Trust in Art Markets

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Abstract: Trust is the cornerstone in financial markets. We exploit the art auction market as the laboratory to test the economic impact of information disclosure. We collect provenance data and apply textual analysis to categorize it into information relating to pedigree (ownership chains relating buyers to artists), exhibition history (museums, art fairs, cultural cities), literature coverage, and authentication (physical and non-physical proof of authenticity by artists, experts). We find that provenance information on average increases the artwork's probability of being sold by 3%, leads to a price premium by 30%, after controlling for artwork characteristics (such as topic, authenticity), artist, time, and auction house fixed effects. In addition, the incremental provenance for the pair of the repeat sales has positive effects on artwork return.

Keywords: Auction; art investment; cultural economics.

JEL Code: D44, G20, G11, Z11

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1. Introduction

Financial decision making requires not only an assessment of the risk-return trade-off, but also an act of trust that the information is reliable and that the overall system is fair (Guiso, Sapienza, and Zingales (2008); Sato (2014)). Trustworthy and reliable information disclosure is highly appreciated and widely utilized in this process. Investors rely on audit reports to evaluate and model target companies. Credit rating agencies regularly issue credit ratings to summarize the overall quality of the underlying assets. However, information disclosure is not the only driver on valuation and return in the traditional financial markets (e.g., the stock, bond, and derivatives markets) and its impact is intertwined with other fundamental factors. Traditional financial markets are comparatively highly regulated with opaque and unified information disclosure requirements. These standard assets offer few heterogeneities in information disclosure. On the contrary, artworks have no fundamental values and the valuation is largely determined by information discourse and buyer preference. The art market renders more variations in information disclosure. Therefore, we choose the art auction market as a laboratory to assess the impact of trust or information disclosure in a direct and detailed approach. This design offers a new angle to answer the research question: how does information disclosure play a role in a financial market?

Art market is different from the traditional financial market in three aspects. First of all, there are some common practices regarding what information to disclose to potential buyers but the discrepancies are much larger due to the lack of regulations. One can obtain artist information, physical attributes, and transaction records of a collective good as well as provenance including pedigree, exhibition history, literature coverage, and authentication. Common sources are catalogues prepared by auction houses, art experts or exhibitors.

Second, the art market is illiquid and opaque. Only 2% of past sales will reenter the auction market and the average repeat sales period is about 7 years (Renneboog and Spaenjers (2013)).

There is no continuous auction market for price formation and negative information is not timely priced due to the lack of short selling possibilities. The buyer and sellers are anonymous in most cases and the reserve prices are usually not revealed. For valuation purpose, as there is no fundamental value of an art piece, one has to rely on hedonic regressions which translate various characteristics into financial value.

Third, the market is saturated with and affected by fakes and forgeries despite the fact that any art piece is unique as there are no exact same paintings nor prints. A former director of the MoMA (the Museum of Modern Art in New York City) once revealed that up to 40% of the high end art market consists of forgeries (Thompson (2010)). Determining the authenticity are essential in art valuation (Bocart and Oosterlinck (2011)). Application of thorough technical inspections will help, while digesting the textual information of provenance relating to an art piece is intuitive and useful.

Art auction market is an important alternative financial market. High-net-worth individuals (HNWIs) hold on average 9% of their investment portfolios in art and other types of collectibles (such as Bordeaux wines, classic cars, superior watches, etc.). The total value of collectibles held by HNWIs is estimated at more than US$ 4 trillion (Deloitte, 2013). Purchases of art through auction houses and internet auctions have grown rapidly over the past two decades (Deloitte, 2014, 2016) and global art sales exceeded US$ 40 billion in 2015 and 2016 (Pownall, 2017). The relevant literature in finance has focused on the risk-return relationship of art (Mei and Moses (2002), Renneboog and Spaenjers (2013), Korteweg, Kräussl, and Verwijmeren (2015), Lovo and Spaenjers (2018)), its macro-economic market drivers (Goetzmann, Renneboog, and Spaenjers (2011), sentiment and hype (Pénasse, Renneboog, and Spaenjers (2014)), and whether behavioral anomalies such as anchoring (Beggs and Graddy (2009), Graddy et al. (2015)) appear in the art market. However, none of these studies focus on the more fundamental question of how

information disclosure and trust play a role in this market in a direct approach and very few studies are on the effects of authenticity or counterfeits (Bocart and Oosterlinck (2011)).

In this paper, we collect provenance data from art auctions and apply textual analysis to disentangle the provenance information into four categories: pedigree, exhibition history, literature coverage, and authentication. The first category, pedigree, is the ownership chain from the artist who created the art work to buyers. It also contains information about inheritance within families as collection. Pedigree is like a biography of an art piece and renders details from the origin of it to hands that hold it. It adds traceability and credibility to an art piece. We compose comprehensive lists of royals, successful businesspersons, influential politicians, celebrities, and other prominent names. String searches are conducted within the pedigree information. As these buyers may have different sources of art expertise to help them in acquiring arts, such real purchases reveal their authenticity opinions. The second category, exhibition history, documents the past exhibitions in various occasions including museums, art fairs, and exhibitions in important cultural cities. Prominent exhibitions such as famous museums or biennale usually have a high standard of art quality and do not tolerate (suspicious) counterfeits. Prominent exhibitions can serve as a filter on authenticity as well as quality and popularity indicator. The third category, literature coverage, offers books, catalogues, and scholarly articles covering the art piece. The most important literature form for art reference is the catalogue raisonné, which includes all the known artworks by an artist. The fourth category, authentication, provides physical or non-physical proof of authenticity issued by the artist, the artist's close family, art experts, or other relevant parties.

By utilizing these novel variables, we improve the accuracy of hedonic regression models. We study the economic impact of various detailed levels of provenance variables on 1) probability of being successfully sold in an auction, 2) valuation of the artwork, 3) performance of return in the subsample of repeat sales. We find that provenance information on average increases the probability of being sold by 3%, leads to a price premium by 30%, after controlling for artwork

characteristics (such as topic and authenticity), and artist, time and auction house fixed effects. In addition, the incremental provenance of the repeat sales has positive effects on the artwork returns. We contribute to the literature in three aspects. First, we investigate the economic impact of information disclosure in a unique financial market in a direct way. Second, we add a set of important variables into the hedonic regression model. These variables are constructed from textual information of provenance untouched in literature and this method can be used in other illiquid or non-standardized financial market. Third, we add to the literature on cultural economics by revealing the important role of provenance in sales realization, valuation, and repeat sales return.

The paper proceeds as following. Section 2 describes methodology and data. Section 3 documents empirical results. Sections 4 concludes.

2. Methodology and data

2.1 Methodology

2.1.1 Hedonic price regression

To investigate the provenance effects on price, we start with hedonic price regression. The main advantage of hedonic model is that information on all observed transactions is included. Our model relates the natural logs of real USD prices to provenance variables, while controlling for a wide range of hedonic characteristics:

$$\ln(P_{it}) = \alpha + \sum_{m=1}^{M} \beta_m X_{mit} + \sum_{t=1}^{T} \gamma_t D_{it} + \sum_{n=1}^{N} \beta_n Provenance_{nit} + \varepsilon_{it} \qquad (1),$$

where P_{it} represents the price of art object i at time t, X_{mit} is the value of characteristic m of item i at time t, and D_{it} is a time dummy variable that equals one if object i is sold in period t (and zero otherwise). $Provenance_{nit}$ is the value of provenance characteristic n of item i at time t. The coefficients β_m reflect the attribution of a relative shadow price to each of the m characteristics, and the coefficients γ_t reflect the time trend, which can be used to construct an art price index. The

coefficients β_n reflect the provenance impacts on prices. We will describe all the hedonic and provenance variables in Data and variables section.

2.1.2 Hedonic linear probability regression

In addition to hedonic price regression, we are also interested in the impacts of provenance information on the probability of being sold of artworks. The dependent variable in the regression is the sale results (sold / unsold). The independent variables in this equation are the same with Equation (1):

$$Prob(sold_{it}) = \alpha + \sum_{m=1}^{M} \beta_m X_{mit} + \sum_{t=1}^{T} \gamma_t D_{it} + \sum_{n=1}^{N} \beta_n Provenance_{nit} + \varepsilon_{it} \qquad (2).$$

2.1.3 Repeat sales returns

Another interesting question is whether the provenance information affects the returns of artworks. We construct repeat sales and examine whether the incremental changes of provenance happening between two sales have an impact on returns for the exact same painting. The dependent variable r_{it} in Equation (3) is the annualized return of the repeat sales. We include the same hedonic control variables as in Equation (1) and Equation (2). $Provenance_{ni(t-k)}$ is the value of provenance characteristic *n* of repeat sale item *i* at time *t-k, and* $Provenance_{nit}$ is the value of provenance characteristic *n* of repeat sale item *i* at time *t.* $Provenance_{nit} - Provenance_{ni(t-k)}$ captures the changes of provenance for the same painting from time *t-k* to time *t.* The coefficients δ_n reflect the incremental provenance effects on the returns of artworks:

$$r_{it} = \alpha + \sum_{m=1}^{M} \beta_m X_{mit} + \sum_{n=1}^{N} \beta_n Provenance_{ni(t-k)}$$

$$+ \sum_{n=1}^{N} \delta_n (Provenance_{nit} - Provenance_{ni(t-k)}) + \varepsilon_{it} \quad (3).$$

We will describe all the hedonic and provenance variables in next subsection (Data and variables).

2.2 Data and variables

We focus on the market for oil paintings, watercolors, and drawings, which are the major transactions in the art market. We collect all relevant transactions from 2007 to 2015 with provenance information in the online database *Blouin Art Sales Index*. The dataset consists of 1,812,807 transactions in total with 1,195,640 sold observations (65.96%) and 617,167 unsold observations (34.04%). The dataset covers 608 auction house branches all over the world and include around 70,000 artists. We choose 2007 as start year because the Art Sales Index has incomplete provenance information and buy-ins (i.e., items that do not reach the reserve price and remain unsold) in the earlier years. For each observation, we have all the artist, artwork, and transaction characteristic such as artist, title, medium, size, attribution, creation year, signed, dated, sold, not sold, price, lot number, low estimate, high estimate, date, auction house, and also provenance text. We deduct the buyer's cost and adjust all the prices to hammer prices in deflated USD. We disentangle the provenance information into four dimensions: pedigree, exhibition, literature, and authentication. We apply textual analysis to the provenance text and categorize each dimension into tens of subfields, which will be discussed in provenance variables subsection.

2.2.1 Classic hedonic variables

We follow Renneboog and Spaenjers (2013) and include all the classic hedonic pricing variables as control variables in our regressions. Our hedonic regressions include a number of attributes related to the artist, the work, and the transaction. The descriptive statistics for the hedonic variables are in Table 1.

[Insert Table 1 about here]

Artist characteristics. We include the artist fixed effects and dead artist dummy. The artist fixed effects capture each artist's uniqueness and reputation. The dummy variable Deceased, which equals one if the sale occurs after the artist's death, captures the effect that the prices for artworks increase after the death of an artist as a supply shock. We have 76.68% transactions occurred when the artists were deceased.

Artwork characteristics. We consider a wide range of price-determining variables that capture the attribution, authenticity, the medium, the size, and the topic of the work of art:

- Attribution. Six levels of attribution are used in the auction world: Attributed (to), Studio (of), Circle (of), School (of), After, and (in the) Style (of). About 3.38% of the observations in our sample carry such an attribution.
- Authenticity. We include Signed, Dated, and Inscribed variables. About 80.41% of artworks are signed, about 36.28% are dated, and about 11.38% are inscribed.
- Medium. We introduce dummies for the different medium categories: Oil, Watercolor, and Drawing. About 68.13% of the transactions are oil paintings, 20.48% are watercolors, and 11.39% are drawings.
- Size. The height and width in centimeters are represented by Height and Width (with squared values Height_2 and Width_2).
- Topic. The subject matter can significantly affect the aesthetic appreciation of art objects. We categorize the works in different topic groups based on the keywords of the artworks' titles and account for 7 major languages used in art auction world[1]. We have13 categories: Abstract, Animals, Landscape, Seascape, Urbanscape, Nude, People, Self Portrait, Portrait, Religion, Still Life, Study, and Other Topics (as the omitted benchmark in our regressions).

[1] They are English, Dutch, French, German, Italian, Spanish, and Portuguese. In our other string search exercises, we also compile keywords in these 7 major languages if necessary and have the keywords list checked by native speakers.

Transaction characteristics. We include dummies that indicate the timing of the sale, and the reputation and location of the auction house:

- Year and month. We control the time effects of auction. The busiest months are May, June, November, and December.
- Auction houses. We make a distinction between different fine art auction houses. For Sotheby's and Christie's, we introduce dummy variables for their London, New York, and other branches (e.g., Sotheby's London, Sotheby's New York, and Sotheby's Other Branches). For two other big British auction houses, Bonhams and Phillips, we make a distinction between their London sales rooms and other branches (e.g., Bonhams London and Bonhams Other Branches). We also create two dummies to account for the sales by important European and American auction houses (Auction European and Auction American) following the same standards in Renneboog and Spaenjers (2013). The classification in details is in the Appendix.

2.2.2 Provenance variables

We apply textual analysis to identify and categorize provenance information. We classify the provenance information into four dimensions: pedigree, exhibition, literature, and authentication. As shown in Table 1, we have 14.20% observations with pedigree information, 3.74% with exhibition information, 4.02% with literature information, and 3.89% with authentication information.

The first dimension is **pedigree.** Pedigree dimension includes the ownership chains and the identity of past owners, for example, whether the painting was once in the collection of prominent collectors, the royal and noble families, wealthy families, CEOs, Time 100 influential people, celebrities and athletes, etc. If the whole ownership chain between the artist and buyers can be traced, the artwork has a higher probability of being authentic. A painting with authenticity signal

or glamour provenance trades at a premium. For example, if a famous individual (e.g., a superstar) has once owned the painting, its provenance induces a signal of authenticity and has glamour effects. A painting once owned by a celebrity not only attracts buyers by its artistic value and the history of the object, but also lures collectors by the associations with the celebrity who owned the painting. Ennobling a work's provenance can turn an ordinary object into an extraordinary one, and a moderately valuable object into a supremely valuable object.

Besides, we examine owner credibility such as whether the work of art was acquired directly from artist, from artist family, from sitter or has descent information. If the artwork is directly from the artists, its provenance serves as a strong signal of the artwork's authenticity. We also check whether the artworks were once sold through some prominent auction houses or some prominent dealers. For all the prominent name lists, we consider both historic and contemporary names. For the textual analysis, we collect the name lists from more than 150 databases and sources, which can be found in the Appendix and Online Appendix. The variables relevant to pedigree dimension are as following.

- Past ownership: Prominent Collector, Royal / Noble, Wealthy Families, CEO, Time 100, Celebrity, and Athlete.
- Descendance: Direct from Artist, From Artist Family, From Sitter, and Descent.
- Past sale channel: Sold at Sotheby's and Christie's, Sold at Bonhams and Phillips, Sold at Historic Auction Houses, Sold at Other Important Auction Houses, and Prominent Dealer.
- Other Collection: Anonymous Corporate Collection, Anonymous Private Collection, and Pedigree Other (unclassified pedigree information).

The descriptive statistics for provenance variables are in Table 2. We have 256,560 observations with pedigree information and the average text length is 104 letters. Among all the observations with pedigree information, about 2.07% of the observations were once in the

collection of prominent collectors, 5.75% in the collection of prominent dealers, 2.39% of royal / noble collectors, 0.68% of wealthy collectors, 0.06% of CEO collectors, 0.08% of Time 100 influential people, 0.2% of celebrities, and 0.12% in the collection of famous athlete collectors. For the owner credibility, about 10.50% observations with pedigree information can be traced back to the very origin where the paintings were purchased directly from artists, 5.29% from the artists' families, and 0.33% from the sitters (the persons pictured in the artwork), and 9.81% contain descendance information in the pedigree text. Regarding the previous sales records, about 15% of observations with pedigree information were once sold at Sotheby's and Christie's, 0.9% at Bonhams and Phillips, 1.33% at historically important auction houses, and 1.30% at other important auction houses.

[Insert Table 2 about here]

The second dimension is **exhibition.** We categorize exhibition records into prominent exhibition, prominent art fair, prominent museum, exhibition in culture city, etc. The past exhibitions reflects the reliability and importance of the provenance information leading to a premium in auction value. The exhibition variables include Prominent Exhibition, Prominent Art Fair, Prominent Museum, Other Museum, Culture City, and Gallery Exhibition.

We have 67,713 observations with exhibition information and the average text length is 209 letters. The average record number is about 1.98. Among all the observations with exhibition information, about 6.20% of the observations were once exhibited at prominent exhibition events, 0.39% at prominent art fair, 17.20% at prominent museums, 29.90% at other museums, 74.10% at culture cities, and 14.90% at galleries.

The third dimension is **literature**. We consider whether the artworks are illustrated in the catalogue raisonné, on the cover page of books, or whether the literature is published by authoritative presses. A catalogue raisonné is a comprehensive listing of all the known artworks

of the artist. If the auction houses and buyers have any doubts on the authenticity, they will always refer to the catalogue raisonné. The literature variables include Catalogue Raisonné, Cover Page, Illustration, Authoritative Press, and Other Literature.

We have 72,906 observations with literature information and the average text length is 242 letters and the average record number is about 1.53. Among all the observations with literature information, about 15.70% of the observations are illustrated in the Catalogue Raisonné, 1.66% are on the cover pages of books, 45.90% are illustrated in books, and 1.15% are in the books published by authoritative presses.

The fourth dimension is **authentication**. We consider two aspects: 1) who has issued the authentication (including artist, artist family, association, expert, and other parties) and 2) what form of the authentication is (physical certificate vs. non-physical confirmation (orally or lacks physical proofs)). We have 10 variables in the authentication dimension:, Artist Physical Artist Family Physical, Association Physical, Expert Physical, Other People Physical, Artist Non-Physical, Artist Family Non-Physical, Association Non-Physical, Expert Non-Physical, and Other People Non-Physical.

We have 70,556 observations with authentication information and the average text length 67 letters. Among all the observations with authentication information, about 31.70% of the observations are with physical authentication issued by artists, 6.16% by artists' families, 15.10% by artists' associations, 2.72% by experts, and 27.60% by other parties. In addition, about 5.31% of the observations are with non-physical authentication by artists, 2.20 % by artists' families, 4.45% by artists' associations, 2.88% by experts, and 6.15% by other parties.

3. Empirical results

3.1 Provenance and prices

Table 3 shows the parameter estimates of the hedonic variables for our hedonic price regression. Eq. (1) is estimated using ordinary least squares (OLS) and the dependent variable is the natural log of the deflated hammer price in USD. For 1,111,220 sales we have complete information on all hedonic characteristics presented in the previous section. For the classic hedonic variables, we have consistent results with Renneboog and Spaenjers (2013). Artworks with attribution "style", "after", "school", "circle", "studio", and "attributed" are priced with large discounts. Signed, dated, or inscribed works tend to have higher prices. Oil paintings and watercolors are priced higher than the drawings. Furthermore, prices increase with size, up to the point that the work becomes too large, which is indicated by the negative coefficients on the squared terms. In addition, artworks on portraits and studies are traded with discounts. Sotheby's London and Christie's London sell artworks with highest prices on average.

[Insert Table 3 about here]

The provenance variables in Column (1) are the dummy variables if the artworks have any information in pedigree, exhibition, literature, and authentication. The presence of pedigree, exhibition, literature, and authentication has big economic effects on the price level of artworks after controlling all the classic hedonic variables. We approximate the price impact by taking the exponent of the coefficient and subtracting one. If the artwork has any pedigree information, the price increases by 20.74%; if has exhibition information, the price goes up by 41.89%; if has literature information, the price goes up by 53.54%; if has authentication information, the price increases by 13.85%. The literature information has biggest impacts on the price of artworks. In Column (2) and Column (3), we use text length and number count variables of pedigree, exhibition,

literature, and authentication, respectively. We have significant and consistent results for the provenance variables in Column (2) and Column (3).

[Insert Table 4 about here]

Table 4 shows the results of the detailed elements of provenance information with all the same control variables applied in Table 3. In pedigree dimension, the past ownership such as prominent collectors, royal / noble families, wealthy families, and famous athletes has big economic effects on the price level of artworks. Artworks are on average priced 24.40% higher if once in the collection of prominent collectors. If the artwork is in the collection of royal / noble families, the price increases by 31.31%; if in the collection of wealthy families, the price increases by 42.45%; if in the collection of famous athletes, the price goes up by 50.11%. The owner credibility also matters for the price of artworks. If the artwork is purchased directly from the artist, the price increases by 13.84%; if the artwork is from the sitter, the price goes up by 11.27%; if the artwork is with any descendance information, the price goes up by 23.63%. However, if the artwork is from the artist' family, this pedigree information does not affect the price, which suggests that buyers are not likely to pay premiums to the artwork which is from the artist' family. In addition, past sale channel also has an impact on the price of artworks. If the artwork was once sold at Sotheby's and Christie's, at the Bonhams and Phillips, at historically important auction houses, or by prominent dealers, the price goes up 23.63%, 7.11%, 10.04%, and 32.87%, respectively.

Exhibition elements also have big impacts on the price level of artworks. If the artwork was once exhibited at prominent exhibitions, the price increases 26.20%. If the artwork was exhibited at prominent museums or other museums, the price goes up by 58.90% and 20.66%, respectively. If the artwork was exhibited at culture cities, the price goes up 24.17%. However, the artwork once displayed in the prominent art fairs does not affect the price level of artworks.

Literature information is another important factor for the valuation of artworks. All the elements in the literature dimension have large economic effects. If the artwork is in the catalogue raisonné of the artist, on the cover page books, illustrated in books, or in the books published by authoritative press, the price increases by 35.74%, 52.76%, 44.20%, and 41.20%, respectively. The artworks with literature information are more likely to be masterpieces by established artists, which have higher prices in the auction markets.

Authentication information gives a signal on the authenticity of the artwork, which also helps create trust in the market. Table 4 shows that the physical authentication by experts has biggest price impact (40.72%) comparing with other issuers of authentication. For the non-physical authentication, the artist confirmation has biggest price impact (32.45%).

Besides all the classic hedonic variables, high estimates and variation of the high estimates to low estimates also provide information about the valuation of the artworks. High estimates may have anchoring effects, which drive the price up. The estimation variation of high and low estimates indicates the uncertainty of the artworks' valuation. Therefore, we also include the high estimates and estimation variation variables in the price model. We regress the high estimates of artworks and the estimate variation on a series of hedonic variables in the first stage, respectively. In the second stage, we include the residuals of the unreported first stages as independent variables and rerun the price Equation (1).

Table 5 presents the second stage results of the hedonic price regression with high estimates residual and estimation variation residual. We have similar results when including the residuals of high estimates and estimation variation. The magnitude of provenance coefficients remains unchanged compared to Table 3. We also regress all the detailed provenance elements and we have consistent results, which is in Online Appendix.

[Insert Table 5 about here]

3.2 Provenance and probability of being sold

In this subsection, we focus on the impacts of provenance on the probability of being sold in auctions. Table 6 shows hedonic linear probability regression with the same control variables in hedonic price regression. In the linear probability regression, we include the reserve price variable because the reserve price could affect the sale results of artworks. If the artwork has a high reserve price, it is likely that the artworks will be bought in when the highest bid is lower than the hidden reserve price. We apply the low estimate as a proxy for the reserve price as auction evidence shows that the reserve price is very close to the low estimate. We have 1,707,136 observations with all hedonic information and low estimates in total.

[Insert Table 6 about here]

Column (1) of Table 6 shows that the presence of provenance information increases the probability of being sold by 2.39%. In Column (2), the provenance variables are the dummy variables if the artworks have any information in pedigree, exhibition, literature, and authentication. If the artwork has pedigree information, the probability of being sold increases by 1.73%. If exhibition information, the probability increases by 3.79%. If literature information, the probability increases by 2.50%. However, authentication information does not affect the probability of being sold. In addition, the negative coefficient of reserve price indicates that the artworks with higher reserve price tend to have lower probability of being sold.

Table 7 presents the results of linear probability regression with provenance details. In pedigree dimension, the past ownership by prominent collectors, royal / noble families, wealthy families, celebrities, and famous athletes increase the probability of being sold by 5.24%, 6.56%, 8.55%, 3.72% and 9.48%, respectively. For the descendance aspect, the artwork that is directly from the artist has 1.45% higher probability of being sold. The artwork with any descendance information increases the probability by 2.88%. However, if the artwork is from the sitter, the

probability decreases by 8.92%. Regarding to past sale channel, if the artwork was once sold at sold at Bonhams and Phillips or sold at historic auction houses, the probability will be 2.77% and 1.64% lower, respectively. But if the artwork was once in the hands of a prominent dealer, the probability will be 3.77% higher.

[Insert Table 7 about here]

Exhibition elements also matter for the probability of being sold. If the artwork was once exhibited at prominent exhibitions, the probability increases by 2.63%. If the artwork was exhibited at prominent museums or other museums, the probability increases by 5.43% and 1.76%, respectively. If the artwork was exhibited at culture cities, the probability increases by 1.92%. If the artwork was exhibited at galleries, the probability increases by 4.30%. However, the artwork once displayed in the prominent art fairs does not have an impact on the artworks' probability of being sold.

Literature information also has an impact on the artworks' probability of being sold. If the artwork is in the catalogue raisonné of the artist, ono the cover page books, illustrated in books, the probability increases by 2.36%, 5.09%, and 2.07%, respectively. Physical authentication by artists or by artist' associations has positive effects on the probability. If the physical certificate was issued by the artist, the probability increases by 5.99%; if by artist' association, the probability increases by 3.48%. Interestingly, if the artwork is with non-physical authentication by artist' family, the probability will decrease by 3.12%, which indicates that the non-physical authentication by artist' family is still doubtful and not trusted by the participants in art auction markets.

3.3 Provenance and returns

In this subsection, we investigate whether provenance has an impact on the returns. We match our sample using artist name, size, title, medium, and the presence of signature and date. We have 6,647 repeat sales pairs from 2007 to 2015 with a holding period of at least half a year. We annualize the returns of repeat sales and regress the returns on the hedonic variables, the provenance variables at first sales, and the incremental changes of provenance between sales. The provenance variables at first sales control the quality of the provenance information of the artworks while the changes of provenance reflect the additional provenance of artworks happening in between the two sales. The hypothesis is that same paintings with the provenance changes may have positive impacts on returns.

Table 8 shows the return regression results. We are interested in the effects of the incremental provenance on returns. Column (1) - (3) are the full repeat sales sample and Column (4) - (6) are the repeat sales which are sold at the same auction houses. We apply the repeat sales at the same auction houses to avoid the documentation biases across different auction houses. The provenance context formats may differ across auction houses. The results show that the changes of exhibition and literature have positive effects on the returns of artworks. The changes of pedigree and authentication do not affect the returns of artworks.

[Insert Table 8 about here]

Interestingly, for the repeat sales which are sold at the same auction houses (Column (4) - (6)), the authentication information at first sale has a negative effect on returns, which indicates that the authentication information has been overpriced in the first sale and make the returns in the second sale smaller. In addition, we also control the changes of auction houses in the full sample (Column (1) - (3)). If the artwork is sold at a bigger auction house at the second sale comparing with the auction house at the first sale, variable Auction House Upgrade equals one. If the artwork

is sold at a smaller auction house at the second sale, variable Auction House Downgrade equals one. We find that the upgrade of auction house at the second sale has significant and big economic effects on the returns. The annualized returns increase by 39.84% if the artwork is sold at a bigger auction house at the second sale, which could be explained by both the quality of the artwork and the marketability of the big auction houses.

We examine the provenance details in Table 9. Column (1) is the full repeat sales sample and Column (2) applies the repeat sales sold at the same auction houses. We focus on the incremental effects of provenance information. If the artwork is in the collection of prominent collectors, exhibited at museums or exhibited at galleries between the two sales, the returns will increase. In addition, the incremental provenance effects will be much larger if the repeat sales are sold at the same auction houses.

[Insert Table 9 about here]

The negative coefficients of Catalogue Raisonne at First Sale, Authentication Physical at First Sale, and Authentication Nonphysical at First Sale in Column (2) indicate that the literature information and authentication information tend to be overpriced at the first sale and will result in lower returns at the next sale. While the positive coefficients of Owner Credibility at First Sale, Prominent Dealer at First Sale, and Museum at First Sale indicate that the artwork with owner credibility such as if the artwork is direct from artist, with prominent dealers or with exhibition history in museums tends to be undervalued at the first sale and will reach higher returns at the next sale.

3.4 Subsample analysis

The provenance information may vary by auction houses, the medium of artworks and by different artists. In this subsection, we investigate the provenance effects on subsamples by auction houses, medium, and schools and movements.

3.4.1 Auction houses

Table 10 shows that the subsamples by big and small auction houses. We define the big auction houses as Christie's, Sotheby's, and other important European and American auction houses. We control the price variations of auction houses by adding the lag average price of each auction house. We report the dummy variables of Pedigree, Exhibition, Literature, and Authentication in Table 10 and the results of provenance details can be found in the online Appendix.

Column (1) and Column (2) show that the pedigree and literature factors have bigger price impacts in big auction houses while the exhibition and authentication factors have bigger price impacts in small auction houses. It is important to note that the variables are in most cases picking up some unobservable differences in quality, and that the regression coefficients thus reflect correlation instead of causality. The explanation could be that the artworks in big auction houses tend to have more artworks with prominent pedigree records and literature coverage. The authentication factor has less price impacts in big auction houses because big auction houses (such as Christie's and Sotheby's) have good reputations, expertise, and guarantee systems, which is a substitute for the authentication. Big auction houses use their reputations to create the trust in the market and guarantee the quality of the artworks. While for the small auction houses, the authentication is vital and has big impacts on price.

[Insert Table 10 about here]

Column (3) and Column (4) show the results of probability of being sold in big and small auction houses. The authentication factor has negative impacts on the probability in big auction houses and has positive impacts in small auction houses after controlling the price levels of the artworks. The results suggest that the authentication factor negatively affects the artworks' probability of being sold in big auction houses. The artworks with authentication information do not reduce doubts on the artwork's authenticity in big auction houses. The artworks with too much authentication information sometimes can be problematic and the buyers would have more doubts on the artwork authenticity if the items have too many certificates. The buyers trust the authenticity of the artworks in big auction houses and the authentication factor is a minor factor when the buyers consider purchasing items in big auction houses. However, the authentication factor has positive impacts on the probability in small auction houses, suggesting that the buyers will refer to the authentication information when purchasing artworks in small auction houses.

3.4.2 Medium

In this part, we repeat the hedonic regression analysis on three complementary subsamples of our data set: oil paintings, watercolors, and drawings. Table 11 presents the price regression results by medium. Column (1) - (3) show that literature factor has biggest price impacts no matter the artworks are oil paintings, watercolors or drawings. The authentication factor plays less important role for drawings.

[Insert Table 11 about here]

Column (4) - (6) show the provenance effects on the probability of being sold. Authentication factor does not affect the probability across different mediums. Pedigree factor is less important for oil paintings comparing with watercolors and drawings.

3.4.3 Art schools and movements

Finally, we examine the provenance price impacts on different art schools and movements. We use the same classification in Renneboog and Spaenjers (2013) and classify the artists into one of the following art movements: Medieval & Renaissance; Baroque; Rococo; Neoclassicism; Romanticism; Realism; Impressionism & Symbolism; Fauvism & Expressionism; Cubism, Futurism & Constructivism; Dada & Surrealism; Abstract Expressionism; Pop; Minimalism & Contemporary.

Table 12 show the hedonic price regression results for different schools and movements. In general, provenance factors are significant for the all schools and movements. The exhibition and literature factors are significant for all schools and movements. However, the pedigree factor does not matter for Neoclassicism, Minimalism & Contemporary and the authentication factor is not significant for Medieval & Renaissance, Neoclassicism, Dada and Surrealism, and Abstract Expressionism.

[Insert Table 12 about here]

4. Conclusion

A serious problem for the art market is the lack of trust because the art market is not transparent and not efficient. In addition, there are many fakes and forgeries circulating in the market. These problems severely undermine the trust in art markets, which in turn have negative effects on the sales realization and prices in the art markets. The authenticity of artworks is fundamental in creating trust in the market and provenance can be a partial solution to the trust problem by giving signals of the artworks' authenticity. Provenance provides a historical record of its ownership and also relevant exhibition and literature information, which gives evidence of artwork authenticity. Reliable and complete provenance information provides evidence of the

likelihood of an item being authentic or an item being of good quality. As a factor in establishing authenticity, thorough and trustworthy provenance information builds up trust in the art market and adds value to the artworks, while the absence of a provenance record raises questions about the attribution or authenticity of artworks, which negatively affects the work's valuation. Furthermore, a distinguished or glamour provenance, recording the work in the collection of a prominent owner or collection, has a positive impact on the artwork's value.

Accurate provenance information is a fundamental prerequisite for pricing but the provenance factor is rarely studied in the literature. The principal reason is that provenance information is difficult to price. Therefore, the pricing of provenance is not systematized. The valuation process of experts and buyers always depends on their experiences and is sometimes swayed by emotions. Previous studies frequently apply the hedonic model to disentangle determinants of prices of artworks by a wide range of value determining characteristics while the essential provenance factor remains missing.

In this paper, we investigate the effects of provenance on sales realization, price levels, and returns of artwork by applying textual analysis to a dataset of about two million paintings and works on paper. We show that provenance information (including pedigree, exhibition, literature and authentication) matters for the sales realization, prices and returns of artworks. We find that provenance information on average increases the probability of being sold by 3%, leads to a price premium by 30%, after controlling for artwork characteristics, artist, time and auction house fixed effects. In addition, the incremental provenance between the pair of repeat sales has positive effects on artwork returns. In conclusion, we study the economic effects of the elements in the provenance information, which can also be applied to other markets which are not liquid and not transparent. The extensive hedonic models with provenance factors can help to better understand and forecast prices and can be applied to alternative investment markets.

Appendix – Variable definitions, sources and string searches[2]

Other Important EU and US Auction houses	- **Auction European**: The category includes all sales by: Lyon & Turnbull (Scotland), Francis Briest / Artcurial Briest (France), Ader, Picard & Tajan / Ader & Tajan / Tajan (France), Bruun Rasmussen (Denmark), Dorotheum (Austria), Koller (Switzerland), Lempertz (Germany), Neumeister (Germany), Finarte (Italy), Bukowskis (Sweden), Stockholms Auktionsverk (Sweden). - **Auction American**: The category includes all sales by: Butterfields (until 2002), Swann Auction Galleries, Skinner, Doyle New York, Freeman's, Leslie Hindman.
Pedigree	*Past ownership* - **Prominent Collector:** Sources: various lists from artnet The World's Top Art Collectors, Forbes Top Billionaire Art Collectors and Grove Art Online People List,etc; 3885 names[3] in total. - **Royal / Noble:** Sources: textual analysis by searching the royal and noble ranks; 364 ranks and titles in total. - **Wealthy Families:** Sources: lists from Forbes World's Billionaires and Contemporary Wealthiest Family list; 8479 names in total. - **CEO:** Sources: various sources such as Business Week, Financial World, Chief Executive, Forbes, Industry Week, Morningstar, Time Magazine, CNN, Electronic Business Magazine, Ernst & Young, The Finance Monthly, Harvard Business Review, The New York Times, Fortune, etc.; 2703 names in total. - **Time 100**: Sources: Time 100 lists of Titans, Pioneers, Artists, Leaders and Icons and Time 100 Persons of The 20 Century; 3519 names in total. - **Celebrities**: Sources: Top 1000 Actors/actresses/directors/producers in IMDb; famous TV hosts and personalities; 6255 names in total. - **Athletes**: Sources: world champions and superstars of sports such as Golf, Basketball, Tennis, Soccer, Baseball, Motorsport, Cricket, and Hockey; 4872 names in total. *Descendance* - **Directly from Artist:** String search examples: from artist; from the artist; directly from artist; directly from the artist; by artist; by the artist; gift(s) (courtesy / donation(s) / goodwill(s) / bequest(s) / endowment(s) / present(s)) of (the) artist. - **From Artist Family:** String search examples: by descent (by inheritance / estate / legacy / inherited / descended / collection) from artist (the artist / by artist / by the artist / of artists / of the artist / from painter / from the painters); artist's (artist`s / artist's / artist‘s) + family (son / daughter / wife / husband / partner / spouse / girlfriend / boyfriend / widow / brother / sister / sibling / cousin /

[2] We only list major souces of the name lists in the Appendix; the full lists are in the online Appendix.

[3] We create various name patterns for each prominent name in our lists such as middle names and initials.

Pedigree (continued)	grandson / granddaughter / uncle / aunt / nephew / niece / heirs / heir / grandnephew / grandniece). - **From Sitter:** String search examples: sitters; sitter; from sitter; from the sitter; from sitters; from the sitters. - **Descent:** String search examples: descent; descended; inheritance; inherited. *Past sales* - **Sold at Sotheby's and Christie's:** String search examples: Christie; Sotheby - **Sold at Bonhams and Phillips:** String search examples: Bonhams; Phillips - **Sold at Historic Auction Houses:** String search examples: Achenbach; Anderson & Garland; Thomas Dodd; F. Dörling; Dorotheum; Dowell's; Hôtel Drouot; Galerie Fischer; Edward Foster & Son; Messrs Foster; Frederik Muller & Co.; John Gerard; Gerard-Tasset-Juge; Gilhofer & Ranschburg; Goesin-Verhaeghe; Pierre François; Paul Graupe; Heinrich Hahn; Hugo Helbing; Galerie Helbing; Internationales Kunst Auktionshaus; George Jones; Albert Kende; S. Kende; Thomas King; August Klipstein; Galerie Kornfeld; Knight Frank & Rutley; W. S. Kündig; Hans W. Lange; Langford; Mathias Lempertz; Heinrich Lempertz; Gallery Lempertz Contempora; Venator & Hanstein; Kunsthaus Lempertz; Leo Spik; Rudolph Lepke; Bignell Marle; P. L. Mastraeten; Franz A. Menna; Corneille Moor; Morrison Mcchlery; Max Perl; Thomas Philipe; Harry Phillips; Mr. Prestage; Puttick & Simpson; William Richardson; George Henry Robins; Henry J. Robins; Robinson & Foster; Robert Saunders; Hodgson & Co; Saunders & Hodgson; Philippus Van Der Schley; James Webber Southgate; George Squibb; Squibb & Son; Rushworth, Abbott & Co; George Stanley; J. A. Stargardt; William Stewart; E. J. Terlinck; ; De Vries; Adolf Weinmüller; Munich Auction House; Benjamin Wheatley; Willis's Rooms; Winstanley & Sons; Puttick & Simpson; Stewart, Wheatley & Adlard; Wheatley & Adlard. - **Sold at Other Important Auction Houses:** String search examples: Butterfields; Lyon & Turnbull; Francis Briest; Artcurial Briest; Tajan; Bruun Rasmussen; Dorotheum; Koller; Lempertz; Neumeister; Finarte; Bukowskis; Stockholms Auktionsverk; Swann Auction Galleries; Swann Galleries; Skinner; Doyle New York; Freeman's; Freeman`s; Freeman's; Leslie Hindman. - **Prominent Dealer**: lists from artnet, Forbes and Wikipedia; 233 names in total *Other* - **Anonymous Corporate Collection:** String search: corporate collection. - **Anonymous Private Collection:** String search examples: private collection.
Exhibition	- **Prominent Exhibition:** String search examples: retrospective; rétrospective; anniversary; anniversaire; biennale; triennale; biannual; biennial; triannual; triennial. - **Prominent Art Fair:** String search examples: ARCO Madrid, Armory Show New York, Art Basel, Art Basel HK, Art Basel Miami Beach, Art Cologne, Art Miami, Art Santa Fe, ARTISSIMA, Documenta Kassel, FIAC Paris, Frieze London,

	Frieze New York, India Art Fair, PAN Amsterdam, TEFAF Maastricht, TEFAF New York, Venice Biennale, BRAFA Brussels - **Prominent Museum:** Sources: most important museums of paintings in important art cities; 517 museums in total. - **Culture City:** Sources: European Capital of Culture and other culture city around the world; 236 cities in total. - **Gallery Exhibition**: other unclassified exhibitions.
Literature	- **Catalogue Raisonné:** String search examples: catalogue raisonne; catalogue raisonné. - **Cover Page:** String search examples: cover. - **Illustration:** String search examples: illustration; illustrated; cover; images; image; photos; photo. - **Authoritative Press:** Sources: notable university presses and world's largest book publishers.
Authentication	- **Authentication:** String search examples: echtheitsbestätigung; gutachten; essay(s); assessment(s); opinion(s); appraisal(s); expert(s); expertise(s); report(s); mail(s); photocertificate(s); photocopy; photocopies; issued; verified; witnessed; authenticity; authentication. - **Forms-physical:** String search examples: photocertificate(s); report; written; handwritten; photocopy; photocopies; photo(s); photogrpahy; photographic; photograph; foto(s); foto's; photogrpahy; fotografische; fotographie; fotografie; fotografie; fotografien; photogrpahy; photographique; photographie(s). - **Issuers-artist:** String search examples: issued (verified / witnessed / certificates / certificate / certificate + signed / certified / authenticity / authenticity signed / authentication / authentication signed / authenticated / identified / identification / confirmed / confirmation / confirmatory information / registered / registration / registration card / registered / recorded / documentation / letter(s) / photo(s) / photo(s) signed / photograph(s) / photograph(s) signed) + by artist (by the artist / from artist / from the artist / of artist / of the artist). - **Issuers-artist family:** String search examples: son; daughter; wife; husband; partner; spouse; girlfriend; boyfriend; widow; brother; sister; sibling; cousin; grandson; granddaughter; uncle; aunt; nephew; niece; family; descendants; descendant; biographer; pupils; pupil; students; student. - **Issuers-association:** String search examples: authentication; board; estate; foundation(s); fundament; stiftung; fondation; fundación; fundação; fondazione; association; vereniging; verband; asociación; associação; associazione; committee; commissie; ausschuss. - **Issuers-expert:** String search examples: Dr; Prof; curator(s); custodian(s); professor(s); doctor(s); director(s); expert(s); expertise(s); professoren; professore; professoressa; professeur(s); professore(s); professori; profesor.

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Table 1 – Descriptive statistics for hedonic variables

Table 1 presents the descriptive statistics for the hedonic variables. Deceased equals one in case the artist is dead at the time of the sale. The attribution dummies Attributed, Studio, Circle, School, After, and Style equal one if the auction catalogue identifies the work as being "attributed to" the artist, from the "studio" of that artist, from the "circle" of the artist, from the artist's "school", "after" the artist, or "in the style of" the artist, respectively. The authenticity dummies Signed, Dated, and Inscribed take the value of one if the work carries a signature of the artist or is dated, inscribed, respectively. The medium dummies Oil, Watercolor, and Drawing indicate whether the work is an oil painting, a watercolor, or a drawing. The variables Height and Width measure the height and the width of the work in centimeters. The month dummies indicate the month of the sale. setting January as the benchmark The auction house dummies Sotheby's London, Sotheby's New York, Sotheby's Other Branches, Christie's London, Christie's New York, Christie's Other Branches, Bonhams London, Bonhams Other Branches, Phillips London, and Phillips Other Branches equal one if the sale takes place at Sotheby's London, Sotheby's New York, another branches of Sotheby's, Christie's London, Christie's New York, another branches of Christie's, Bonhams London, another offices of Bonhams, Phillips London, or another sales rooms of Phillips, respectively. Auction European and Auction American are dummy variables that equal one if the sale takes place at a large Continental European or a large American auction house, respectively (see Appendix). Pedigree, Exhibition, Literature, and Authentication are the dummy variables if the artworks have any information of pedigree, exhibition, literature, and authentication, respectively. Pedigree (Text Length), Exhibition (Text Length), Literature (Text Length) and Authentication (Text Length) are the text length of pedigree, exhibition, literature, and authentication information, respectively. Exhibition (Number Count) and Literature (Number Count) are the record number count of exhibition and literature information, respectively. For each variable, we report the number of observations (N), the mean, the standard deviation (S.D.), the minimum value, and maximum value.

	N	Mean	S.D.	Min	Max
Artist Characteristics					
DECEASED	1812807	0.7668	0.4228	0	1
Artwork Characteristics					
Attribution Dummies					
Attributed	1812807	0.0275	0.1635	0	1
Studio	1812807	0.0012	0.0344	0	1
Circle	1812807	0.0025	0.0495	0	1
School	1812807	0.0002	0.0142	0	1
After	1812807	0.0020	0.0452	0	1
Style	1812807	0.0004	0.0210	0	1
Authenticity Dummies					
Signed	1812807	0.8041	0.3969	0	1
Dated	1812807	0.3628	0.4808	0	1
Inscribed	1812807	0.1138	0.3176	0	1
Medium Dummies					

	N	Mean	S.D.	Min	Max
Oil	1812807	0.6813	0.466	0	1
Watercolor	1812807	0.2048	0.4035	0	1
Drawing	1812807	0.1139	0.3177	0	1
Size Variables					
Height	1812807	59.4621	51.1393	1	10000
Width	1806082	61.3305	73.8626	0	50353
Topic Dummies					
Abstract	1812807	0.0233	0.1508	0	1
Animals	1812807	0.0474	0.2125	0	1
Landscape	1812807	0.1492	0.3563	0	1
Seascape	1812807	0.0426	0.2018	0	1
Urbanscape	1812807	0.0877	0.2828	0	1
Nude	1812807	0.0137	0.1161	0	1
People	1812807	0.0841	0.2776	0	1
Self Portrait	1812807	0.0033	0.0572	0	1
Portrait	1812807	0.0356	0.1853	0	1
Religion	1812807	0.0199	0.1396	0	1
Still Life	1812807	0.0584	0.2345	0	1
Study	1812807	0.0128	0.1126	0	1
Transaction Characteristics					
Month					
January	1812807	0.0377	0.1905	0	1
February	1812807	0.0516	0.2212	0	1
March	1812807	0.0869	0.2817	0	1
April	1812807	0.0774	0.2673	0	1
May	1812807	0.1183	0.323	0	1
June	1812807	0.1301	0.3364	0	1
July	1812807	0.0424	0.2015	0	1
August	1812807	0.0221	0.1470	0	1
September	1812807	0.0676	0.2511	0	1
October	1812807	0.0977	0.2968	0	1
November	1812807	0.1456	0.3527	0	1
December	1812807	0.1226	0.328	0	1
Auction House					
Sotheby's London	1812807	0.0224	0.1481	0	1
Sotheby's New York	1812807	0.0236	0.1518	0	1
Sotheby's Other Branches	1812807	0.0203	0.141	0	1
Christie's London	1812807	0.0153	0.1227	0	1
Christie's New York	1812807	0.0236	0.1519	0	1
Christie's Other Branches	1812807	0.0501	0.2182	0	1
Bonhams London	1812807	0.0103	0.1011	0	1
Bonhams Other Branches	1812807	0.0438	0.2047	0	1
Phillips London	1812807	0.0026	0.0514	0	1
Phillips Other Branches	1812807	0.0036	0.06	0	1
Auction American	1812807	0.0316	0.1749	0	1
Auction European	1812807	0.1182	0.3228	0	1
Provenance Information					
Pedigree	1812807	0.1420	0.349	0	1

	N	Mean	S.D.	Min	Max
Exhibition	1812807	0.0374	0.190	0	1
Literature	1812807	0.0402	0.196	0	1
Authentication	1812807	0.0389	0.193	0	1
Pedigree (Text Length)	1812807	14.72	67.95	0	9034
Exhibition (Text Length)	1812807	7.8020	67.58	0	6828
Literature (Text Length)	1812807	9.7240	91.23	0	22413
Authentication (Text Length)	1812807	12.29	29.63	1	6234
Exhibition (Number Count)	1812807	0.0738	0.634	0	46
Literature (Number Count)	1812807	0.0615	0.567	0	150

Table 2 – Descriptive statistics for provenance variables

Table 2 presents the descriptive statistics for the provenance variables. Pedigree (Text Length) is the text length of pedigree information. Prominent Collector, Prominent Dealer, Royal / Noble, Wealthy Families, CEO, Time 100, Celebrity, and Athlete equal one if the artworks are once in the collections of prominent collectors, prominent dealers, royal / noble families, wealthy families, CEO, Time 100, celebrity, and athlete, respectively. Direct from Artist, From Artist Family, and From Sitter equal one if the artworks are acquired directly from artists, from the artists' families, and from the sitters, respectively. Descent equals one if the artworks contain any descendance information in the pedigree text. Sold at Sotheby's and Christie's, Sold at Bonhams and Phillips, Sold at Historic Auction Houses and Sold at Other Important Auction Houses equal one if the artworks are once sold at Sotheby's and Christie's, at Bonhams, Phillips, at historically important auction houses, and at other important auction houses, respectively. Anonymous Corporate Collection and Anonymous Private Collection equal one if the artworks are once in the corporate and private collections, respectively. Pedigree Other equals one if the artworks have other unclassified pedigree information. Exhibition (Text Length) is the text length of exhibition information and Exhibition (Number Count) is the number count of exhibition information. Prominent Exhibition, Prominent Art Fair, Prominent Museum, Other Museum, Culture City, and Gallery Exhibition equal one if the artworks are once exhibited at prominent exhibitions, prominent art fairs, prominent museums, other museums, culture cities, and gallery exhibitions, respectively. Literature (Text Length) is the text length of literature information and Literature (number count) is the number count of literature information. Catalogue Raisonné, Cover Page, Illustration, and Authoritative Press equal one if the artworks are illustrated in the catalogue raisonné, on the cover page of books, or in the literature which are published by the authoritative press, respectively. Other Literature equals one if the artworks contain other unclassified literature information. Authentication (Text Length) is the text length of authentication information. Artist Physical, Artist Family Physical, Association Physical, Expert Physical, and Other People Physical equal one if the artworks are with physical authentication issued by artists, by artists' families, by artists' associations, by experts and by other parties, respectively. Artist Non-Physical, Artist Family Non-Physical, Association Non-Physical, Expert Non-Physical, and Other People Non-Physical equal one if the artworks are with non-physical authentication issued by artists, by artists' families, by artists' associations, by experts and by other parties, respectively. Variables with "Number Count" indicate the number count variables instead of dummies. For each variable, we report the number of observations (N), the conditional mean, the standard deviation (S.D.), the minimum value, and maximum value.

	N	Mean	S.D.	Min	Max
Pedigree					
Pedigree (Text Length)	256,560	104	152.8	0	9034
Prominent Collector	256,560	0.0207	0.1420	0	1
Royal / Noble	256,560	0.0239	0.1530	0	1
Wealthy Families	256,560	0.0068	0.0822	0	1
CEO	256,560	0.0006	0.0245	0	1
Time 100	256,560	0.0008	0.0289	0	1
Celebrity	256,560	0.0020	0.0446	0	1
Athlete	256,560	0.0012	0.0352	0	1
Direct from Artist	256,560	0.1050	0.3070	0	1
From Artist Family	256,560	0.0529	0.2240	0	1
From Sitter	256,560	0.0033	0.0576	0	1
Descent	256,560	0.0981	0.2970	0	1
Sold at Sotheby's and Christie's	256,560	0.1500	0.3570	0	1
Sold at Bonhams and Phillips	256,560	0.0090	0.0942	0	1
Sold at Historic Auction Houses	256,560	0.0133	0.1150	0	1
Sold at Other Important Auction Houses	256,560	0.0130	0.1130	0	1
Prominent Dealer	256,560	0.0575	0.2330	0	1
Anonymous Corporate Collection	256,560	0.0016	0.0401	0	1
Anonymous Private Collection	256,560	0.2600	0.4380	0	1
Pedigree Other	256,560	0.4250	0.4940	0	1
Prominent Collector (Number Count)	256,560	0.0213	0.1690	0	8
Prominent Dealer (Number Count)	256,560	0.0624	0.2640	0	6
Descent (Number Count)	256,560	0.1090	0.3610	0	11
Sold at Sotheby's and Christie's (Number Count)	256,560	0.1780	0.4660	0	12
Sold at Bonhams and Phillips (Number Count)	256,560	0.0092	0.0983	0	5
Sold at Other Important Auction Houses (Number Count)	256,560	0.0137	0.1230	0	3
Sold at Historic Auction Houses (Number Count)	256,560	0.0150	0.1370	0	5
Exhibition					
Exhibition (Text Length)	67,713	208.9	283.3	1	6828
Exhibition (Number Count)	67,713	1.9760	2.6480	0	46
Prominent Exhibition	67,713	0.0620	0.2410	0	1
Prominent Art Fair	67,713	0.0039	0.0620	0	1
Prominent Museum	67,713	0.1720	0.3780	0	1
Other Museum	67,713	0.2990	0.4580	0	1
Culture City	67,713	0.7410	0.4380	0	1
Gallery Exhibition	67,713	0.1490	0.3560	0	1
Prominent Exhibition (Number Count)	67,713	0.0708	0.3050	0	18
Prominent Art Fair (Number Count)	67,713	0.0041	0.0674	0	4
Prominent Museum (Number Count)	67,713	0.2730	0.7860	0	20
Other Museum (Number Count)	67,713	0.2992	0.4579	0	1
Culture City (Number Count)	67,713	1.5740	2.1210	0	41
Literature					
Literature (Text Length)	72,906	241.8	388.4	0	22413
Literature (Number Count)	72,906	1.5300	2.3970	0	150
Catalogue Raisonné	72,906	0.1570	0.3640	0	1
Cover Page	72,906	0.0166	0.1280	0	1
Illustration	72,906	0.4590	0.4980	0	1
Authoritative Press	72,906	0.0115	0.1060	0	1

	N	Mean	S.D.	Min	Max
Other Literature	72,906	0.4810	0.5000	0	1
Catalogue Raisonné (Number Count)	72,906	0.1690	0.4100	0	6
Cover Page (Number Count)	72,906	0.0181	0.1490	0	6
Illustration (Number Count)	72,906	0.8450	1.6170	0	89
Authoritative Press (Number Count)	72,906	0.0122	0.1180	0	4
Authentication					
Authentication (Text Length)	70,556	66.896	63.3479	6	4101
Artist Physical	70,556	0.3170	0.4650	0	1
Artist Family Physical	70,556	0.0616	0.2400	0	1
Association Physical	70,556	0.1510	0.3580	0	1
Expert Physical	70,556	0.0272	0.1630	0	1
Other People Physical	70,556	0.2760	0.4470	0	1
Artist Non-Physical	70,556	0.0531	0.2240	0	1
Artist Family Non-Physical	70,556	0.0220	0.1470	0	1
Association Non-Physical	70,556	0.0445	0.2060	0	1
Expert Non-Physical	70,556	0.0288	0.1670	0	1
Other People Non-Physical	70,556	0.0615	0.2400	0	1

Table 3 – Baseline hedonic price regression results

Table 3 presents the baseline hedonic price regression results. Eq. (1) is estimated using OLS. The dependent variable is the natural log of deflated hammer price in USD. In Column (1), provenance variables are the dummy variables if the artworks have any information of pedigree, exhibition, literature, and authentication, respectively. Column (2) uses the natural log of text length of pedigree, exhibition, literature, and authentication information. Column (3) uses the number count variables of exhibition, literature, and the dummy variables of pedigree and authentication. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are reported in parentheses.

VARIABLES	(1) dummy	(2) length	(3) number
Artist Characteristics			
Deceased	0.1900***	0.1916***	0.1912***
	(0.0211)	(0.0211)	(0.0210)
Artwork Characteristics			
Attribution			
Attributed	-0.8278***	-0.8207***	-0.8339***
	(0.0360)	(0.0357)	(0.0362)
Studio	-0.7771***	-0.7638***	-0.7775***
	(0.0930)	(0.0893)	(0.0960)
Circle	-0.9265***	-0.9042***	-0.9337***
	(0.0980)	(0.0928)	(0.0976)
School	-0.9362***	-0.9096***	-0.9087***
	(0.1010)	(0.0964)	(0.0977)
After	-1.5346***	-1.5103***	-1.5307***
	(0.1212)	(0.1136)	(0.1217)
Style	-1.3193***	-1.2851***	-1.3213***
	(0.1053)	(0.0994)	(0.1044)
Authenticity			
Signed	0.0746**	0.0746**	0.0737**
	(0.0309)	(0.0302)	(0.0311)
Dated	0.1602***	0.1584***	0.1588***
	(0.0133)	(0.0131)	(0.0134)
Inscribed	0.0337***	0.0307***	0.0351***
	(0.0111)	(0.0112)	(0.0112)
Medium			
Oil	1.3427***	1.3368***	1.3422***
	(0.0296)	(0.0288)	(0.0292)
Watercolor	0.5227***	0.5205***	0.5207***
	(0.0310)	(0.0305)	(0.0307)
Size			
Height	0.0056***	0.0056***	0.0056***
	(0.0003)	(0.0003)	(0.0003)
Width	0.0049***	0.0049***	0.0049***
	(0.0003)	(0.0003)	(0.0003)
Height_2	-0.0000***	-0.0000***	-0.0000***
	(0.0000)	(0.0000)	(0.0000)
Width_2	-0.0000***	-0.0000***	-0.0000***

VARIABLES	(1) dummy	(2) length	(3) number
	(0.0000)	(0.0000)	(0.0000)
Topic			
Abstract	0.0341	0.0334	0.0302
	(0.0334)	(0.0338)	(0.0334)
Animals	0.0303	0.0298	0.0325
	(0.0350)	(0.0354)	(0.0348)
Landscape	0.0805	0.0800	0.0825
	(0.0534)	(0.0538)	(0.0532)
Seascape	0.1165***	0.1159***	0.1194***
	(0.0326)	(0.0328)	(0.0324)
Urbanscape	0.1679***	0.1667***	0.1701***
	(0.0288)	(0.0291)	(0.0287)
Nude	0.0086	0.0094	0.0102
	(0.0340)	(0.0343)	(0.0338)
People	0.0489*	0.0482	0.0510*
	(0.0292)	(0.0295)	(0.0291)
Self Portrait	0.2407***	0.2353***	0.2494***
	(0.0433)	(0.0436)	(0.0438)
Portrait	-0.1370***	-0.1366***	-0.1349***
	(0.0278)	(0.0280)	(0.0276)
Religion	0.0825***	0.0801***	0.0856***
	(0.0306)	(0.0309)	(0.0306)
Still Life	0.0847**	0.0838*	0.0875**
	(0.0431)	(0.0434)	(0.0429)
Study	-0.1375***	-0.1374***	-0.1354***
	(0.0262)	(0.0264)	(0.0262)
Other Topic	0.1497***	0.1486***	0.1535***
	(0.0453)	(0.0458)	(0.0451)
Transaction Characteristics			
Auction House			
Sotheby's London	0.9789***	0.9438***	1.0046***
	(0.0389)	(0.0398)	(0.0367)
Sotheby's New York	0.7814***	0.7450***	0.7952***
	(0.0459)	(0.0466)	(0.0440)
Sotheby's Other Branches	0.5620***	0.5517***	0.5885***
	(0.0486)	(0.0468)	(0.0488)
Christie's London	0.9361***	0.8892***	0.9625***
	(0.0421)	(0.0431)	(0.0379)
Christie's New York	0.4944***	0.4579***	0.5081***
	(0.0358)	(0.0372)	(0.0337)
Christie's Other Branches	0.3139***	0.2973***	0.3392***
	(0.0383)	(0.0365)	(0.0420)
Bonhams London	0.6413***	0.6224***	0.6517***
	(0.0276)	(0.0277)	(0.0271)
Bonhams Other Branches	0.0447	0.0338	0.0489
	(0.0627)	(0.0625)	(0.0634)
Phillips London	0.4901***	0.4865***	0.5115***
	(0.0757)	(0.0757)	(0.0767)
Phillips Other Branches	0.4337***	0.4230***	0.4611***
	(0.1366)	(0.1323)	(0.1368)

VARIABLES	(1) dummy	(2) length	(3) number
Auction American	-0.0966**	-0.0968**	-0.0987**
	(0.0388)	(0.0391)	(0.0387)
Auction European	0.2168***	0.2161***	0.2170***
	(0.0484)	(0.0483)	(0.0484)
	Provenance		
Pedigree	0.1885***	0.0531***	0.2379***
	(0.0170)	(0.0045)	(0.0194)
Exhibition	0.3499***	0.0734***	0.1043***
	(0.0208)	(0.0041)	(0.0066)
Literature	0.4288***	0.0869***	0.1266***
	(0.0336)	(0.0063)	(0.0054)
Authentication	0.1297***	0.0614***	0.1305***
	(0.0226)	(0.0100)	(0.0220)
Artist FE	YES	YES	YES
Year FE	YES	YES	YES
Month FE	YES	YES	YES
Observations	1,111,220	1,111,220	1,111,220
R-squared	0.7805	0.7817	0.7807

Table 4 – Hedonic price regression results with provenance details

Table 4 presents the hedonic price regression results with provenance details. Eq. (1) is estimated using OLS. The dependent variable is the natural log of deflated hammer price in USD. The descriptive statistics for the independent variables are shown in Table 2. Provenance variables are dummy variables in Column (1) and the corresponding price impacts (i.e., the exponent of the estimated coefficient minus one) are in Column (2). Column (3) uses number count variables of Prominent Collector, Descent, Sold at Sotheby's and Christie's, Sold at Bonhams and Phillips, Sold at Other Important Auction Houses, Sold at Historic Auction Houses, Prominent Dealer, Prominent Exhibition, Prominent Art Fair, Prominent Museum, Other Museum, Culture City, Catalogue Raisonné, Cover Page, Illustration, and Authoritative Press. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are reported in parentheses.

VARIABLES	(1) dummy	(2) price impact	(3) number
	Pedigree		
Past Ownership			
Prominent Collector	0.2183***	24.40%	0.1289***
	(0.0405)		(0.0239)
Royal / Noble	0.2724***	31.31%	0.2460***
	(0.0262)		(0.0275)
Wealthy Families	0.3538***	42.45%	0.3756***
	(0.0479)		(0.0660)
CEO	0.1479	15.94%	0.0016
	(0.1021)		(0.0905)
Time100	0.0841	8.77%	0.0010
	(0.0842)		(0.1065)
Celebrity	0.1288	13.75%	0.2102
	(0.1308)		(0.1492)
Athlete	0.4062***	50.11%	0.4018***
	(0.1358)		(0.1069)
Descendance			
Direct from Artist	0.1296***	13.84%	0.1319***
	(0.0142)		(0.0146)
From Artist Family	0.0070	0.70%	0.0147
	(0.0239)		(0.0236)
From Sitter	0.1068**	11.27%	0.0973*
	(0.0515)		(0.0581)
Descent	0.2121***	23.63%	0.1791***
	(0.0190)		(0.0112)
Past Sales Channel			
Sold at Sotheby's and Christie's	0.2121***	23.63%	0.1666***
	(0.0243)		(0.0220)
Sold at Bonhams and Phillips	0.0687*	7.11%	0.0458
	(0.0387)		(0.0332)
Sold at Historic Auction Houses	0.0957***	10.04%	0.0799*
	(0.0363)		(0.0409)
Sold at Other Important Auction Houses	-0.0463	-4.52%	-0.0231
	(0.0393)		(0.0346)

Prominent Dealer	0.2842***	32.87%	0.2421***
	(0.0378)		(0.0334)
Other Collection			
Anonymous Corporate Collection	0.1038**	10.94%	0.1157**
	(0.0482)		(0.0530)
Anonymous Private Collection	0.1793***	19.64%	0.1932***
	(0.0222)		(0.0230)
Pedigree Other	0.1323***	14.15%	0.1356***
	(0.0133)		(0.0132)
Exhibition			
Prominent Exhibition	0.2327***	26.20%	0.0783***
	(0.0247)		(0.0167)
Prominent Art Fair	-0.0055	-0.55%	-0.0473
	(0.0648)		(0.0601)
Prominent Museum	0.4631***	58.90%	0.2976***
	(0.0331)		(0.0174)
Other Museum	0.1878***	20.66%	0.2562***
	(0.0147)		(0.0219)
Culture City	0.2165***	24.17%	0.0830***
	(0.0147)		(0.0059)
Gallery Exhibition	0.2535***	28.85%	0.2563***
	(0.0220)		(0.0210)
Literature			
Catalogue Raisonné	0.3056***	35.74%	0.2895***
	(0.0448)		(0.0356)
Cover Page	0.4237***	52.76%	0.0868*
	(0.0513)		(0.0491)
Illustration	0.3660***	44.20%	0.1197***
	(0.0366)		(0.0069)
Authoritative Press	0.3450***	41.20%	0.2556***
	(0.0876)		(0.0868)
Other Literature	0.3186***	37.52%	0.3151***
	(0.0252)		(0.0240)
Authentication			
Artist Physical	0.0828***	8.63%	0.0821***
	(0.0262)		(0.0259)
Artist Family Physical	0.0674*	6.97%	0.0652*
	(0.0385)		(0.0384)
Association Physical	0.1199***	12.74%	0.1200***
	(0.0410)		(0.0408)
Expert Physical	0.3416***	40.72%	0.3415***
	(0.0517)		(0.0515)
Other People Physical	0.1148***	12.16%	0.1126***
	(0.0302)		(0.0300)
Artist Non-Physical	0.2810***	32.45%	0.2806***
	(0.0287)		(0.0286)
Artist Family Non-Physical	0.0039	0.39%	0.0113
	(0.0597)		(0.0543)
Association Non-Physical	0.1889***	20.79%	0.1872***
	(0.0352)		(0.0361)

Expert Non-Physical	0.1654***	17.99%	0.1670***
	(0.0482)		(0.0482)
Other People Non-Physical	0.1340***	14.34%	0.1350***
	(0.0393)		(0.0390)
Artist FE	YES		YES
Attribution	YES		YES
Authenticity	YES		YES
Medium	YES		YES
Size	YES		YES
Topic	YES		YES
Year	YES		YES
Month	YES		YES
Auction house	YES		YES
Observations	1,111,220		1,111,220
R-squared	0.7819		0.7820

Table 5 – Hedonic price regression results with high estimates and estimate variations

Table 5 presents the second stage hedonic price regression results. Eq. (1) is estimated using OLS. The dependent variable is the natural log of deflated hammer price in USD. Provenance variables are dummy variables. Column (1) includes the high estimate residual from the first stage regression; Column (2) includes the estimate variation residual from the first stage regression; Column (3) includes residuals of both high estimate and estimate variation. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are reported in parentheses.

VARIABLES	(1)	(2)	(3)
Pedigree	0.1856***	0.1873***	0.1856***
	(0.0094)	(0.0173)	(0.0094)
Exhibition	0.3504***	0.3504***	0.3505***
	(0.0056)	(0.0214)	(0.0056)
Literature	0.4281***	0.4268***	0.4281***
	(0.0127)	(0.0339)	(0.0127)
Authentication	0.1274***	0.1294***	0.1274***
	(0.0169)	(0.0229)	(0.0169)
Residuals High Estimate	0.8804***		0.8809***
	(0.0084)		(0.0083)
Residuals Estimate Variations		-0.0015*	-0.0056***
		(0.0008)	(0.0010)
Artist FE	YES	YES	YES
Attribution	YES	YES	YES
Authenticity	YES	YES	YES
Medium	YES	YES	YES
Size	YES	YES	YES
Topic	YES	YES	YES
Year	YES	YES	YES
Month	YES	YES	YES
Auction house	YES	YES	YES
Observations	985,877	1,075,955	985,877
R-squared	0.9221	0.7832	0.9222

Table 6 – Hedonic linear probability regression results

Table 6 presents the baseline hedonic linear probability regression results. Eq. (2) is estimated using OLS. The dependent variable is the sale results (sold / unsold). The independent variables in this equation are the same with Eq. (1). In Column (1), Provenance equal one if artworks have any provenance information (pedigree, exhibition, literature, or authentication). In Column (2), Pedigree, Exhibition, Literature, and Authentication are dummy variables if the artworks have any information of pedigree, exhibition, literature, and authentication, respectively. Column (3) uses the natural log of text length of pedigree, exhibition, literature, and authentication information. Column (4) uses the number count variables of exhibition, literature and the dummy variables of pedigree and authentication. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are reported in parentheses.

VARIABLES	(1) dummy	(2) dummy	(3) length	(4) number
		Artist Characteristics		
Deceased	0.0262***	0.0265***	0.0267***	0.0266***
	(0.0059)	(0.0059)	(0.0059)	(0.0059)
		Artwork Characteristics		
Attribution				
Attributed	-0.0991***	-0.0991***	-0.0988***	-0.0995***
	(0.0073)	(0.0074)	(0.0074)	(0.0073)
Studio	-0.1044***	-0.1020***	-0.1015***	-0.1019***
	(0.0117)	(0.0116)	(0.0115)	(0.0116)
Circle	-0.1683***	-0.1646***	-0.1633***	-0.1649***
	(0.0145)	(0.0149)	(0.0150)	(0.0148)
School	-0.1631***	-0.1603***	-0.1588***	-0.1586***
	(0.0369)	(0.0372)	(0.0373)	(0.0373)
After	-0.2075***	-0.2033***	-0.2028***	-0.2028***
	(0.0169)	(0.0167)	(0.0165)	(0.0167)
Style	-0.1443***	-0.1411***	-0.1394***	-0.1408***
	(0.0226)	(0.0229)	(0.0230)	(0.0228)
Authenticity				
Signed	0.0311***	0.0314***	0.0313***	0.0313***
	(0.0067)	(0.0067)	(0.0066)	(0.0067)
Dated	0.0285***	0.0286***	0.0284***	0.0286***
	(0.0029)	(0.0029)	(0.0028)	(0.0029)
Inscribed	0.0125***	0.0127***	0.0121***	0.0128***
	(0.0047)	(0.0046)	(0.0046)	(0.0046)
Medium				
Oil	0.1406***	0.1404***	0.1411***	0.1404***
	(0.0079)	(0.0080)	(0.0079)	(0.0079)
Watercolor	0.0567***	0.0565***	0.0569***	0.0564***
	(0.0058)	(0.0058)	(0.0057)	(0.0057)
Size				
Height	0.0003***	0.0003***	0.0003***	0.0003***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Width	0.0003***	0.0002***	0.0003***	0.0003***

VARIABLES	(1) dummy	(2) dummy	(3) length	(4) number
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Height_2	-0.0000***	-0.0000***	-0.0000***	-0.0000***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Width_2	-0.0000***	-0.0000***	-0.0000***	-0.0000***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Topic				
Abstract	0.0014	0.0013	0.0014	0.0010
	(0.0080)	(0.0081)	(0.0081)	(0.0081)
Animals	0.0098*	0.0096	0.0095	0.0097
	(0.0059)	(0.0059)	(0.0060)	(0.0059)
Landscape	0.0098	0.0096	0.0096	0.0098
	(0.0079)	(0.0080)	(0.0081)	(0.0080)
Seascape	0.0313***	0.0311***	0.0310***	0.0313***
	(0.0057)	(0.0058)	(0.0058)	(0.0057)
Urbanscape	0.0295***	0.0292***	0.0291***	0.0294***
	(0.0051)	(0.0051)	(0.0052)	(0.0051)
Nude	0.0133*	0.0133*	0.0132*	0.0133*
	(0.0068)	(0.0069)	(0.0070)	(0.0069)
People	0.0038	0.0035	0.0035	0.0037
	(0.0056)	(0.0056)	(0.0057)	(0.0056)
Self Portrait	0.0397***	0.0384***	0.0380***	0.0389***
	(0.0124)	(0.0125)	(0.0125)	(0.0125)
Portrait	-0.0318***	-0.0320***	-0.0321***	-0.0320***
	(0.0054)	(0.0055)	(0.0055)	(0.0055)
Religion	0.0072	0.0069	0.0065	0.0071
	(0.0059)	(0.0060)	(0.0060)	(0.0060)
Still Life	0.0092	0.0090	0.0090	0.0092
	(0.0073)	(0.0074)	(0.0075)	(0.0074)
Study	-0.0005	-0.0002	-0.0006	-0.0000
	(0.0058)	(0.0058)	(0.0059)	(0.0058)
Other Topic	0.0214***	0.0209***	0.0208***	0.0212***
	(0.0073)	(0.0074)	(0.0074)	(0.0073)
Transaction Characteristics				
Auction House				
Sotheby's London	0.1139***	0.1087***	0.1076***	0.1105***
	(0.0119)	(0.0112)	(0.0111)	(0.0113)
Sotheby's New York	0.1215***	0.1175***	0.1162***	0.1184***
	(0.0119)	(0.0114)	(0.0114)	(0.0114)
Sotheby's Other Branches	0.1099***	0.1069***	0.1075***	0.1087***
	(0.0202)	(0.0197)	(0.0196)	(0.0197)
Christie's London	0.1486***	0.1384***	0.1366***	0.1408***
	(0.0127)	(0.0119)	(0.0118)	(0.0120)
Christie's New York	0.1735***	0.1665***	0.1655***	0.1677***
	(0.0112)	(0.0107)	(0.0106)	(0.0107)
Christie's Other Branches	0.1214***	0.1182***	0.1178***	0.1201***
	(0.0177)	(0.0168)	(0.0167)	(0.0171)
Bonhams London	-0.0129	-0.0149	-0.0155	-0.0139
	(0.0108)	(0.0106)	(0.0106)	(0.0106)
Bonhams Other Branches	-0.0567***	-0.0579***	-0.0585***	-0.0576***
	(0.0139)	(0.0137)	(0.0137)	(0.0138)

VARIABLES	(1) dummy	(2) dummy	(3) length	(4) number
Phillips London	0.0660***	0.0599***	0.0605***	0.0618***
	(0.0172)	(0.0170)	(0.0169)	(0.0170)
Phillips Other Branches	0.0799***	0.0732***	0.0736***	0.0754***
	(0.0153)	(0.0145)	(0.0143)	(0.0146)
Auction American	0.0861***	0.0858***	0.0859***	0.0856***
	(0.0112)	(0.0111)	(0.0111)	(0.0111)
Auction European	-0.0130	-0.0127	-0.0126	-0.0126
	(0.0185)	(0.0186)	(0.0186)	(0.0186)
Reserve Price				
Reserve Price	-0.0649***	-0.0661***	-0.0668***	-0.0662***
	(0.0036)	(0.0036)	(0.0036)	(0.0035)
Provenance				
Provenance	0.0239***			
	(0.0055)			
Pedigree		0.0173***	0.0044***	0.0211***
		(0.0062)	(0.0014)	(0.0062)
Exhibition		0.0379***	0.0079***	0.0098***
		(0.0041)	(0.0008)	(0.0009)
Literature		0.0250***	0.0056***	0.0092***
		(0.0063)	(0.0011)	(0.0013)
Authentication		0.0102	0.0115***	0.0104
		(0.0133)	(0.0033)	(0.0133)
Artist FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Month FE	YES	YES	YES	YES
Observations	1,707,136	1,707,136	1,707,136	1,707,136
R-squared	0.1747	0.1750	0.1752	0.1750

Table 7 – Hedonic linear probability regression results with provenance details

Table 7 presents the results of hedonic linear probability regression with provenance details. Eq. (2) is estimated using OLS. The dependent variable is the sale results (sold / unsold). The independent variables in this equation are the same with Eq. (1). The descriptive statistics for the independent variables are shown in Table 2. Pedigree, Exhibition, Literature and Authentication are dummy variables if the artworks have any information of pedigree, exhibition, literature, and authentication in Column (1). Column (2) uses number count variables of Prominent Collector, Descent, Sold at Sotheby's and Christie's, Sold at Bonhams and Phillips, Sold at Other Important Auction Houses, Sold at Historic Auction Houses, Prominent Dealer, Prominent Exhibition, Prominent Art Fair, Prominent Museum, Other Museum, Culture City, Catalogue Raisonné, Cover Page, Illustration, and Authoritative Press. Reserve Price is the natural log of low estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are reported in parentheses.

VARIABLES	(1) dummy	(3) number
Reserve Price	-0.0665***	-0.0665***
	(0.0036)	(0.0035)
Pedigree		
Past Ownership		
Prominent Collector	0.0524***	0.0309***
	(0.0113)	(0.0081)
Royal / Noble	0.0656***	0.0657***
	(0.0148)	(0.0151)
Wealthy Families	0.0855***	0.0938***
	(0.0232)	(0.0262)
CEO	-0.0101	-0.0191
	(0.0343)	(0.0312)
Time100	-0.0167	-0.0274
	(0.0372)	(0.0374)
Celebrity	0.0372**	0.0558***
	(0.0170)	(0.0156)
Athlete	0.0948***	0.0952***
	(0.0289)	(0.0293)
Descendance		
Direct from Artist	0.0145***	0.0146***
	(0.0056)	(0.0055)
From Artist Family	-0.0027	-0.0017
	(0.0049)	(0.0047)
From Sitter	-0.0892***	-0.0899***
	(0.0185)	(0.0184)
Descent	0.0288***	0.0215***
	(0.0045)	(0.0035)
Past Sale Channel		
Sold at Sotheby's and Christie's	-0.0060	-0.0072**
	(0.0042)	(0.0030)
Sold at Bonhams and Phillips	-0.0277*	-0.0242*

	(0.0147)	(0.0139)
Sold at Historic Auction Houses	-0.0164**	-0.0161***
	(0.0072)	(0.0058)
Sold at Other Important Auction Houses	-0.0133	-0.0112
	(0.0083)	(0.0080)
Prominent Dealer	0.0377***	0.0247***
	(0.0064)	(0.0080)
Other Collection		
Anonymous Corporate Collection	0.0976***	0.0989***
	(0.0376)	(0.0378)
Anonymous Private Collection	-0.0051	-0.0041
	(0.0084)	(0.0084)
Pedigree Other	0.0274***	0.0268***
	(0.0058)	(0.0057)
Exhibition		
Prominent Exhibition	0.0263***	0.0176***
	(0.0081)	(0.0066)
Prominent Art Fair	0.0015	-0.0006
	(0.0298)	(0.0232)
Prominent Museum	0.0543***	0.0379***
	(0.0083)	(0.0059)
Other Museum	0.0176***	0.0255***
	(0.0042)	(0.0048)
Culture City	0.0192***	0.0053***
	(0.0034)	(0.0011)
Gallery Exhibition	0.0430***	0.0428***
	(0.0077)	(0.0076)
Literature		
Catalogue Raisonné	0.0236**	0.0190**
	(0.0095)	(0.0086)
Cover Page	0.0509***	0.0187*
	(0.0143)	(0.0113)
Illustration	0.0207***	0.0112***
	(0.0079)	(0.0022)
Authoritative Press	0.0130	0.0112
	(0.0183)	(0.0161)
Other Literature	0.0149*	0.0167**
	(0.0081)	(0.0081)
Authentication		
Artist Physical	0.0599***	0.0598***
	(0.0172)	(0.0172)
Artist Family Physical	-0.0166	-0.0167
	(0.0152)	(0.0152)
Association Physical	0.0348**	0.0348**
	(0.0148)	(0.0148)
Expert Physical	-0.0169	-0.0170
	(0.0179)	(0.0179)
Other People Physical	0.0011	0.0009
	(0.0129)	(0.0129)
Artist Non-Physical	0.0348	0.0348

	(0.0224)	(0.0224)
Artist Family Non-Physical	-0.0312*	-0.0310*
	(0.0171)	(0.0171)
Association Non-Physical	-0.0381	-0.0380
	(0.0240)	(0.0240)
Expert Non-Physical	-0.0292	-0.0291
	(0.0211)	(0.0212)
Other People Non-Physical	-0.0206	-0.0204
	(0.0136)	(0.0136)
Artist FE	YES	YES
Attribution	YES	YES
Authenticity	YES	YES
Medium	YES	YES
Size	YES	YES
Topic	YES	YES
Year	YES	YES
Month	YES	YES
Auction house	YES	YES
Observations	1,707,136	1,707,136
R-squared	0.1755	0.1755

Table 8 – Return regression results

Table 8 presents the baseline return regression results of repeat sales. Eq. (3) is estimated using OLS. The dependent variable is annualized return of repeat sales. The independent variables in this equation are the same with the first price equation. All the variables ending with "at First Sale" are the provenance variables at the first sale and variables starting with "Changes" are the provenance changes over time. Auction House Upgrade equals one if the artwork is sold at a bigger auction house at the second sale comparing with the auction house at the first sale. Auction House Downgrade equals one if the artwork is sold at a smaller auction house at the second sale. In Column (1) and Column (4), Pedigree, Exhibition, Literature, and Authentication are dummy variables if the artworks have any information of pedigree, exhibition, literature and authentication, respectively. Column (2) and Column (4) use the natural log of text length of pedigree, exhibition, literature, and authentication information. Column (3) and Column (6) use the number count variables of exhibition, literature and the dummy variables of pedigree and authentication. Column (1) – (3) are the full repeat sales sample and Column (4) – (6) use the repeat sales which are sold at the same auction houses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are reported in parentheses.

VARIABLES	(1) dummy	(2) length	(3) number	(4) dummy	(5) length	(6) number
Provenance at First Sale						
Pedigree at First Sale	0.1391	0.0480*	0.1694	0.6753	0.1977	0.7027
	(0.2291)	(0.0270)	(0.1485)	(0.5931)	(0.1282)	(0.6052)
Exhibition at First Sale	0.0553	-0.0069	0.0099	0.1232	-0.0019	0.0466
	(0.0726)	(0.0291)	(0.0394)	(0.2382)	(0.0408)	(0.0414)
Literature at First Sale	0.0919	0.0005	-0.0220	0.1619	0.0062	-0.0404
	(0.0673)	(0.0272)	(0.0566)	(0.1221)	(0.0232)	(0.0414)
Authentication at First Sale	-0.1725	-0.0683	-0.1727	-0.1784*	-0.1153**	-0.1762*
	(0.1189)	(0.0416)	(0.1110)	(0.0943)	(0.0554)	(0.0934)
Provenance Changes						
Changes Pedigree	-0.0551	0.0076	-0.0187	-0.1382	0.0160	-0.1062
	(0.1472)	(0.0232)	(0.1159)	(0.4136)	(0.0691)	(0.4151)
Changes Exhibition	0.1582**	0.0250	0.0232	0.2761*	0.0548**	0.0739*
	(0.0695)	(0.0303)	(0.0424)	(0.1468)	(0.0273)	(0.0391)
Changes Literature	0.1453**	0.0176	-0.0039	0.2706***	0.0413*	-0.0187
	(0.0623)	(0.0247)	(0.0385)	(0.0713)	(0.0223)	(0.0436)
Changes Authentication	0.0068	0.0017	0.0095	0.0227	-0.0054	0.0296
	(0.0595)	(0.0223)	(0.0996)	(0.0612)	(0.0235)	(0.0629)
Auction Houses Changes						
Auction House Upgrade	0.3984***	0.3957**	0.4006**			
	(0.1238)	(0.1625)	(0.1625)			
Auction House Downgrade	-0.1865	-0.1927	-0.1914			
	(0.1531)	(0.1183)	(0.1187)			
Artist FE	YES	YES	YES	YES	YES	YES
Attribution	YES	YES	YES	YES	YES	YES
Authenticity	YES	YES	YES	YES	YES	YES
Medium	YES	YES	YES	YES	YES	YES

Size	YES	YES	YES	YES	YES	YES
Topic	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
Month	YES	YES	YES	YES	YES	YES
Auction house	YES	YES	YES	YES	YES	YES
Observations	6,647	6,647	6,647	4,236	4,236	4,236
R-squared	0.3369	0.3367	0.3366	0.3940	0.3947	0.3935

Table 9 – Return regression with provenance details

Table 9 presents the baseline return regression results of repeat sales. Eq. (3) is estimated using OLS. The dependent variable is annualized return of repeat sales. The independent variables in this equation are the same with the first price equation. All the variables ending with "at First Sale" are the provenance variables at the first sale and variables starting with "Changes" are the provenance changes over time. Auction House Upgrade equals one if the artwork is sold at a bigger auction house at the second sale comparing with the auction house at the first sale. Auction House Downgrade equals one if the artwork is sold at a smaller auction house at the second sale. Famous Owner at First Sale equal one if the artwork with pedigree information of royal / noble, wealthy families, CEO, Time 100, celebrity, or athlete at first sale. Owner Credibility at First Sale equal one if the artwork is direct from artist, from artist family, from sitter or with descendance information at first sale. Famous Auction House at first sale equal one if the artwork is once sold at Sotheby's, Christie's, Bonhams, Phillips, historically important auction houses, or at other important auction houses. Other Collection at First Sale equal one if the artwork is in anonymous corporate collection or anonymous private collection at first sale. Authentication Physical at First Sale equal one if the authentication information is with physical form and Authentication Nonphysical at First Sale equal one if authentication information is with non-physical form at first sale. Column (1) is the full repeat sales sample and Column (2) uses the repeat sales sold at the same auction houses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are reported in parentheses.

VARIABLES	(1) Full sample	(2) Same Auction houses
Provenance at First Sale		
Prominent Collector at First Sale	0.1586	0.8522
	(0.1714)	(0.6775)
Famous Owner at First Sale	0.3268	-0.3349
	(0.4276)	(0.6137)
Owner Credibility at First Sale	-0.1262	0.5480*
	(0.1108)	(0.2910)
Famous Auction House at First Sale	0.0997	0.4103
	(0.1716)	(0.4031)
Prominent Dealer at First Sale	0.2171	0.8242**
	(0.2114)	(0.3840)
Other Collection at First Sale	0.0057	0.1662
	(0.1070)	(0.3334)
Pedigree Other at First Sale	0.2560	0.6421
	(0.3062)	(0.5509)
Prominent Exhibition at First Sale	-0.0866	0.2826
	(0.2280)	(0.6255)
Prominent Art Fair at First Sale	-0.3467	-1.4739
	(0.5242)	(1.1621)
Museum at First Sale	0.1565*	0.3717*
	(0.0888)	(0.2170)
Culture City at First Sale	-0.0120	-0.1919
	(0.0706)	(0.2071)

Gallery Exhibition at First Sale	0.2348	0.0326
	(0.1757)	(0.2303)
Catalogue Raisonne at First Sale	-0.1245	-0.4358*
	(0.1836)	(0.2516)
Cover Page Illustration at First Sale	0.0736	0.3417
	(0.1087)	(0.3485)
Authoritative Press at First Sale	-0.1370	-0.1642
	(0.1742)	(0.2004)
Other Literature at First Sale	0.1383	0.1892
	(0.0924)	(0.1339)
Authentication Physical at First Sale	-0.1302	-0.1627*
	(0.0960)	(0.0929)
Authentication Nonphysical at First Sale	-0.4125	-0.4253**
	(0.2743)	(0.1964)
Provenance Changes		
Changes Prominent Collector	0.3156**	0.7381*
	(0.1514)	(0.3886)
Changes Famous Owner	1.6297	4.4978
	(1.8188)	(4.0730)
Changes Owner Credibility	-0.0726	-0.0309
	(0.0552)	(0.1337)
Changes Famous Auctionhouse	0.0050	0.1413
	(0.0953)	(0.2549)
Changes Prominent Dealer	0.4603	1.2009***
	(0.4585)	(0.4357)
Changes Other Collection	-0.0210	-0.0157
	(0.0981)	(0.2141)
Changes Pedigree Other	-0.0598	-0.3662
	(0.1845)	(0.4705)
Changes Prominent Exhibition	-0.0911	0.3971
	(0.1867)	(0.5471)
Changes Prominent Art Fair	0.5650	-
	(0.6709)	
Changes Museum	0.2085***	0.6230**
	(0.0722)	(0.2921)
Changes Culture City	0.0271	-0.1277
	(0.0939)	(0.1716)
Changes Gallery Exhibition	0.2866*	0.2700
	(0.1693)	(0.3226)
Changes Catalogue Raisonne	0.0176	0.0011
	(0.1365)	(0.2566)
Changes Cover Page Illustration	0.1436	0.1101
	(0.1213)	(0.3365)
Changes Authoritative Press	-0.1480***	-0.1234
	(0.0540)	(0.1023)
Changes Other Literature	0.1425	0.2916***
	(0.0883)	(0.0956)
Changes Authentication Physical	0.0022	0.0260
	(0.0679)	(0.0529)
Changes Authentication Nonphysical	-0.0530	-0.0645
	(0.1125)	(0.1541)
Auction Houses Changes		
Auction House Upgrade	0.3914***	

	(0.1202)	
Auction House Downgrade	-0.1808	
	(0.1480)	
Artist FE	YES	YES
Attribution	YES	YES
Authenticity	YES	YES
Medium	YES	YES
Size	YES	YES
Topic	YES	YES
Year	YES	YES
Month	YES	YES
Auction house	YES	YES
Observations	6,647	4,236
R-squared	0.3397	0.3997

Table 10 – Hedonic price regression for subsamples by auction houses

Table 10 presents the hedonic regression results for subsamples by auction houses. Eq. (1) is estimated using OLS. The dependent variable in Column (1) and Column (2) is the natural log of deflated hammer price in USD; the dependent variable in Column (3) and Column (4) is the sale results (sold / unsold) namely the probability of being sold. Pedigree, Exhibition, Literature and Authentication are the dummy variables if the artworks have any information of pedigree, exhibition, literature, and authentication, respectively. Column (1) and Column (3) use the subsample for big auction houses; Column (2) and Column (4) use the subsample for small auction houses. Lag Average Price is the natural log of lag average price of each auction house. Reserve Price is the natural log of low estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are reported in parentheses.

VARIABLES	(1) PRICE Big auction houses	(2) PRICE Small auction houses	(3) PROB Big auction houses	(4) PROB Small auction houses
Pedigree	0.1743***	0.0973***	0.0161***	0.0240*
	(0.0047)	(0.0065)	(0.0017)	(0.0129)
Exhibition	0.3287***	0.3655***	0.0354***	0.0560***
	(0.0070)	(0.0146)	(0.0024)	(0.0118)
Literature	0.4519***	0.3308***	0.0268***	0.0220
	(0.0075)	(0.0122)	(0.0025)	(0.0147)
Authentication	0.0412***	0.1733***	-0.0231***	0.0254**
	(0.0119)	(0.0066)	(0.0046)	(0.0128)
Lag Average Price	0.2295***	0.2579***		
	(0.0027)	(0.0021)		
Reserve Price			-0.0598***	-0.0711***
			(0.0008)	(0.0050)
Artist FE	YES	YES	YES	YES
Attribution	YES	YES	YES	YES
Authenticity	YES	YES	YES	YES
Medium	YES	YES	YES	YES
Size	YES	YES	YES	YES
Topic	YES	YES	YES	YES
Year	YES	YES	YES	YES
Month	YES	YES	YES	YES
Auction house	YES	YES	YES	YES
Observations	366,604	585,294	601,790	1,083,846
R-squared	0.8103	0.7544	0.1929	0.2006

Table 11 – Hedonic price regression for subsamples by medium

Table 11 presents the hedonic regression results for subsamples by medium. Eq. (1) is estimated using OLS. The dependent variable in Column (1) - (3) is the natural log of deflated hammer price in USD; the dependent variable in Column (4) - (6) is the sale results (sold / unsold) namely the probability of being sold. Pedigree, Exhibition, Literature and Authentication are the dummy variables if the artworks have any information of pedigree, exhibition, literature, and authentication, respectively. Column (1) and Column (4) use the subsample for oil paintings; Column (2) and Column (5) use the subsample for watercolors; Column (3) and Column (6) use the subsample for drawings. Reserve Price is the natural log of low estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are reported in parentheses.

VARIABLES	(1) PRICE Oil painting	(2) PRICE Watercolor	(3) PRICE Drawing	(4) PROB Oil painting	(5) PROB Watercolor	(6) PROB Drawing
Pedigree	0.1844***	0.1453***	0.2123***	0.0126*	0.0339***	0.0320***
	(0.0169)	(0.0222)	(0.0277)	(0.0067)	(0.0070)	(0.0082)
Exhibition	0.3165***	0.3107***	0.3514***	0.0386***	0.0351***	0.0477***
	(0.0176)	(0.0233)	(0.0384)	(0.0038)	(0.0076)	(0.0115)
Literature	0.3392***	0.4102***	0.4126***	0.0234***	0.0300***	0.0397***
	(0.0307)	(0.0285)	(0.0360)	(0.0067)	(0.0085)	(0.0122)
Authentication	0.1308***	0.1780***	0.0791***	0.0130	0.0120	0.0011
	(0.0234)	(0.0245)	(0.0262)	(0.0140)	(0.0122)	(0.0145)
Reserve Price				-0.0771***	-0.0625***	-0.0649***
				(0.0036)	(0.0054)	(0.0058)
Artist FE	YES	YES	YES	YES	YES	YES
Attribution	YES	YES	YES	YES	YES	YES
Authenticity	YES	YES	YES	YES	YES	YES
Medium	YES	YES	YES	YES	YES	YES
Size	YES	YES	YES	YES	YES	YES
Topic	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
Month	YES	YES	YES	YES	YES	YES
Auction house	YES	YES	YES	YES	YES	YES
Observations	751,340	223,026	119,048	1,157,799	339,288	187,975
R-squared	0.8156	0.7772	0.7318	0.1950	0.1982	0.2031

Table 12 – Hedonic price regression for subsamples by schools and movements

Table 12 presents the hedonic price regression results for subsamples by schools and movements. Eq. (1) is estimated using OLS. The dependent variable is the natural log of hammer price in USD. Pedigree, Exhibition, Literature and Authentication are the dummy variables if the artworks have any information of pedigree, exhibition, literature, and authentication, respectively. Column (1) – (13) are subsamples of art schools and movements: Medieval & Renaissance; Baroque; Rococo; Neoclassicism; Romanticism; Realism; Impressionism & Symbolism; Fauvism & Expressionism; Cubism, Futurism & Constructivism; Dada & Surrealism; Abstract Expressionism; Pop; Minimalism & Contemporary. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are reported in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
VARIABLES	Medieval and Renaissance	Baroque	Rococo	Neoclassicism	Romanticism	Realism	Impressionism and Symbolism	Fauvism and Expressionism	Cubism Futurism and Constructivism	Dada and Surrealism	Abstract Expressionism	Pop	Minimalism and Contemporary
Pedigree	0.128***	0.158***	0.138**	0.026	0.245***	0.118***	0.183***	0.073*	0.119**	0.100*	0.155***	0.553***	0.118
	(0.042)	(0.027)	(0.054)	(0.053)	(0.055)	(0.038)	(0.031)	(0.039)	(0.051)	(0.059)	(0.034)	(0.120)	(0.073)
Exhibi	0.368***	0.424***	0.441***	0.345***	0.348***	0.385***	0.449***	0.311***	0.362***	0.363***	0.203***	0.522***	0.348***
-tion	(0.090)	(0.072)	(0.083)	(0.096)	(0.082)	(0.037)	(0.030)	(0.037)	(0.033)	(0.040)	(0.033)	(0.051)	(0.020)
Litera	0.416***	0.373***	0.452***	0.531***	0.345***	0.478***	0.276***	0.368***	0.516***	0.495***	0.516***	0.438***	0.441***
-ture	(0.083)	(0.039)	(0.063)	(0.119)	(0.081)	(0.038)	(0.040)	(0.045)	(0.070)	(0.052)	(0.040)	(0.076)	(0.084)
Authenti	-0.187	0.208***	0.303**	-0.118	0.444***	0.151***	0.139***	0.129***	0.188***	0.052	-0.003	0.153**	0.257***
-cation	(0.132)	(0.046)	(0.126)	(0.195)	(0.087)	(0.050)	(0.041)	(0.038)	(0.052)	(0.044)	(0.045)	(0.076)	(0.065)
Artist FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Attribution	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Authenticity	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Medium	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Size	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Topic	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Month	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Auction house	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Artist FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	4,634	18,129	4,715	2,802	9,292	14,281	23,553	19,034	14,592	15,467	15,611	9,120	12,739
R-squared	0.682	0.648	0.663	0.652	0.705	0.734	0.779	0.773	0.771	0.767	0.767	0.766	0.775