Indices

The most common research models for assessing art price and price indices have been hedonic and repeat-sale models, which are used extensively in real estate valuation. Both models assume that the price of a given work at auction at a given time is the aggregate of a fixed component of price that reflects the unique quality of the work, an index of aggregate price movements, and an error term.[16] While the hedonic model assumes the fixed component is determined by a number of hedonic variables, the repeat-sale model controls for these variables explicitly by only analyzing works that were resold during the given time period at the expense of discarding data for works that did not resell. Although the hedonic model allows for the use of all of the data in a certain time period, it assumes that a small set of variables captures much of the variability in price, and the characteristics of works sold does not vary greatly over time. An example of some of the work done with these models include Chanel et al. (1996), which uses a sample of paintings from 1855-1969 and find real returns of 4.9% and 5.0% from the hedonic and repeat-sales methods respectively. Mei and Moses (2001) use a sample of American, Impressionist, and Old Masters works from 1875-2000 and find real returns of 4.9% from the repeat-sales methods. Higgs and Worthington (2005) take a closer look at the Australian art market from 1973-2003, and find returns of 7% using the hedonic model. Closer examination of

[16] Ibid.

their hedonic characteristics also lead them to conclude that prices are higher for works painted by certain artists and deceased artists, executed in oil or acrylic, or auctioned at Sotheby's and Christie's. While many, such as Goetzmann (1993) and Korteweg, Kraussl, and Verwijmeren (2013), have used CAPM models to conclude that the returns on fine art are less than those on traditional long-term investments given the market's riskiness, I hope my research will be able to provide clarity on strategic decisions that command higher prices at auction, and ultimately have implications for the choices made by both buyers and sellers of fine art with the goal of maximizing investment potential.

Law of One Price

The bulk of this research builds upon the existing literature on violations of the law of one price in the art auction industry done by Pesando (1993) and Pesando and Shum (2007). Pesando and Shum (2007), revisiting the results of Pesando (1993), test the law of one price using realized prices for all Picasso prints, as well as the 100 prints that make up Picasso's Vollard Suite, sold at auction worldwide between 1977-2004. To compare sales at Christie's with those at Sotheby's, and sales in the U.S. with those in Europe, they identify pairs of identical prints sold within a 30 day window and calculate the percentage of prices realized in the first auction house or market that are higher than those in the second, the mean difference in price divided by the mean price, and the mean absolute price difference divided by the mean price. They find that during the period 1977-1992, prices are 9% less on average at Christie's than at Sotheby's, significant at a 5% level. During the period 1993-2004, prices were 12% higher on average at Christie's than Sotheby's, significant at a 5% level. For the entire sample period, prices were higher in U.S. markets than Europe. Mei and Moses (2002) test these results

using repeat-sales data and find mixed evidence of price differences between the two auction houses.

My research will expand upon Pesando's findings of these violations by focusing further on specific aspects of the auction experience, such as the declining price anomaly explored by Beggs and Graddy (1997) and other variables detailed in Section IV.

Declining Price Anomaly

While previous work on price had attributed fixed effects to inherent characteristics of the work, such as artist, canvas size, and medium, Beggs and Graddy (1997) is the first to analyze the effects of the structure of the art auction by empirically testing the declining price anomaly. The declining price anomaly occurs when identical items sold sequentially at auction follow a declining pattern of realized prices. They examine the order of lots at auction in relation to the final hammer price for a sample of Contemporary art and a sample of Impressionist and Modern Art. Their theoretical model shows that ordering a sale from highest to lowest value is an optimal strategy for an auction house. The results of their empirical analysis show that both estimates and price realized relative to the average auction estimate is less for items that appear later in auctions. This declining price anomaly has also been observed by Ashenfelter (1989) and McAfee and Vincent (1993) in wine auctions and Ashenfelter and Genesove (1992) in condominiums sold in real estate auctions. My research will test for the declining price anomaly by examining lot placement as a hedonic characteristic of price.

Auction Estimates

A number of papers have researched the accuracy of auction estimates and have reached divided conclusions. Theoretical literature, such as that of Milgrom and Weber (1982a) show

that the best policy for auction houses is to provide accurate estimates based on the value of the work. Ashenfelter (1989) and Abowd and Ashefelter (1988) find that auction houses are truthful, and that the average of the high and low estimate is highly correlated with the final realized price. However, others, such as Bauwens and Ginsburgh (2000) and Beggs and Grady (1997) find systematic over and under estimations. Bauwens and Ginsburgh (2000) also conclude that experts do not fully take into account all of the information contained within the auction catalogue, implying that prediction bias could be ameliorated with better use of the hedonic characteristics published in the catalogues.

A possible explanation is that auction experts are inefficient at using all available information and make systematic errors. Anecdotal evidence provided by the trials in the Christie's and Sotheby's price-fixing scandal suggests another possible explanation—strategic manipulation of estimates to impact realized prices.[17] While executives of the auction houses denied involving valuation experts in price-fixing activities, Mei and Moses (2002) find that both Sotheby's and Christie's have a persistent upward bias in their estimates for the purpose of increasing realized prices. This paper seeks to test the correlation between presale estimates and final realized prices, as well as the possibility that auction house experts strategically set estimates by taking into account the variables detailed in Section IV.

IV. Explanation of Dataset and Variables

The sample used in this study is comprised of the sale history of Andy Warhol's 1970 print series *Flowers,* featured on the title page of this paper. This specific series was chosen for a number of reasons. Warhol's work focused on themes of commercialism and mass production,

[17] Ibid.

and hence his studio, which he dubbed his "factory," was prolific at producing prints for mass distribution and sale, just like the everyday objects they often represented. As a result, there exist many prints to examine. Research on art market trends also considers the market for Warhol works an indicator for the Post-War and Contemporary art market as a whole. Since 2002, Warhol has consistently been among the top three most traded artists by value.[18] As seen in Chart 1, market movements for Warhol's work closely mirrors that of the top 25 Impressionist, Modern, and Contemporary artists.

Furthermore, unlike the Old Masters prints, where the quality and coloration of each print is highly important for its valuation and its price on the market, Warhol's focus on mass production leaves us with prints that are meant to be as identical in quality and price as possible.[19] Although the *Flowers* prints come in ten different color variations, their depiction of a rather uncontroversial subject also serves to stabilize their price against collectors who may be passionate about certain celebrities or events.

In total, Warhol's studio produced 250 editions of each of the ten color variations, as well as 26 artist's proofs.[20] A dataset on their sales was manually constructed using price data contained in ArtNet's price database. Information provided by ArtNet includes price, sale date, sale location, auction house, lot number, estimates, and any descriptions of provenance and physical condition of the work. The rest of the variables in the data set were obtained by referencing archived auction catalogues and results published online by auction houses, as well as directly contacting auction houses. The first observation occurs in 1989 and the data set

[18] "The Pop Master's Highs and Lows." The Economist. The Economist Newspaper, 28 Nov. 2009. Web.
[19] Based on the expert opinion of Professor Alfred Acres from the Georgetown University Department of Art and Art History, who specializes in the history of prints.
[20] Warhol, Andy, and Michael Lobel. *Andy Warhol Flowers*. New York: Eykyn Maclean, 2012. Print.

extends through the end of 2014 for a total of 212 observations. All prices and estimates have been multiplied by the CPI so that all observations are in 2014 dollars.

A number of variables will be examined both as dependent and independent variables in the equations modeled. Sold is a dummy variable representing whether the work was sold or bought in. The variable PricePremium represents the final realized price of the work, inclusive of the buyer's premium at the time of sale. While the buyer's premium differs by auction house, it is assumed that buyers should take into account buyer's premium and adjust their bids accordingly. Most published estimates by the auction houses do not include buyer's premiums, whereas in most cases, reported final prices of individual works and total sale sums do include buyer's premiums. This serves to inflate auction houses' reporting of their results. For example, houses can report that a certain number of works in a sale sold for higher than their estimates, where the final reported price includes buyer's premiums and the estimates did not.[21] To correct for this, final realized prices are multiplied by one minus the buyer's premium to obtain the variable PriceHammer. The variable AverageEstimate is determined by averaging the low and high estimates provided by the auction house.

The first hedonic characteristic examined is lot order, in order to test for the declining price anomaly. It is represented by a continuous variable determined by dividing the work's lot number by the total lots offered in a sale. If the declining price anomaly holds, when regressed against realized price, the coefficient of this variable should be negative, as works that come up later in auction should fetch lower prices.

Another characteristic of auction environments studied is the sale rate of the total sale. The variable for sale rate is a continuous variable determined by dividing the number of lots sold

[21] Rosenbaum, Lee. "Making Sales Look Stronger." Wall Street Journal, 15 Nov. 2008. Web.

by the total number of lots offered for sale. Because information on unsold lots is often omitted from auction house public records, in many cases the total number of lots offered was determined by examining archived auction catalogues and pre-sale press. It is hypothesized that when regressed against likelihood of sale and realized price, the coefficient on this variable should be negative, as having a high number of lots unsold will weaken buyer confidence in the sale.

Furthermore, it is anticipated that there exist spillover effects from expensive and well-known works that are included in the sale—as they attract a higher caliber of buyers to bid up the price of all the lots offered. These spillover effects are represented by a variable for the average price of the sale—a continuous variable determined by dividing the total sale sum (net of the *Flowers* print), inclusive of buyer's premium, by the number of lots sold. It is hypothesized that when regressed against likelihood of sale and realized price, the coefficient will be positive.

A number of dummy variables are introduced to examine fixed effects. A group of dummy variables represent the caliber of auction house, using small auction houses as a reference group. Medium will represent Bonhams and Phillips de Pury, while Major will represent Christie's and Sotheby's. Another group of dummy variables represent the type of sale the work is included in. Using general sales (sales that include fine and decorative arts, as well as sculpture and design) as a reference group, it will include dummies Prints to represent sales of Prints and Multiples, and IMC to represent sales of Impressionist, Modern, or Contemporary art (or combinations of those styles). Dummy variables Emerging and Traditional represent emerging markets (Shanghai, Seoul, Tokyo, Hong Kong) and major traditional art markets (New York, London, Paris), using minor markets as a reference. The dummy variable Evening represents evening sales, using day sales as a reference. It is hypothesized that evening sales will

have a larger positive effect on price, as evening sales are considered more prestigious events and often require tickets and cocktail or black tie attire. The dummy variable PeakMonth represents spring and fall months, when major auction houses hold their biggest sales, using winter and summer months as a reference. Finally, dummy variables for year are included, using Year 1 (1989) as a reference.

A variable that was intended for study was the existence of good provenance, such as being owned by a famous collector, celebrity, or museum. In the industry, provenance is widely believed to be a major determining factor of a work's popularity at sale. While provenance is an aspect that is publicized and highlighted to potential buyers in auction catalogues, for this sample of prints, very few works had provenances significant enough to be mentioned. Therefore, this variable was excluded.

V. Empirical Methodology

As seen by the summary of variables in Table 1, missing data exists for the LotOrder, SaleRate, and AverageEstimate variables, making for a total of 190 complete observations after listwise deletion. This results from an unwillingness of some auction houses to disclose sale information. Because the missing data is random, the multiple imputation method, developed by Rubin (1987) was used to fill in missing variables in the incomplete observations.[22] Multiple imputation is a Monte Carlo technique where missing values are replaced with average outcomes across *m* simulated versions. A summary of imputation results for $m = 0$ (before imputation), $m = 1$, and $m = 20$ is provided in Table 2.

[22] Rubin, Donald B. Multiple Imputation for Nonresponse in Surveys. New York: Wiley, 1987. Print.

The first equation estimated tests the effects of the auction environment on the likelihood that a work sells. The below equation is estimated with a logit model, where a coding of 1 for Sold indicates that the work sold and a coding of 0 indicates that the work was bought in.

Equation 1:

$$Sold_{it} = B_1 + B_2 LotOrder_{it} + B_3\, SaleRate_{it} + B_4 ln(AveragePrice)_{it} + B_5 ln(AverageEstimate) + \delta_1 Medium_{it} + \delta_2 Major_{it} + \delta_3 Prints_{it} + \delta_4 IMC_{it} + \delta_5 Evening_{it} + \delta_6 Emerging_{it} + \delta_7 Traditional_{it} + \delta_8 PeakMonth_{it} + \gamma_1 (PeakMonth\ x\ Emerging)_{it} + \gamma_2 (PeakMonth\ x\ Traditional)_{it} + \varepsilon_{it}$$

The year dummy variables are excluded in this model because the small number of observations for some years led to their omission. The PeakMonth dummy and dummies for location of sale are interacted to take into account travel schedules of buyers, as major sales usually take place in traditional art markets as well as some big emerging markets in recent years. As a result, spring and fall sales are hypothesized to be more important in major market locations where buyers will plan to travel for sales, and less important in smaller markets.

The second equation regresses the effects of the auction environment on the final realized price of the work, inclusive of buyer's premium.[23] The below equation only examines work that were sold.

[23] The final realized price inclusive of buyer's premium, as opposed to the hammer price, is used because it is price published by the majority of auction houses. Most data on total sale sum, and hence also the AveragePrice variable, is also inclusive of buyer's premiums.

Equation 2:

$$ln(PricePremium)_{it} = B_1 + B_2 LotOrder_{it} + B_3 SaleRate_{it} + B_4 ln(AveragePrice)_{it} + \delta_1 Medium_{it} + \delta_2 Major_{it} + \delta_3 Prints_{it} + \delta_4 IMC_{it} + \delta_5 Evening_{it} + \delta_6 Emerging_{it} + \delta_7 Traditional_{it} + \delta_8 PeakMonth_{it} + \gamma_1 (PeakMonth\ x\ Emerging)_{it} + \gamma_2 (PeakMonth\ x\ Traditional)_{it} + \delta_9 Year2_{it} + \ldots . \delta_{30} Year22 + \varepsilon_{it}$$

The predictor variables in this equation are the same as those in Equation 1, with the omission of the AverageEstimate variable. This paper seeks to study the possibility that auction houses strategically set estimates based on factors beyond the inherent value of the work. Therefore, if auction houses themselves take into account the predictor variables when setting estimates, including the AverageEstimate would introduce issues of endogeneity.

The third equation tests the possibility of strategic estimate setting by regressing elements of the auction environment against the average of the low and high estimate.

Equation 3:

$$ln(AverageEstimate)_{it} = B_1 + B_2 LotOrder_{it} + B_3 SaleRate_{it} + B_4 ln(AveragePrice)_{it} + \delta_1 Medium_{it} + \delta_2 Major_{it} + \delta_3 Prints_{it} + \delta_4 IMC_{it} + \delta_5 Evening_{it} + \delta_6 Emerging_{it} + \delta_7 Traditional_{it} + \delta_8 PeakMonth_{it} + \gamma_1 (PeakMonth\ x\ Emerging)_{it} + \gamma_2 (PeakMonth\ x\ Traditional)_{it} + \delta_9 Year2_{it} + \ldots . \delta_{30} Year22 + \varepsilon_{it}$$

The final equation models the relationship between the average estimate and the hammer price of the work for works that sold in order to test the predictive ability of auction house estimates.

Equation 4:

$$ln(PriceHammer)_{it} = B_1 + B_2 ln(AverageEstimate)_{it} + \varepsilon_{it}$$

Potential Endogeneity

A number of variables tested in the above models could suffer from issues of endogeneity and reverse causality. If auction houses follow the optimal strategy theorized by Beggs and Graddy (1997) and order sales strategically from highest to lowest value, the result for LotOrder could be affected. It is possible that a certain print has unobservable quality or condition flaws not captured by the data, or is not expected to be in high demand in a certain sale, and hence is assigned a high lot number by the auction houses. In this case, reverse causality could be present, such that it is not the high lot number that causes the lower probability of sale, but inherent characteristics of the work that led to its placement later in the sale.

Furthermore, a high sale rate and average price of sale are indicative of sales that contain sought-after works, and thus attract a high number and caliber of eager buyers. Auction houses will naturally include higher quality and value prints in sales with other higher value works, therefore these works may have higher likelihood of sale and realized price because of their greater inherent value which led to their inclusion in more prestigious sales in the first place. However, as discussed in Section IV, this specific sample was chosen because their quality is believed to differ minimally. In addition, very little variation in auction catalogue descriptions of the physical condition of the prints was noted during the data collection phase. The effects of potential endogeneity are further discussed in Section VII.

VI. Econometric Results

Equation 1

The results for Equation 1 are found in Table 3. The coefficient of LotOrder is negative and significant at the 10% level, providing some evidence that having higher lot numbers not only decrease realized prices—as observed with the declining price anomaly—but also deceases the likelihood that a work sells. The regression results suggest that on average, the probability of sale is 22.8% less for *Flowers* prints that are the last lot offered as opposed to the first.

The coefficient of SaleRate is positive and significant at the 1% level, implying that the greater the ratio of works that sell, the more likely it is that the individual print sells. Relatedly, the coefficient of ln(AveragePrice) is positive and significant at the 10% level, providing evidence of spillover effects from important works that are included in a sale. The results suggest that a 1% increase in the average price of a sale increases the probability of sale by 5.3%.

The coefficient of ln(AverageEstimate) is negative and significant at the 1% level, suggesting that a 1% increase in the average estimate decreases probability that the works sells by 16.9%. This result is contrary to a conception held by some in the industry that fine art is a Veblen good, for which demand is positively correlated with price. If this were true, setting higher estimates should attract a higher caliber of bidders and increase the likelihood of sale and realized prices.

The coefficient of Medium is positive and significant at the 10% level. The results imply that being auctioned by Bonhams or Phillips increases the probability of sale by 23.3%. The coefficient of Major is also positive, but of smaller magnitude and not significant. A possible explanation for the higher likelihood of sale at the medium auction houses is that Christie's and Sotheby's tend to focus on the higher end of the market and place less effort into pursing lower

value consignments, whereas Bonhams and Phillips focus precisely on those less valuable consignments or niche markets that the major houses pass over. In 2007, the average price of a work sold was $50,000 at Sotheby's and $35,000 at Christie's.[24] Meanwhile, in 2006, the average price of a work sold across all other auction houses was just above $7,000. In the sample studied by this paper, the average price inclusive of buyer's premium for a *Flowers* print is $24,078.70—putting these prints in the range of works targeted by medium auction houses. Therefore, it is possible that the medium houses place more marketing and sales effort into these works—such as giving them features in the catalogue—than do the major houses, where these works are less likely to be highlight items. This can be seen with the difference in lot order of the prints across the two auction houses. The average lot order is .655 for medium houses, and .911 for major houses. Given the evidence for the declining price anomaly, and assuming the auction houses approximately structure their sales from high to low value works, it is clear that these prints are given more importance by medium auction houses than major ones.

Although insignificant, a number of the variables in this equation are of hypothesized signs. The coefficient of Emerging and Evening are positive, suggesting that realized prices are higher in emerging markets than tertiary ones, and for works included in evening sales than day sales.

Equation 2

The results of Equation 2 are found in the first column of Table 4. The coefficient of ln(AveragePrice) is positive and significant at the 1% level, suggesting that a 1% increase in the average price of the sale increases the realized price of the print by 0.119%. This result further

[24] Thompson, 100.

corroborates the hypothesis that there exist spillover effects on price from the other works included in a sale.

The coefficient of the interaction of PeakMonth and Emerging is negative and significant at the 10% level, implying that prices in emerging markets during peak months are lower than prices in small markets in summer or winter months. However, while insignificant, the coefficients of Emerging and PeakMonth are both positive, suggesting that the hypothesized positive correlation between these variables and realized prices may still hold.

Although insignificant, the negative coefficient of LotOrder further corroborates the existence of the declining price anomaly in this sample. The positive coefficient of SaleRate also suggests that a higher sale rate for the total sale not only increases likelihood of sale, but also the realized prices of works that sold. Finally, the positive coefficient of Evening supports conventional wisdom that the prestige of evening sales helps increase realized prices.

Equation 3

The results of Equation 3 are found in the second column of Table 4. As in Equation 2, the coefficient of ln(AveragePrice) is positive and significant at the 1% level, suggesting that a 1% increase in the average price of a sale is correlated with a 0.175% higher average pre-sale estimate. This result implies that auction houses take into account the value of other works in the sale when setting estimates for each specific work.

An interesting result is that the coefficients for both Medium and Major are negative and significant at a 5% and 1% level respectively. The results suggest that compared to small auction houses, average estimates are 17.6% lower at Bonhams and Phillips and 27.5% lower at Christie's and Sotheby's. It seems unlikely that estimates are set solely based on the inherent value of and demand for a work, as medium and major auction houses should be able to win

higher quality consignments for their sales, not lower ones. Instead, this result supports the conclusion that larger auction houses are more strategic at setting estimates than smaller houses—as seen in the first regression, the coefficient of ln(AverageEstimate) is negative and significant at the 1% level, suggesting that lower estimates increase the likelihood of sale. Similar findings have been observed in the real estate market with the pricing strategy of experienced brokers and sellers.[25]

The magnitude and significance of the results for the year dummy variables in Equations 2 and 3 are consistent with art market trends in the last two decades (see Chart 1). The first observation, the reference year, occurred during a bubble in the market that lasted from 1989 to 1990. All subsequent coefficients are negative until 1999. Since about 2006, the share of Warhol works in the total auction gross has grown significantly due to increased demand for Warhol, corresponding to higher prices and highly significant higher magnitude coefficients. In fact, 74% of the observations in this sample occur after 2005.

In addition, the high R-square values for both Equations 2 and 3 are notable. The results suggest that over 80% of the variation in price for effectively identical prints can be explained by year-on-year market trends and differences in the auction environment, signifying that strategic decisions and negotiations made by sellers and auction houses may be highly impactful.

Equation 4

The results of Equation 4 are found in Table 5. The result is positive and significant at the 1% level and supports that auction estimates are highly correlated with realized hammer prices.

[25] Benjamin, John, and Peter T. Chinloy. "Pricing, exposure and residential listing strategies." *Journal of Real Estate Research* 20.1 (2000): 61-74.

This sample also suggests overestimation by auction houses, as a 1% increase in the average estimate is associated with a 0.869% increase in the hammer price.

While this analysis would benefit from examining Equation 4 for each caliber of auction house in order to determine which houses set more accurate estimates, the limited number of observations for each led to insignificance. Finally, although this result could signify that auction houses are accurate predictors of value and demand, the possibility of reverse causality exists, where buyers are credulous of estimates that are set strategically.

VII. Potential Sources of Error

The largest source of error stems from the difficulty of obtaining data for the sample. The small sample size and large number of variables tested leads to insignificance for some of the variables. For example, no meaningful conclusions could be gathered from the variables representing the type of sale the work is included in—likely because the majority of works in the sample were included in prints sales.

Because the art market is relatively obscure and unregulated, information published by auction houses varies significantly. For auction houses located outside of the U.S., data obtained outside of ArtNet—primarily total sale sums—utilized foreign exchange rates from the day of the sale. Meanwhile, it is suspected the price data on prints obtained from ArtNet uses slightly different exchange rates, such as from the date the results were published or entered into the ArtNet system. While this error is assumed to be small, it nevertheless could impact final results due to the small nature of the sample.

In addition, whereas ArtNet provided the price inclusive of buyer's premium, finding records of historical buyer's premiums in order to determine the hammer price proved

challenging, especially for smaller auction houses. In some cases, buyer's premiums were approximated based on industry standards at the time. This approximation could affect some of the data on hammer prices, and subsequently the results of Equation 4.

The use of the multiple imputation method naturally introduces the possibility of error into the data. However, this amount of error is assumed to be small, as the missing data is for the most part random and only about 9% of the data is imputed. Results obtained without the imputed data are greatly similar, without the higher levels of significance allowed for by more observations.

Finally, while this paper assumes that the majority of prints in the sample are homogenous and thus discounts potential issues of endogeneity, there lingers the possibility that some differences in the preservation and physical condition of the prints are not mentioned in presale reports or in auction catalogues. Because this cannot be observed in the data, this paper concludes that differences between auction houses' estimates cannot be entirely attributed to differences in quality or condition. In reality, estimates are used by auction houses and buyers as a strong indicator of precisely these factors. Although the information may not be detailed in the catalogues, there could exist unobservable unique characteristics of the works that are captured by the auction estimate.

VIII. Concluding Remarks and Areas for Further Research

The results of this study suggest that clear violations of the law of one price exist in the art auction industry, stemming from unique sale environments created by the auction experience. The most significant factors that increase the likelihood of sale for identical prints are a high rate of sale for the total auction, a relatively low presale estimate, a high average price for the total

sale, a low lot number, and being auctioned by Bonhams or Phillips. Aside from market trends, the most significant factor that increases the realized price of a work are a high average price for the total sale—indicative of spillover effects from other works included in the same sale. The results also suggest that on some level, auction houses set presale estimates strategically, based on factors aside from the inherent quality and condition of the work. The most important factors that auction houses take into account when setting estimates seem to be the value of other works included in the sale. Larger, more established houses are likely more strategic at setting estimates—valuing lower to increase the probability of sale. All in all, presale estimates do prove significantly correlated with realized hammer prices. However, whether this is because auction houses are good predictors of value and demand, or if investors are credulous of estimates that take into account other factors remains unclear and beyond the scope of this paper.

A prudent seller would be wise to negotiate with medium auction houses for his or her work to be included in a sale with high valued and in-demand works, with an early lot placement, and relatively low presale estimate.

Due to the time constraints of this study, the sample was restricted only to *Flowers* prints. An interesting experiment for further study would be to perform the same empirical exercises on another set of prints, perhaps from a different artist or art historical style, in order to better be able to generalize these results for the market as a whole. Additionally, while the effects of provenance could not be studied for this sample, older prints, such as Old Master's prints by artists like Albrecht Dûrer are more likely to have longer and more notable provenances—making them more appropriate samples to examine this question.

Access to a wide archive of auction catalogues would also allow for a closer examination of the effects of marketing undertaken by the auction house. For example, a variable indicating

whether the work received a full-page feature in the catalogue or was on the front cover could have been included in the equations modeled. Perhaps this would require limiting the sample to major auction houses for which such records exist. Finally, a rapidly growing market in the art industry is that of online sales. As smaller startups like Paddle8 and Artsy are seeing success auctioning work exclusively online, the major houses are also adjusting to meet this new demand. Christie's is increasingly emphasizing online sales for jewelry and luxury items, while Sotheby's very recently launched an online sales platform partnered with EBay. While the dynamics of online auctions are largely different from physical showroom sales, it would be interesting to see how the availability of an online market place impacts the sale of works—especially less expensive, more commoditized works like prints.

Table 1: Summary of Variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Sold	212	.840	.368	0	1
PricePremium	212	24078.7	17291.07	0	84450.19
PriceHammer	212	19794.33	14160.09	0	67290.99
LotOrder	202	.773	.276	.004	1
SaleRate	192	.751	.134	.218	.993
AverageEstimate	212	22492.35	11576.98	4000	84450
AveragePrice	190	22690.63	34686.49	1613.703	354416
PeakMonth	212	.717	.452	0	1
Medium	212	.10	.30	0	1
Major	212	.505	.501	0	1
Prints	212	.613	.488	0	1
IMC	212	.25	.434	0	1
Emerging	212	.085	.279	0	1
Traditional	212	.642	.481	0	1
Evening	212	.080	.272	0	1
Year1 (1989)	212	.024	.152	0	1
Year2 (1992)	212	.009	.097	0	1
Year3 (1993)	212	.009	.097	0	1
Year4 (1994)	212	.014	.118	0	1
Year5 (1996)	212	.028	.166	0	1

Year6 (1997)	212	.005	.069	0	1
Year7 (1998)	212	.014	.118	0	1
Year8 (1999)	212	.014	.118	0	1
Year9 (2001)	212	.038	.191	0	1
Year10 (2002)	212	.004	.069	0	1
Year11 (2003)	212	.071	.257	0	1
Year12 (2004)	212	.005	.069	0	1
Year13 (2005)	212	.024	.152	0	1
Year14 (2006)	212	.052	.222	0	1
Year15 (2007)	212	.071	.257	0	1
Year16 (2008)	212	.099	.299	0	1
Year17 (2009)	212	.038	.191	0	1
Year18 (2010)	212	.061	.240	0	1
Year19 (2011)	212	.066	.245	0	1
Year20 (2012)	212	.066	.245	0	1
Year21 (2013)	212	.118	.323	0	1
Year22 (2014)	212	.170	.376	0	1

Table 2: Summary of Results of Multiple Imputation

***m* = 0**

Variable	Obs	Mean	Std. Dev.	Min	Max
LotOrder	202	0.773	0.276	0.004	1
SaleRate	192	0.751	0.134	0.218	0.993
AveragePrice	190	22690.63	34686.49	1613.703	354416
ln(AveragePrice)	190	9.660	0.808	7.386	12.778

***m* = 1**

Variable	Obs	Mean	Std. Dev.	Min	Max
LotOrder	212	0.772	0.275	0.004	1
SaleRate	212	0.745	0.136	0.218	0.993
AveragePrice	212	26203.07	46151.63	1613.703	354416
ln(AveragePrice)	212	9.692	0.864	7.386	13.690

***m* = 20**

Variable	Obs	Mean	Std. Dev.	Min	Max
LotOrder	212	0.765	0.282	0.002	1
SaleRate	212	0.744	0.140	0.218	0.993
AveragePrice	212	26675.77	46020.93	480.018	354416
Ln(AveragePrice)	212	9.687	0.856	7.386	12.778

Table 3: Results, Equation 1

VARIABLES	(1) Logit Coeff	(2) Odds Ratio	(3) Average Marginal Effects
Sold			
LotOrder	-2.740*	0.0646*	-0.228*
	(1.523)	(0.0984)	(0.123)
SaleRate	5.537***	254.0***	0.461***
	(2.028)	(515.0)	(0.159)
ln(AveragePrice)	0.637*	1.891*	0.053*
	(0.380)	(0.719)	(0.031)
ln(AverageEstimate)	-2.031***	0.131***	-0.169***
	(0.650)	(0.0852)	(0.051)
Medium	2.788*	16.25*	0.233*
	(1.424)	(23.14)	(0.116)
Major	1.145	3.143	0.096
	(0.877)	(2.756)	(.072)
Prints	-1.407	0.245	-0.118
	(1.352)	(0.331)	(0.113)
IMC	-0.467	0.627	-0.039
	(0.987)	(0.618)	(0.082)
Emerging	1.272	3.569	0.106
	(1.425)	(5.086)	(0.118)
Traditional	-0.0289	0.971	-0.002
	(1.137)	(1.104)	(0.095)
Evening	0.382	1.466	0.032
	(1.062)	(1.556)	(.089)
PeakMonth	-0.104	0.901	-0.009
	(0.976)	(0.879)	(0.081)
PeakMonth_Emerging	-1.299	0.273	-0.108
	(1.729)	(0.472)	(0.143)
PeakMonth_Traditional	1.871	6.495	0.156
	(1.307)	(8.487)	(0.108)
Constant	13.71**	897,174**	2.640**
	(6.317)	(5.668e+06)	(0.365)
Observations	212	212	212

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Results, Equations 2 & 3

VARIABLES	(1) ln(PricePremium)	(2) ln(AverageEstimate)
LotOrder	-0.197	-0.0256
	(0.151)	(0.133)
SaleRate	0.264	0.318
	(0.222)	(0.193)
ln(AveragePrice)	0.119***	0.175***
	(0.0358)	(0.0335)
Medium	-0.137	-0.176**
	(0.0975)	(0.0856)
Major	0.0162	-0.275***
	(0.103)	(0.0920)
Prints	0.0228	0.173
	(0.146)	(0.128)
IMC	0.115	0.0912
	(0.107)	(0.0901)
Emerging	0.155	-0.125
	(0.168)	(0.151)
Traditional	0.0137	0.000720
	(0.143)	(0.112)
Evening	0.0947	0.0794
	(0.117)	(0.103)
PeakMonth	0.122	0.0513
	(0.134)	(0.100)
PeakMonth_Emerging	-0.399*	0.0784
	(0.220)	(0.175)
PeakMonth_Traditional	-0.110	-0.0546
	(0.157)	(0.122)
Year2	-0.687***	-0.0253
	(0.257)	(0.247)
Year3	-0.555**	-0.241
	(0.249)	(0.237)
Year4	-0.602***	-0.612***
	(0.225)	(0.212)
Year5	-0.617***	-0.452***
	(0.187)	(0.168)
Year6	-0.724**	-0.565*
	(0.340)	(0.337)
Year7	-0.489**	-0.218
	(0.235)	(0.213)
Year8	-0.0930	-0.204
	(0.215)	(0.203)
Year9	-0.325*	-0.375**

	(0.168)	(0.155)
Year10	-0.148	-0.299
	(0.312)	(0.301)
Year11	0.109	0.0844
	(0.164)	(0.147)
Year12	0.248	-0.0973
	(0.312)	(0.301)
Year13	0.440**	0.0894
	(0.196)	(0.183)
Year14	0.815***	0.582***
	(0.181)	(0.165)
Year15	1.096***	0.674***
	(0.172)	(0.156)
Year16	0.922***	1.212***
	(0.181)	(0.158)
Year17	0.443**	0.587***
	(0.201)	(0.167)
Year18	0.659***	0.818***
	(0.183)	(0.166)
Year19	0.774***	0.797***
	(0.180)	(0.159)
Year20	0.820***	0.864***
	(0.172)	(0.156)
Year21	0.804***	0.838***
	(0.166)	(0.148)
Year22	0.913***	0.672***
	(0.168)	(0.150)
Constant	8.254***	7.414***
	(0.428)	(0.376)
Observations	178	212
R-square	0.849	0.831
Adj. R-square	0.813	0.798

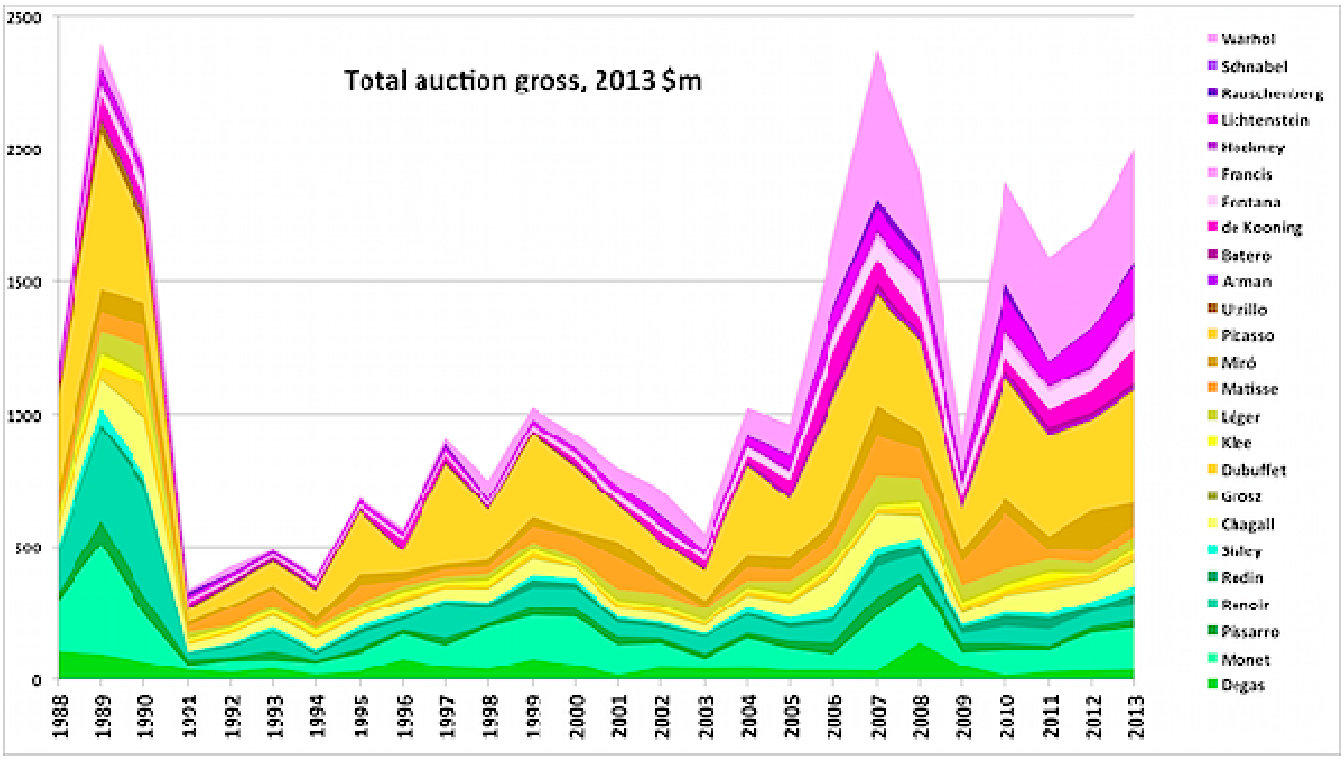
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Results, Equation 4

VARIABLES	(1) ln(PriceHammer)
ln(AverageEstimate)	0.869***
	(0.0394)
Constant	1.377***
	(0.387)
Observations	178
R-square	0.735
Adj. R-square	0.733

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Chart 1: Total Auction Gross by Artist[26]



[26] Salmon, Felix. "Art Market Chart of the Day, Auction Gross Edition." *Reuters*. Reuters, 16 Dec. 2013. Web.

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