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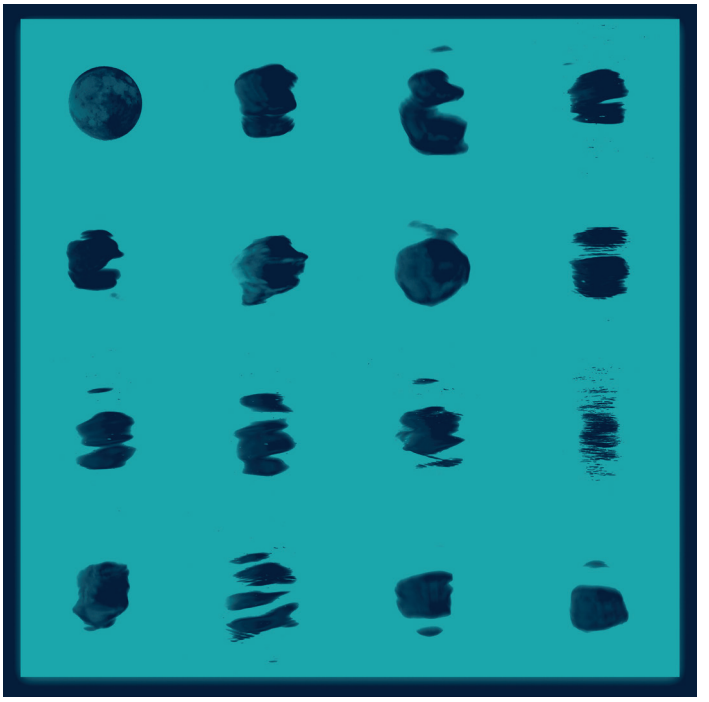
Asymmetries in Art Markets

Marina Gertsberg



ASYMMETRIES IN ART MARKETS

MARINA GERTSBERG
Maastricht University School of Business and Economics
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A thesis submitted the degree of
Doctor of Philosophy at Maastricht University

September 6, 2019

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"If you criticize what you're doing too early you'll never write the first line."

Max Frisch

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Chapter 1

Introduction

Most traditional asset pricing models are based on the assumption of frictionless markets and imply the absence of any transaction costs, taxes, and differences in access to information. While this assumption offers a convenient framework for model development markets for different assets vary in the extent to which they adhere to it. Market frictions are associated with significant adverse economic implications as they impose large costs on market participants and may result in inefficient equilibria or market failures. Market imperfections can also create profit opportunities for agents who are able to exploit them. Investors and firms who are subject to lower costs with respect to these market frictions can extract economic rents and gain a competitive advantage until they dissipate.

One major source of market frictions is information asymmetry. It describes a situation in which one party in a transaction has an advantage over the other due to better information about the value of a good and arise when information is not freely available. This imbalance will have a destabilizing effect on the market for the particular good, since each party is aware of its relative position in the transaction. To account for the uncertainty about the true quality of the good, the agent with less information will apply a discount to the price or stay away from the trade altogether unless the agent with the superior information is able to credibly signal its true value. As the agent with the better information is aware of the applied discount, in equilibrium, the quality of the traded goods will be adjusted downward to reflect the valuation of the less informed agent. The model was formulated by Akerlof (1970) in his seminal work using the example of the used car market and is known as the *lemon's problem*. In his context, the used car owner represents the

better-informed party and the potential buyer is the less informed party. *Lemons* are the lower quality used cars that are left on the market in equilibrium.

The model provides a clear illustration of how markets can be impacted by uncertainty surrounding the quality of a good. Nevertheless, the way individual agents attain different levels of information in the first place and how much profit they can extract from this power imbalance in the presence of information asymmetries remains an interesting question. In Akerlof's used car market example, the new car has gone through a transformation after the initial purchase which increased its level of uncertainty about its true quality and decreased the buyer's ability to compare it to other cars of the same model and brand. This gives the seller of the low quality car an informational advantage because she has been the owner of the car for a period of time and has had direct exposure to its defects. While it is difficult to imagine that anyone else could attain the same level of granular knowledge, it is specific to the particular car. Yet it is less clear how an informational advantage can be maintained and be systematically exploited to extract higher profits.

The literature on two-sided markets with the seminal work by Rochet and Tirole (2003) provides important answers on the role of intermediaries in markets characterized by an interdependence between buyers and sellers. It delivers insights on how intermediaries as trading platforms can create optimal pricing strategies for the two market sides and focuses on the profit-maximizing extent of cooperation across different platform providers. Typically, the focus is on goods subject to network externalities (e.g. credit cards, video game consoles, or newspapers) and how platform participation is affected in response to price adjustments on both sides as opposed to benefits and costs for intermediaries resulting from uncertainty with regard to quality.

In this dissertation, I provide empirical evidence on the impact of information asymmetries on prices and the market performance of individual agents. In three separate essays, I analyze this relationship by focusing on three factors that can alter the costs of access to information and become sources of informational advantage - expertise, networks, and group belonging. Here, expertise (chapter 2) refers to the level of knowledge an agent is able to accumulate; networks (chapter 3) relate to the size and density of an agent's links within the nexus of other market participants; and group belonging (chapter 4) refers to the individual characteristics (in this case gender) of the producer of the good that is subject to the information asymmetry, which may be used by other market participants to infer quality. In the presence of information asymmetries, differences in the distribution of these factors across

market participants will matter since they will influence the ease of obtaining information which in turn will affect market prices and their potential to extract rents. I use the art market as a setting due to its strong susceptibility to information asymmetries arising from a high level of product heterogeneity.

Information asymmetries appear to persist even with large increases in freely available information and a smaller perceived distance between trading partners as a result of advances in technology. What testifies this is the continued reliance on intermediaries as experts who step in and lower the costs associated with information asymmetries across a large variety of industries and products including the market for used cars, the underwriter industry, M&A advisory as well as the labor market (e.g. head hunters). While technology may facilitate access to information, this development is counterbalanced with increases in complexity making valuation more difficult. New investment vehicles with unconventional underlying cash flows (e.g. cryptocurrencies) emerge, intangible assets constitute an ever-increasing part of firm value and interdependencies between businesses multiply. This dissertation is motivated by the lack of understanding about the way agents exploit their informational advantage to gain a competitive edge and extract economic rents. It provides insights on the factors that contribute to a persisting imbalance of power between different market participants as a result of an unequal distribution of information in the market.

1.1 Information Asymmetries in the Art Market

The art market provides a unique testing ground to investigate the economic impact of information asymmetries on market performance and sources of informational advantage. Uncertainty about quality is very pronounced in the art market. An intuitive explanation lies in the heterogeneous nature of art as a good. Most pieces of art are individual works. Thus, in contrast to the case of (used) cars every artwork is different and unique from the point when it is produced. Resales of artworks occur on a highly infrequent basis. Moreover, while artworks can be compared along a number of (hedonic) characteristics including artist attributes, technique, genre, size, age, provenance and attribution these are insufficient to construct perfect comparables. The value of a piece of art does not derive only from these properties,

technical skill or production costs, but also from its meaning, which is socially constructed (Bourdieu, 1979). As a result, the lack of long and recent price histories and the absence of good comparables make art susceptible to large information asymmetries with respect to quality.

Despite the presence of large information asymmetries, the art market evolved from being a direct search market more than two centuries ago. Artworks are sold at auction or through dealers who purchase them on their own account and act as market makers. A public trading platform for art was founded in 1766 by James Christie in London with the foundation of the first auction house, *Christie's*. It was established just 164 years after the inauguration of the first stock exchange (Amsterdam Bourse). Over time, the art market, encompassing the markets for design objects, installations, photography, prints, paintings, and works on paper, has grown substantially. Based on historical auction data, it reached a total sales volume of $2.6 million between 1850 and 1913 (De Silva, Gertsberg, & Pownall). In 2016, sales amounted to $45 billion and included proceedings from auctions as well as private (dealer) sales (Pownall, 2017). Nevertheless, the art market has never approached the trading volumes and levels of efficiency at which securities trade on stock exchanges.

The nature and source of uncertainty about the quality of an artwork varies depending on the maturity of an artist. For contemporary artists, buyers face uncertainty about the ability and future potential of the new artist, as only a few signals are available at that time. This context finds resemblance in the context of crowdfunding campaigns where founders of new ventures try to raise capital. The market space consist of a large number of firms diverse in quality and nature. The entrepreneurs typically have a limited track record in founding and their ventures can rarely demonstrate sales numbers. While educational background, connections to other entrepreneurs and previous work experience proxy their quality and level of effort they will exert, considerable uncertainty still remains. Moreover, complete contracts cannot be negotiated to ensure performance. In the case of artists, education, previous commissions or an exhibition history are important. At the same time, a number of artists are self-taught and signs public recognition may be sparse. Furthermore, it is even more difficult to specify what constitutes an appropriate level of effort given that a creative process is typically erratic. In addition to uncertainty with regard to the artist herself, there is also market risk. As for the case of new products or services, art needs to find approval and generate demand within a target market. Moreover, tastes and trends are difficult to predict and subject to

change. In contrast, the market value for the artworks of deceased artists is typically already established. Despite the fact that every artwork is different, a longer price history for the artist's body of work is available. In some cases, a number of artworks were traded repeatedly. Here, uncertainty about quality relates to questions regarding authenticity, condition and provenance. However, even the market for the artworks of established artists can be subject to changes in tastes.

1.2 Sources of Informational Advantage in the Art Market

As illustrated above, information asymmetries in the art market are substantial. For agents who have a cost advantage in information collection, this provides incentives to step in as intermediaries and facilitate trade. However, the level of knowledge required to establish the value of an artwork is large and costly to obtain. Determining the quality of an individual work of art requires a background in art history, insights about the market conditions for the artists as well as the artwork's past ownership history. Therefore, the intermediary's level of expertise will represent an important source of informational advantage. It is crucial to form an accurate price estimate and is decisive in the amount of profits that can be reaped from a transaction. Furthermore, it may also impact how long a competitive advantage can be sustained before competitors catch up and profits dissipate. The presence of large premia for expertise is also documented in the financial advisory and the M&A underwriter market, which is characterized by uncertainty with respect to a firm's future cash flows (Brealey, Leland, & Pyle, 1977; Chemmanur & Fulghieri, 1994; Campbell & Kracaw, 1980). However, the size of the rents that highly experienced art market intermediaries can extract, tends to exceed the profits that can be extracted by financial advisors or underwriters reflecting the excessive level of uncertainty about the quality of an artwork. While the average compensation of underwriters on an offering is 12% (Barry, Muscarella, & Vetsuypens, 1991) art dealers charge a commission of 30% to 70% on every sale from an artist they represent. Similarly, auction houses demand a premium of about 20% from both buyers and sellers on a sales transaction (Cameron, 2011).

In chapter 2 of this dissertation, evidence is presented that expertise can yield substantial market power, which is highly persistent. It studies the value of expertise using a historical London-based auction data set spanning from 1800 to 1913. This represents the period when the modern art market and the art dealing profession emerged. Throughout the 19^{th} century, auctions were among the primary sources of artwork supply for dealers. The evolution of the art dealing industry is used to show how dealer expertise, as a result of an accumulated market share, affects competitive dynamics that govern entry, exit and growth in the art market. First, it illustrates that entry into the market coincides primarily with the intensity of the current trading activity of dealers and is deterred by increased competition. Second, acquisition strategies of different dealer types at auctions are observed. Controlling for artwork characteristics, the study demonstrates that dealers with a larger market share pay higher prices at auction. These results suggest that art dealers with a greater expertise are able to form more accurate value estimates and charge their clients a higher premium. This conjecture is supported by the finding that the market players who accumulate more expertise and pay higher prices have a lower probability of market exit as opposed to dealers who have less expertise and pay relatively lower prices. Lastly, it appears that expertise is cumulative and sticky, as suggested by the fact that the three dealers who emerged to become the top players in the market remained in their positions for over half a century.

The extent to which valuable information can be accumulated critically depends on access to proprietary information channels. In the field of securities trading, there is empirical evidence that investors benefit from private information acquired through social networks in the form of higher returns (Cohen, Frazzini, & Malloy, 2008). The gains from preferential access to information are exacerbated in the art market as manifested by the fact that very little information is of a public nature, which prevents the dissipation of profits and may contribute to persistent market power .

Therefore, chapter 3 of this dissertation employs network measures to analyze auction outcomes to illustrate the importance of an art dealer's position within the network of buyers and sellers. The historical auction data that was used in chapter 2 offers a very clean setting in which to study the formation of the network, because relationships were not yet characterized by complexity and opaqueness, as is the case for many of contemporary social and financial network structures. Recognizing that information can be enhanced and is transferred through interaction with other market participants, the study investigates how the network position

of an art dealer influences the choice of trading partners, the prices paid at auction as well as longevity in the market. It is shown that network size and depth as well as similarities in product specialization between trading partners (homophily) strongly influence the decision to form links. Furthermore, it appears that a larger and deeper network exacerbates informational asymmetries across buyers and leads to higher profits through lower prices and facilitates longer market presence. These results provide supporting evidence that bargaining power and reduced information asymmetries are the main driving forces for network formation, alongside the strategic bidding behavior of art dealers.

The presence of large uncertainties in the art market with respect to quality is also reflected in the distribution of payoffs with a small number of artworks trading at extremely high prices. Such market structures are also known as *superstar markets*. Payoffs in these markets are disproportionate to the level of talent and profits are highly rank-dependent. As a result, a small number of individuals absorb the largest portion of revenues. The seminal work by Adler (1985) provides an information-related explanation for why the art market is a superstar market. Adler (1985) who argues that utility from art consumption rises with the amount of knowledge one possesses about the artist. Superstars emerge because it is cheaper to acquire knowledge about better-known artists. A potential implication is that in the presence of large uncertainties with respect to quality, high costs of information acquisition, and the chance of disproportionately large pay-offs, a salient group characteristic of an artist (such as gender, age or ethnicity), which is inconsistent with attributes of past superstars may become an informational disadvantage. If characteristics of current or past superstars are used to infer the future potential of an artist, the possession of features associated with underrepresented groups could increase the costs of informational collection for potential buyers.

Chapter 4 analyzes whether a market structure characterized by the superstar effect may result in inequality and barriers for certain market participants who deviate from these archetypes in their attributes and who are not able to credibly signal information. In particular, the study aims to answer the question of whether the superstar effect prevalent in the art market materializes as a glass ceiling for female artists who constitute the underrepresented group. Nearly the entire population of auction price records for European- and North American-based artists from 2000 to 2017 is used to study auction outcomes for male and female artists. The findings show that women are less likely to be traded in the auction market conditional on being represented by galleries. This suggests that the female artists who are traded at auction

are subject to different selection criteria compared to their male colleagues. Potentially female artworks need appreciate more in value than a comparable artwork by a man before a seller decides to put it up for sale at auction. Alternatively, women are more likely to be discouraged by their lower chances to succeed in the market leaving only the most talented female artists behind. Such a selection bias may explain the average price premium found for female artworks at auction, which is likely due to a supply squeeze caused by a small number of female artists at the top of the market. In particular, evidence is presented that this effect can be attributed to female artists from older generations. At the same time, an increase is observed in the share of contemporary artworks by women traded at auction. These artworks sell at a price discount compared to contemporary artworks by men, providing evidence of lower barriers for female artists in recent times. This may be the result of better access to financial resources and education as well as decreased information asymmetries with regard to female artists in recent decades. At the same time, this is indicative of a situation whereby opportunities for women formally improve while the perception of their status does not progress proportionally.

Chapter 2

Market Evolution and the Power of Expertise*

This paper addresses the question of whether accumulation of expertise affects market prices. Using a unique historical data set, we show the value of expertise during the evolution of the art market. First, we illustrate how market dynamics encourage entry of dealers with heterogeneous characteristics. Second, our results provide evidence that dealers with higher market shares pay about 21% more for an artwork, controlling for quality. Third, our results indicate that dealers who accumulate higher market shares are more likely to survive in the market. Our evidence outlines the importance of expertise in an emerging market characterized by uncertainty and product heterogeneity.

2.1 Introduction

In this study, we use a rare London-based fine art auction data set with buyer and seller identities, which provides us with a unique opportunity to examine a market evolution, where value is created through the accumulation of expertise as proxied

* This chapter is co-authored with Dakshina G. De Silva (Lancaster University) and Rachel A.J. Pownall (Maastricht University)

by a consistently higher market share. At the time, art auctions constituted among the most important market platform for art dealers to replenish artwork inventories. Tracking the evolution of the market, we observe dealers' entry, bidding, and survival patterns throughout a time period from 1800 to 1913. As trading volume increases, market entry is encouraged and total purchases by dealers triple over the period. Through the evolution, we observe dealers accumulating different amounts of market share. We demonstrate that dealers with larger expertise, as proxied by higher accumulated market shares, bid more aggressively. We further show that more expertise enables dealers to survive longer. Our empirical findings emphasize the importance of expertise in a market characterized by high product heterogeneity and uncertainty.

Gains from superior expertise can be large. Experts accumulate unique industry knowledge and provide informal unwritten guarantees on the quality of the products. In this way, they perform a crucial role in markets acting as certifying bodies. Due to specialization and the resulting economies of scale, information can be collected and processed more efficiently. As a result, experts create value for which a premium can be charged. This added value is intangible in nature and, thus, difficult to quantify. For instance, Houser and Wooders (2006) show that seller reputation has a positive effect on price in online consumer-to-consumer auctions for computer processors. Furthermore, in a recent study Fraiberger, Sinatra, Resch, Riedl, and Barabási (2018) show evidence of the relevance of the reputation of the institutions an artist is connected to. Our focus is on expertise as a result of accumulation of knowledge rather than reputation.

Intermediaries are crucial in helping to establish prices across many markets. In markets where heterogeneous goods and services are traded, information asymmetries between buyers and sellers are magnified. In this case, the buyer is uncertain about the value of a good as quality is not directly observable at the time of the purchase. For art and wine, high-end gastronomy, and real estate asymmetric information or uncertainty concerning the value of a good is more prevalent than in markets. Therefore, experts have a greater opportunity to extract higher rents.

The art market and the associated emergence of the art dealer profession offer us an excellent setting to examine the role of expertise as a result of market share accumulation. Art dealers can be regarded as entrepreneurs and the brokers of the art market; they produce information and coordinate demand and supply as intermediaries. From our perspective, the art market has the advantage of not having been subject to radical changes throughout time. The mechanism with which trade takes

place in the art market at auction is essentially the same as in its outset, more than two centuries ago. Art dealers and auction houses are still the main sales channels and responsible for information production.

Within the context of the art market this is the first study, as far as we are aware, to empirically investigate the role of expertise throughout the evolution of a new industry. Using information on individual art dealer characteristics we are also the first to empirically analyze acquisition strategies in auctions. We contribute to the body of literature on the role of intermediaries and their added value in markets characterized by information asymmetries. We demonstrate the importance of expertise in such settings. In addition, the findings have implications for market evolution research by providing evidence of the determinants that drive entry and survival in the art market.

Our empirical analysis is conducted in three parts. First, we investigate patterns and drivers for the market entry of dealers which led to their institutionalization in the 19th century. We expect entrants to be heterogeneous in their characteristics which will influence their bidding behavior and industry structure as a whole. We then analyze the effect of the dealers' relative market shares on acquisition strategies at auctions. In particular, we are interested in knowing whether dealers with more market expertise display a different bidding strategy than dealers with less market expertise conditional on artwork characteristics. We use the dealer's past market share to proxy his individual level of market expertise[2] and distinguish between expert (top 10%) and non-expert dealers (below 10%). Our expectation is that dealers with higher market shares will, on average, acquire artworks at higher prices than dealers with less market share as they have a better expertise that results in easier access to clientele and a superior ability to promote artists in the market. Consequently, they can extract higher profits from the future resale of the artworks. Lastly, we investigate how relative market share affects survival in the market. We expect non-expert dealers (with lower market shares) to exit the market earlier as they fail to generate sufficient profits.

Our results show that the entry into the market coincides primarily with the intensity of the current trading activity of dealers and is deterred by increased competition. With respect to the acquisition strategies of different types of dealers, the results further provide very clear evidence that dealers with relatively higher market shares pay, on average, 21% more for an artwork. This pattern holds for the

[2] We refer to art dealers in this study in the male form since all art dealers present in our data set are male.

whole distribution of prices and is especially pronounced in the upper part of the distribution. Moreover, we find that dealers with larger market shares are about 7.5% percent more likely to survive the market. This supports the conjecture that art dealers benefit from a larger market shares that allows them to accumulate expertise. This enables them to extract higher rents which ultimately explains market survival.

There has been a large number of studies on the importance of intermediaries for information production and value certification, especially in the area of financial advisory and intermediation (Brealey et al., 1977; Chemmanur & Fulghieri, 1994; Campbell & Kracaw, 1980). Among others, these studies find evidence that advisers with more industry expertise are more likely to be selected for mandates and achieve higher returns for their clients, particularly in the presence of information asymmetries (Ertugrul & Krishnan, 2011; Golubov, Petmezas, & Travlos, 2012; Song, Wei, & Zhou, 2013). Furthermore, Mizrach and Weerts (2009) find that online traders increase their profits with additional experience over time as well as with a growing Herfindahl index. Thus, while there is empirical evidence that firms can benefit from more expertise, these studies do not consider its impact on the overall industry structure and the evolutionary path of an emerging market. Our analysis extends this literature by demonstrating how differences in market expertise influence the evolution of a market.

Many studies analyze industry evolutions of new products from their birth until maturity (Agarwal & Gort, 1996; Carroll & Hannan, 1989; Dunne, Roberts, & Samuelson, 1988; Gort & Klepper, 1982). These efforts focus on empirically deriving stylized facts which explain evolutionary paths of new industries along the different stages of the product life-cycle. For instance, a number of studies analyze how various market characteristics such as technology (Agarwal & Audretsch, 2001; Doms, Dunne, & Roberts, 1995), competition (Bresnahan & Reiss, 1991), or the stage of the product cycle (Agarwal & Gort, 1996; Gort & Klepper, 1982) affect the probability of entry, growth and survival rates. Other studies (Carroll, Bigelow, Seidel, & Tsai, 1996; Mitchell, 1991) solely concentrate on entry timing and probability investigating the competitive dynamics between start-ups and incumbents (Schumpeterian competition). A recent study by Nanda, Samila, and Sorenson finds that there is performance persistence in venture capital. The authors show that initial IPO's result in higher future IPO rates which can be explained by better access to deal flow after initial success which raises the quality of later investments. While these studies consider market characteristics, we extend these studies by taking into account the

effect of individual characteristics of market players on the evolution of an industry. Our data set provides us with the identities and characteristics of buyers and sellers and, therefore, give us the unique opportunity to establish historically who the major market players at auction are. Furthermore, we identify dealer attributes such as market share, experience and financial capacity, which contribute to the differential bidding strategies and survival in the market.

In the domain of art market research, a number of significant studies is available documenting the development and determinants of art prices over long time spans (De Silva, Pownall, & Wolk, 2012; Etro & Pagani, 2012; Etro & Stepanova, 2015; Goetzmann, 1993; Renneboog & Spaenjers, 2013; Spear, Sohm, & Ago, 2010) or during periods of important historical and economic events (Hiraki, Ito, Spieth, & Takezawa, 2009; Oosterlinck, 2017). However, few empirical studies are available on the competitive conduct of professional intermediaries and the industry dynamics that govern their entry, growth, and exit. As buyer identities in the secondary as well as primary art market usually remain undisclosed, research in this field has been limited to qualitative socio-economic studies (Arora & Vermeylen, 2013; Bayer, 2015; Montias, 1988; Stourton & Sebag-Montefiore, 2012; Velthuis, 2003, 2013). A recent study by Ginsburgh, Radermecker, and Tommasi (2019) provides causal emprical evidence that expert certification of authencity increases art prices by 60%. The authors focus on the effect of one expert (Klaus Ertz) on the body of work of a single artist (Peter Brueghel the Younger) over a period of 45 years. Another study that focuses on a single expert (Roger de Piles (1635-1709)) and shows the significance and reliability of an expert's opinion in the art market was conducted by Graddy (2013). Nevertheless, the evolution of expertise of intermediaries, its effect on acquisition strategies as well as sustained market presence still remain a puzzle. A study on the French art market from the mid 17^{th} century until the first half of the 18^{th} century by Etro and Stepanova (2015) takes into account the role of dealers at art auctions in Paris. The authors provide first evidence of the emerging power of art dealers and their influence on prices at auction. However, the study does not cover the period when the market power of art dealers unfolds in the second half of the 18^{th} century. Overall, up until now, the effect of a firm's expertise on industry evolution, bidding strategies and, eventually, firm survival has not been researched in such a comprehensive way. Therefore, this study is also motivated by the lack of empirical evidence in this field.

The paper is organized as follows. In section 2, we describe the evolution of the art market and the drivers that led to the proliferation of the modern art dealer as

its integral component. The employed data set is presented in section 3. Section 4 is dedicated to the empirical analysis and details the methodology and results. We finish with some concluding remarks and implications for the art market as well as other fields in section 5.

2.2 Institutional Background

2.2.1 The Evolution of the Art Market

In 1700, with the decline of the economic pre-dominance of the Netherlands relative to its neighbors England and France, London became the wealthiest and largest city in Europe (Israel, 1995).[3] The Reformation caused a redistribution of wealth which led to the emergence of a rich upper class (Bayer, 2015, p.16). Aristocrats built large mansions and used art as decoration, which was directly commissioned from artists. These artworks rarely circulated to other buyers and tended to remain in family estates. Therefore, the supply of artworks for trade was very low during the 17th century. When many aristocrats fell into financial distress around the mid-19th century, posthumous estates came up for sale and had to be liquidated quickly. In addition, the Settled Lands act of 1882 allowed tax free disposal of property which also included artworks and antiques (Cooper, 1977, p.19). At the same time, conflicts on the continent, especially the French Revolution, led to the dispersion of many prominent art collections (e.g. the Orléans collection) which ended up for sale in London ("British Sales 1780–1800: The Rise of the London Art Market", 2016). These events increased the availability of artworks in the market and constituted the main source of supply at auctions. The supplied artworks were mainly Old Masters or contemporary works from foreign, especially Dutch or Flemish, artists. Collecting art gained in popularity among the upper classes, manifested in high prices. However, many of the circulating artworks were forgeries or cheap copies. Local artists enjoyed a very bad standing in the market due to foreign competition and little support of native artists by the national government (Bayer, 2015, p.17).

[3] Montias (2010) provides an excellent recount of the art auction market in Amsterdam for that time period.

The establishment of the Christie's auction house in 1766 (which became the largest auctioneer of fine art) revolutionized the art trade. Auction sales were not only spectacular events for bourgeois society, but also constituted a process of innovation in the art trade. Direct contact between the producer of art and the consumer was not necessary anymore to purchase an artwork (Bayer, 2015, p.25). Auctions offered a public exchange platform and helped to establish a market price for artworks. Early on, auction houses already had policies and regulations in place to protect themselves from fraud and ensure timely payment by sellers and buyers. By the 19th century, laws were enforced which explicitly prohibited price manipulation tactics to protect the consumer (Bayer, 2015, p.74ff). This safe regulatory environment enhanced market liquidity and efficiency and led to higher trade volumes. Christie's enjoyed a near to monopoly position among auction houses as it managed to build-up an exceptional reputation in the art world. The founder, James Christie, was known to be a very charismatic businessman. He liaised with dealers and offered financial assistance to sellers. As a result, many important collections (consisting of both Old Masters and contemporary art) were disposed of through the auction house and it was the primary source of supply for professional art dealers. Similar to a clearinghouse of today, the auction house became an irreplaceable institution in the art market as a supplier of artworks and a provider of liquidity to the art market (Stourton & Sebag-Montefiore, 2012).

The Industrial Revolution further increased the economic prosperity of the United Kingdom (UK) and elevated a larger share of the population into the upper and middle classes. In the 19th centuries, the UK remained relatively peaceful and free of disruptive events which could adversely affect the economy. Further, the UK's rate of urbanization and literacy were among the highest in Europe in the 19th century (Buringh & Van Zanden, 2009). Additionally, the early establishment of the Bank of England (in 1694) provided the country with a highly sophisticated financial infrastructure for that time, offering various financial products (Bayer, 2015, p.16ff). This spurred consumerism among the British population and enabled the art market to flourish.

By the middle of the 19th century, contemporary artists eventually managed to establish themselves in the art market at the expense of Old Masters and foreign living artists. This was thanks to institutions (such as the Royal Academy) which enabled the exhibition of art and made it accessible to a wider public. However, the breakthrough of contemporary art was achieved through art dealers. They not only took

over marketing activities but also materialized these efforts by generating sales. Due to the popularity of British contemporary artists, the supply of artworks grew almost exponentially (Bayer, 2015, p.24ff). Artists, such as William Hunt, William Frith, and Benjamin West became mass producers of art. To increase market competitiveness, most artists became specialized in a certain signature subject or style (e.g. Hunt's *Bird Nest*). To reach a larger target audience, artists started to produce works with different levels of quality. While copies or prints were affordable for a larger mass of buyers, so-called sensation paintings were in a price range that could be paid only by the wealthiest section of the population (Bayer, 2015, p.110ff). Other important market transformations were a departure from historical painting as a theme as well the tendency to produce artworks of smaller sizes due to a diminishing return to scale (Bayer, 2015, p.68). Artworks started to become commodities and were created to please consumers. As a result, the total amount of buyers at auction increased, which further improved liquidity and efficiency in the market.

In summary, the art market in the UK was able to evolve due to uninterrupted and continuous economic growth, a mature financial infrastructure, and the emergence of auction houses. The large demand for art generated the need for specialization and a division of labor between the artistic production process and support functions such as marketing and sales. This created business opportunities for middlemen who would dominate and further revolutionize the trade in the 19th century making London the central global marketplace for art.

Having provided an overview of the 18th- and 19th century London art market, we will now take a deeper look at the role and industry structure of art dealership.

2.2.2 The History of Art Dealers

The professional art trader emerged in the late 17th century in the Netherlands and matured during the 19th century in the UK to become what is known as an art dealer today (Bayer, 2015). The dealer is part of the socio-economic and institutional ecosystem of the art world and is responsible for the establishment of the value of artworks. As described in the section above, his professionalization occurred throughout the process of the commoditization of art as a good in the early 19th century due to the need for a division of labor. Artists realized that they could

not effectively execute production as well as marketing and sales. Thus, the exploding demand for contemporary local art in the middle of the 19thcentury was thanks to the entrepreneurial activity by these middlemen who acted on this business opportunity.

When the supply of artworks was still scarce and there was little demand for local art in the 16th- and 17th century, dealers had to travel to Continental Europe to acquire paintings in a so-called *Grand Tour*. They would then sell these artworks through auctions or to private buyers (Bayer, 2015). Due to the relatively high financial and operational risks, dealers initially acted as agents and mainly bought artworks on behalf of their clients or organized auction sales where they would sell their inventory. As the supply of artworks increased through the liquidation of aristocratic estates, conflicts in Continental Europe, and the rise of local living artists, business risks decreased.[4] As a result, art dealers started to become more daring and bought artworks for their own stock which were sold on their own premises. Auctions ceased to be used as the main sales channel and were increasingly used to fill up inventory and perform liquidity sales of artworks that could not be sold to private clients (Bayer, 2015, p.106ff). A mature financial infrastructure in London greatly supported this development as it facilitated access to capital. The growing reputation and influence of certain art dealers granted them taste-making abilities and enabled a faster turnover of inventory. It caused the dealer-controlled and consumer-oriented London art trade to become the most important international art market before the First World War (Stourton & Sebag-Montefiore, 2012).

Art dealers catered to both the middle and upper classes of society. Art was often seen as a speculative venture. While it required some financial resources, no degree or professional society certificate was needed to become an art dealer, lowering the barriers to entry. It was lucrative, even for the rich, to sell parts of their valuable collections (Stourton & Sebag-Montefiore, 2012, p.14). However, building up expertise as a trustworthy dealer who resolved uncertainty about the quality of art was crucial as collectors often relied on the dealers' judgment about the future potential of an emerging artist. With respect to Old Masters, the dealer's expertise played an important role in certifying the authenticity of an artwork. Often, Old Masters appeared for sale to the public for the first time as they were previously commissioned and owned by aristocrats. Thus, in our analysis, we do not make a difference

[4] Conflicts in Continental Europe during that time included, among others, the French Revolutionary Wars (1792-1802) and the Napoleonic Wars (1803-1815).

between dealer acquisitions of Old Masters such as Rubens or Rembrandt and contemporary artists like Turner.[5] From today's perspective, one could argue that a dealer, or gallerists distinguishes himself by his ability to promote new, upcoming artists in the primary market as opposed to selling established artists. However, in the 19th century, Old Masters were not established artists and did not have a market price yet. It was, hence, the dealer's responsibility to certify the provenance and quality of the artworks since many forgeries were circulating (Arora & Vermeylen, 2013). Dealing with Old Masters was not without risk and sometimes even more cumbersome than selling the work of contemporary local artists over which dealers could exert more control. A steady supply of Old Masters was difficult to maintain. Often, Old Masters had to be imported, which required a mature logistical infrastructure, a good support environment abroad and a lot of expertise to distinguish forgeries from originals. To make a profit on these artworks, large premiums had to be charged from the client. For this reason, dealers jointly engaged in the public devaluation of Old Masters and started to collaborate with contemporary native artists. This resulted in a market downturn for Old Masters and large price increases for artworks by contemporary British artists in the late 19th century (Bayer, 2015, p.81ff). Despite being associated with certain movements or styles, most dealers were not highly specialized. They employed risk mitigation techniques such as the trading of portfolios of already established artists which helped them to introduce new emerging artists to the market. Also, dealers acted as matching agents in order to sell to each other's clients (Bayer, 2015, p.90ff).

In building a reputation, the dealer's pool of artists, collectors, auction houses, the media and other dealers played a decisive role. They provided the dealer with privileged information about the quality of the artworks, sources of supply, access to wealthy clients, and good publicity. In the 19th century, art dealers eventually took over the role of art academies in dictating what constituted good art and greatly influenced buyer preferences. They further took over the role of patronage from the aristocracy and started to support emerging artists. As a consequence, art dealers also had a say in the productive process of artists, advising them on popular themes and narratives which would lead to commercial success. By boosting the artist's popularity, they simultaneously also improved their own reputation in the market. At the same time, artists were dependent on dealer representation for commercial success. Dealers provided artists with trademark styles and made sure that output

[5] The share of Old Masters in the data set is 26.5%. For robustness, we repeated all regression using a sample consisting of contemporary artists at that time only. We observed similar results.

was sufficiently large to satisfy demand. The art dealer Arthur Tooth, for instance, brought 403 new paintings into the market within two years. He also represented artists like James Smith who was known for his waterfall paintings [p.100ff](Bayer, 2015). Thus, although intangible in nature, a reputable and skilled dealer was indeed able to add value to the works of artists.

The end of the 19th century was a century of avant-garde dealers (e.g. Grosvenor and Leicester) who greatly influenced taste. This period produced the most successful and well-known dealers to date. These dealers were entrepreneurs who were entirely committed to the artists they represented (Stourton & Sebag-Montefiore, 2012, p.274). They were also responsible for the departure of the historical painting in favor of landscape paintings (Bayer, 2015, p.105). For instance, the establishment of the Impressionist movement was thanks to influential dealers such as the French dealer Durand-Ruel. He created a market for the painters of this movement who were previously not well received. Durand-Ruel was active as a dealer between 1859 and 1922, with galleries in Paris, London, Brussels and New York, where he represented artists like Edgar Degas, Pierre-Auguste Renoir, Alfred Sisley and Paul Cézanne ("Paul Durand-Ruel", 2015). Practices which were employed by him and other successful dealers to push artists in the market included the set-up of galleries with branches in several locations, regular individual exhibitions with free entry, partnerships with providers of capital, frequent press releases, and protection of market prices for the artists they represented.[6] In their function as market makers, art dealers were also said to perform price stabilizing acquisitions at auctions to maintain a liquid market for the artists they were trading. After all, auctions were public events and could also have been used by dealers as a marketing device to send a signal to the market in order to affect the public's perception of certain artists. (Bayer, 2015, p.108). Some dealers also offered inducements to agents, consultants, or experts who advised well-known collectors with the goal to make them promote certain artists. The late-19th century dealer, William Buchanan, and the 20th century dealer, Lord Duveen, who cooperated with the art expert, Bernard Brenson, were known for these practices (Stourton & Sebag-Montefiore, 2012, p.159). In general, one could categorize art dealers in the 19th century as middlemen, gatekeepers

[6] As noted by Bayer (2015, p.116), especially for new artists, there is anecdotal evidence of price manipulation where dealers intentionally bid up prices during the auction. As auctions were and still are the only platform where art prices are public, they enable the dealer to send a positive signal to the market about the value of an artist that would allow him to charge higher prices in later sales.

of quality and taste-makers, who were largely responsible for the cross-border proliferation of the London art market.

The preceding section gave an overview of how the art market developed throughout the 19th century. The Christie's auction house as well as art dealers constituted the key elements that led to the commercialization of art. This development continued after the first- and second world war throughout the 20th century until today.

2.3 Data

The source of our unique historical data set is the auction transactions recorded by Graves (1918). Algernon Graves was a British art dealer and a historian who was responsible for initiating the practice of provenance research. He was widely known for the documentation of artwork sales held in Britain during the 18th and 19th centuries (American Art News, 1922). In three volumes, Graves documents art auctions that took place in London-based auction houses. We retrieved these three volumes from the Victoria and Albert Museum Library in London. The data set includes 37,677 sales transactions for fine art in 57 London-based auction houses from 1741 to 1913. Historical records indicate that the data set is a representative sample of auction sales over this period (Bayer, 2015).[7] Its unique feature is the availability of the original sellers' and buyers' identities in the transactions. There are 3,678 unique sellers and 3,668 distinct buyers in the sample.

The data, moreover, provide information on the name of the artist and her living status, the name of the artwork and year of origin, the medium used as well as the school or movement the artwork can be attributed to. There are 1,801 different artists and, with respect to the medium, we differentiate between paintings, drawings, engravings, copies, and sculptures. We categorize the artworks into Old Masters from the continent, Old Masters from the Low Countries, and British and Continental contemporary art. To provide an even more granular segmentation, we also differentiate based on artistic genre or artwork subject. In total, we arrive at nine different genres (Animal, Genre, History, Landscape, Marine, Mythologize, Portrait, Religion and Still Life). In addition, transaction data are available, such as the name of the

[7] The Christie's auction house, which is included in the data, captures 92% of the market share by number of acquisitions and 96% by value of acquisitions.

auction house where the sale took place, whether the transaction was part of a collection sale, the date of sale and, lastly, the nominal sales price in Pounds, Shillings and Pence. All prices are converted into British Pounds. Note that price estimates that were formed by the auction houses were not published in auction catalogs before 1973 and are, therefore, not available in the data at hand. Further, an index based on the hedonics of the artwork (i.e., the aforementioned attributes of the sale) is created in order to deflate sales prices with 1850 as the base year.[8] In creating the hedonic index, we follow the methodology of Anderson (1974), Chanel (1995), Frey and Pommerehne (1989) where the price is regressed on the set of the idiosyncratic characteristics of the artwork in addition to time (year) dummies.[9] An overview of the employed artwork characteristics can be found in Table A3.1 of the appendix. We only have sufficient data to deflate prices as of 1828. Therefore, all analyzes that involve values dominated in real British Pounds are conducted using data after this year.

All transactions are based on the English auction in which the buyer with the highest bid receives the item. Only the final hammer prices are observed. This implies that, for every auction, the winner and the final bid are known. As we are interested in the behavior of professional art buyers, our selected sample consists of 17,454 transactions conditioned on art dealer identified as the buyer, leaving us with 27 distinct auction houses, 1,187 different artists, and 2,251 sellers. However, it is important to note that the Christie's auction house captures 97% of the market by number and by value of acquisitions and remained the dominating auctioneer throughout the sample period. Besides the first and last names of the buyers, the original data does not provide any other biographical information. Therefore, we used museum archives

[8] The values of the index are the exponents of the time dummy coefficients which are then indexed to a selected base year (in our case 1850) which is set equal to 1. A hedonic index is particularly useful for the data at hand as, in contrast to the repeat sales index, it makes efficient use of the data. While for a repeat sales index at least two transactions of each artwork are needed, every transaction can be used in the hedonic index. It should be noted that hedonic indexes for art auctions are prone to a selection bias as not every artwork has the same chance to be traded at auction. Artworks of lower quality or those that have declined in value are less likely to be offered for sale. Similarly, very high-end works (such as Old Masters) are also less likely to be put up for auction as they are often in museums.

[9] The hedonic index can be provided upon request.

to identify art dealers among our buyers.[10] With this search, we were able to classify 138 distinct buyers as dealers who, in total, account for 43% of all transactions. Buy-ins are excluded from the analysis.[11]

Our key interest is expertise and how bidding strategies and survival rates differ between dealers that vary on this characteristics. We denote these two types of dealers *expert* and *non-expert* dealers. The distinction is made based on the previous year's accumulated market shares of the individual dealers. While expert dealers have a market share of 10% or more, non-expert dealers represent all remaining dealers. The threshold of 10% best identifies the leading dealers at the time based on historical records. Our results, however, are also robust to market share thresholds of 5% and 1%. We use the number and value of acquisitions per dealer by year to construct the variable. Lastly, we are aware that non-expert dealers do not remain entirely inexperienced and develop over time. However, we choose this terminology throughout our analysis for the sake of distinction.

For the price analysis, we restrict the time period to the years 1850 to 1913 which leaves us with 130 dealers in total. The period between 1800 and 1850 is used to build a history of initial market shares which is used to classify bidders into expert and non-expert dealers. The rationale behind this choice is that, according to historical records, this was the time when the auction market in the UK reached a high level of maturity with a stable supply of Old Masters as well as rising interest in contemporary art (Stourton & Sebag-Montefiore, 2012). More importantly, at that time, art dealers started to act as principals, buying for their own stock. Previous to this, they acted as agents on behalf of major wealthy buyers which could affect acquisition strategies in a different way due to a more passive role played by dealers. It is worth mentioning that we conducted research on instances of collusion between art dealers throughout the sample period as it could impact the interpretation of our results. However, we could not find any anecdotal evidence of such cases in historical records. There is discussion of ring activity (Cooper, 1977, p.88) in the 1920s but not during the period before. This decade lies outside of our sample period. Further, Etro and Stepanova (2015) finds some evidence of collusion between art dealers at

[10] The historical nature of the data set limited how much information could be extracted on the identities and biographies of the individual buyers. For instance, we cannot distinguish between full-time and part-time dealers. Moreover, we cannot always clearly distinguish between businesses that discontinue and mergers or partnerships. In cases in which dealerships were held by families over generations, we do not distinguish between different family members who managed the business in different ownership periods.

[11] In auctions, a buy-in takes place when an artwork was not sold as it fails to meet the seller's reserve price. In our data set, buy-ins represent only 5.6% of all transactions.

auction in the French market before 1850. None of the dealers who are mentioned to part of these rings are present in our data set. Even though we cannot entirely exclude the existence of single cases of collusion, the long time span and large size of our data set renders the chance that these cases might have a strong impact on our results unlikely. In addition, we cannot exclude the possibility that not all art dealers made use of auction sales to replenish their inventory. However, our data set includes a large share of the most well known art dealers who were active at that time in London such as Agnew's, Colnaghi or Wertheimer.

In the last part of the analysis, where the survival rates of different dealer types are investigated, we employ the sample starting in 1828 as we are interested in the full life-cycle of the dealers. We consolidate acquisitions per dealer on a yearly basis.

The following section will provide descriptive statistics on the the growing art market and illustrate how the art dealer industry developed within this market based on evidence in our data set.

2.3.1 Descriptive Statistics

The Art Market

We start our analysis by looking at the overall development of the art market in terms of auction sales during the period 1800 to 1913. As until today numbers on the size of the private art market are not available we rely on the sales value at auction in order to proxy the size of the art market. Nowadays, auction sales account for approximately 50% of total sales value (Pownall, 2017). Based on historical records we know that auctions constituted a very important exchange platform and preceded art dealers as a sales channels. For instance, important collections were frequently liquidated through auctions as apposed to private sales (Bayer, 2015). Therefore, we will refer to the auction market as the art market in this study.

Figures 2.1(a) and 2.1(b) show the size of the market over the investigated period in terms of number and value of transactions. Both figures clearly show the dramatic increase in artwork sales after 1870. While there were, on average, 181 sale transactions per year before 1870, the volume increased to an average of 685 transactions per year from 1870 until 1913. Even more dramatic is the jump in the value of the

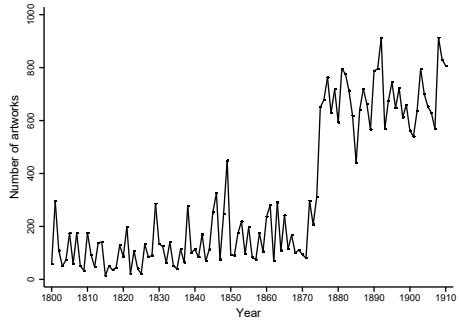
artworks sold. The total art market value amounted to an average of £22,365 until 1870 and exploded afterward to an average annual size of £170,641. Furthermore, the art market also increased its weight in the GDP of the UK economy over the same period as shown in Figure 2.1(c). The share of the total art market as a portion of real GDP doubled from an average of 0.006% before 1870 to 0.012% after 1870.[12] As a result, not only has the size of the art market quadrupled in terms of number of sale transactions, but art prices also increased eightfold.[13] The phenomenal growth of the art market around 1870 was due to the proliferation of and resulting growth in demand for contemporary local artists. This exploding demand was satisfied with an increase in the amount of professional artists and their production output as well as product diversification into new themes and styles. However, the spike in the size of the art market was also the result of the Franco-Prussian war and the Paris commune during that time. A lot of French artists and dealers looked for exile in London and increased the supply of contemporary artworks.[14] Overall, the success of local living artists can be attributed to dealers who heavily promoted these artists so as to become less reliant on sales from Old Masters which was a more risky business due to limited supply of these works and the existence of many forgeries (Bayer, 2015, p.113ff).

To identify the players in this growing art market, we plot the number of different buyer types in Figure 2.2(a). We differentiate between commercial and non-commercial buyers. While commercial buyers are represented by dealers, the group of non-commercial buyers includes aristocrats, the bourgeoisie, artists, and civil servants. We can see that the number of non-commercial buyers more than doubled between 1800 and 1913, from an average of 47 buyers per year until 1850 to an average of 118 in the years between 1850 and 1913. Even though dealers represent a smaller buyer group in absolute terms, they quadrupled from an average of eight dealers per year before 1850 to an average of 33 from 1850 until the beginning of the 20^{th}century. The number of entrants per year is presented in Figure 2.2(b). Despite fluctuations in the number of yearly entries, the number of new players increased dramatically after 1850, from up to two new entrants to a maximum of eight new dealers per year. This can be interpreted as a sign of increased profit opportunities in the market. Thus, the dealer industry expanded dramatically over time.

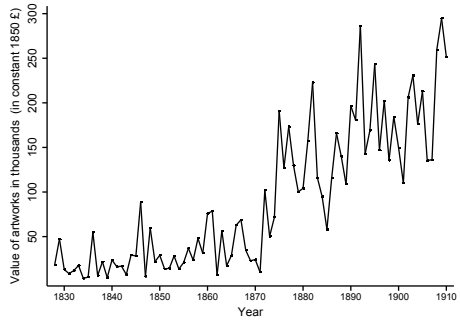
[12] In 2015, the UK art market accounted for 0.5% of the national GDP. The data on the GDP was extracted from the Bank of England and the UK Office for National Statistics. It was available as of the year 1830.

[13] This number is not adjusted for the quality of the artworks traded.

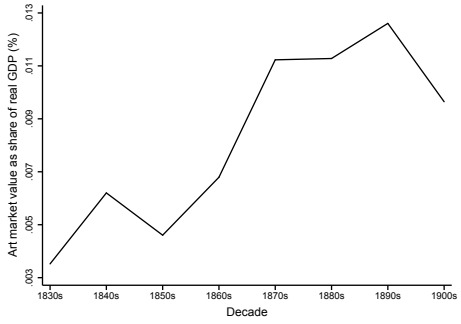
[14] In our data set most of the traded artworks can be attributed to living British artists as opposed to French artists.



(a) Size of market (by number)

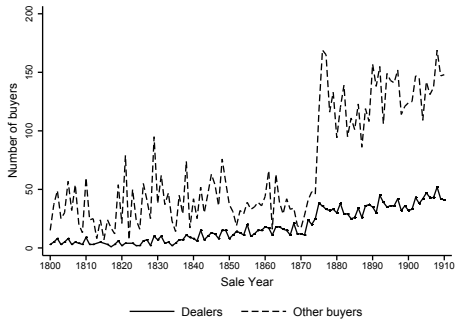


(b) Size of market (by value)

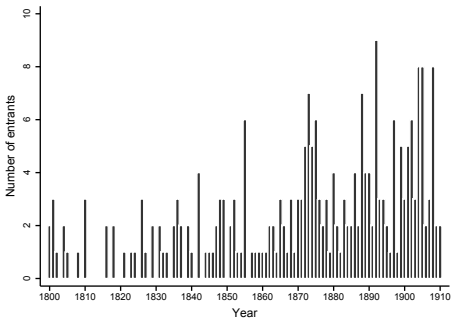


(c) The art market as a share of GDP

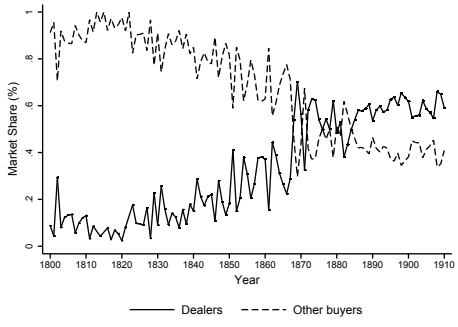
FIGURE 2.1: Art Market Evolution



(a) Number of buyers in the market



(b) Number of entrants in the market



(c) Proportion of market captured by buyers (by number)

(d) Proportion of market captured by buyers (by value)

FIGURE 2.2: Art Market Evolution - Buyers (1800-1913)

The emerging dominance of dealers as the main buyers in auctions becomes apparent throughout the second half of the 19thcentury. Figure 2.2(c) shows the market share captured by dealers versus other buyers by the number of acquired artworks. Figure 4.2(d) depicts the market share of both groups by the value of their acquisitions after 1800. Before 1850, art dealers captured an average market share of 17% when market share is calculated by the number of acquisitions (Figure 2.2(c)) and 19% when market share is calculated by the value of acquisitions (Figure 2.2(d)). In both figures, we can observe that the difference between the two buyer groups becomes smaller and eventually equalizes close to the year 1880. When market shares are calculated based on number of acquisitions (Figure2.2(c)), the average market share of art dealers reaches 57% between 1850 and 1913. The gap between dealers and other buyers widens even further at the beginning of the 20th century. In terms of value of the artworks (Figure 2.2(d)), dealer acquisitions attain an average share of 66% between 1880 and 1913. This amounts to an average purchase value of £140,000 by dealers per year. While, in peak years, about 33 dealers bought up to 600 artworks valued at £150,000, the 118 remaining buyers bought up to 380 artworks for a maximum total amount of £100,000. Thus, art dealers did not only buy more artworks than other buyers, their acquisitions were individually also more expensive. Overall, this graphical analysis illustrates that, even though art dealers were a smaller buyer group, they grew faster (especially around 1850) and substantially overshot other buyers after 1880.

Overall, the art market as we know it today emerged in the 18th century and experienced significant growth in the 19th century due to the proliferation of contemporary local artists. During this period, professional art dealers rapidly became the dominant buyers in auctions. The subsequent section will zoom into the market structure of the dealer market.

Art Dealers

The most important and successful art dealers emerged in the early 19th century. The vast majority of them were family businesses with a background as artists, print- and frame-makers or passionate collectors. Despite some changes in ownership, they remained in business over generations. Agnew and Sons was among the most influential art dealerships in London. It was also the biggest buyer in our data set. The gallery opened in 1860 in Mayfair in London and had already been operating as

a print publisher in Manchester since 1817. In 2013, the gallery was taken over, after six generations, by Lord Anthony Crichton-Stuart, a former head of Christie's Old Master paintings department ("Agnews Gallery History", 2014). The second biggest player in our data set, Paul Colnaghi, is still active as a dealer in the market for Old Masters. Located in Mayfair, it is now one of the oldest galleries in the world (Harrison, 2011). The dealership of the Vokins family, which constitutes the third-largest dealer in the data set, became active at the end of the 18thcentury and remained in the market until the beginning of the 20th century. It was originally a carving, gilding, and frame-making business and enjoyed a very high reputation. Figure 2.3 shows the market shares for these top three dealers by the number of acquisitions over the whole sample period within the population of art dealers. Agnew clearly dominates the market with a share between 30% and 60% over the whole period after 1860 and an overall average market share of 40%. The dealer lost market share in times when art market sales increased and a large number of new players entered the market. Agnew is followed by Colnaghi and Vokins who both had an average market share of about 10% over the whole sample period. Consequently, the top three players in the market consistently captured a market share between 40% and 70% among all dealers. When looking at the full market of buyers, which includes dealers as well as all other purchasers (Figure 2.4), the market shares of the top three dealers dilute but remain nevertheless sufficiently high to constitute a large market share. While Agnew still has a market share between 10% and 40%, with an average share of 20%, Colnaghi and Vokins each overall maintain a market share of 5%. Table 2.1 lists the top 25 dealers, with the numbers and values of their acquisitions. Here, the leap of Agnew, in terms of value, over the other dealers becomes even more evident. From a total market value of about £4.8 million, £2.0 million can be attributed to Agnew, which amounts to a share of 43%. Each of the next ten largest players by market value reach only a tenth of this amount. Further, the top 10 dealers own more than 70% of the market in terms of number and value of acquisitions. This observation highlights how persistent the market positions of the top players were and how difficult it was to challenge these as an entrant.

We note that the study is based on the art dealership industry in London. Therefore, we cannot exclude the possibility that some dealers were also active in other markets. Paris, for instance, was also a significant trading location for art and it might well be the case that certain dealers had clients there and, consequently, exported to these markets. However, London was the most important art market in the 19th century and the beginning of the 20th century (Bayer, 2015). We therefore assume

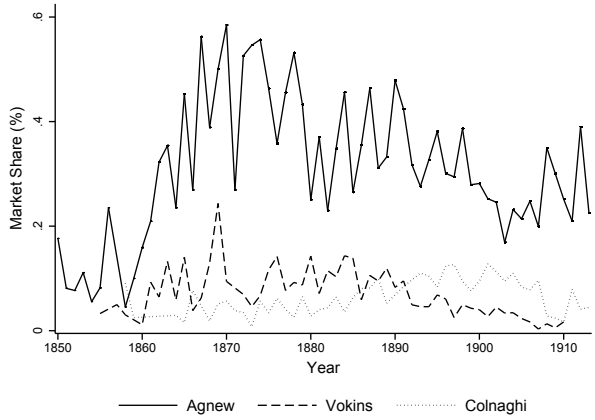


FIGURE 2.3: Market Shares 1850-1913 - Top 3 (dealer market)

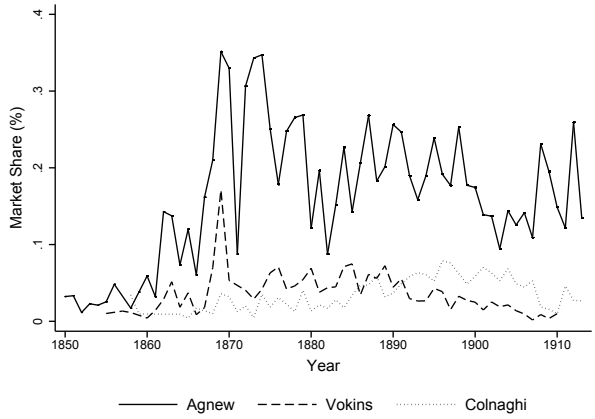


FIGURE 2.4: Market Shares 1850-1913 - Top 3 (whole market)

TABLE 2.1: Top 25 dealers with number and value of acquisitions

Rank	Dealer	Number of Acquisitions	Value of Acquisitions (in constant 1850 £)
1	Agnew	5,469	2,048,069.00
2	Colnaghi	1,126	343,614.60
3	Vokins	999	213,989.70
4	Tooth	906	221,443.80
5	Wallis	823	213,925.50
6	McLean	754	127,714.60
7	Gooden & Fox	609	150,744.30
8	Permain	399	59,701.42
9	Wertheimer	322	225,116.60
10	Lesser	304	54,234.73
11	Sampson	277	39,956.71
12	Smith	262	49,071.33
13	White	232	46,380.61
14	Leggatt	208	21,783.16
15	Shepherd	200	22,163.04
16	Graves	197	37,295.82
17	Polak	170	15,524.76
18	Lawrie	144	68,065.40
19	Dowdeswell	136	39,376.35
20	Sedelmeyer	128	40,439.52
21	Davis	128	76,061.21
22	Gambart	115	31,009.02
23	Pilgram & Lefevre	114	31,560.53
24	Grindley	113	12,582.82
25	Obach	102	31,209.49
26-138	Others	2,344	569,018.93

that dealers who had a strong competitive position in the UK art market were also successful in other markets.

The type of acquisitions in terms of artistic school made by the largest dealers is depicted in Table 2.2. First, we can see that the spread of the acquisitions across the four different schools is approximately the same for at least seven of the top 10 dealers. Modern British is by far the most popular category. Except for two dealers (Colnaghi and Lesser), who focus more on Old Masters, the purchases of all dealers consist of more than 50% of Modern British artists. The Modern British school is followed by Continental Modern art, which accounts for 14% of overall acquisitions. Old Master paintings from the Low Countries as well as from the Continent are the least acquired categories with a share of less than 10% each.[15] Another interesting finding in the table is that most of the top 10 dealers purchase a higher share of Modern British artists than other buyers. This fact points to a particular interest in this category by the largest dealers who probably were involved in the promotion of these artists and, thus, had a stake in their success. An overview of the top five artists purchased by the 10 largest dealers is provided in the Appendix in Table A2.1. We also broke down acquisitions of the top 10 dealers by artistic genre (Table 3.2). Without exception, all of them concentrated their purchases in Landscape, Genre, and Portrait artworks. Landscape and Genre paintings were contemporary subjects which were the focus of most dealers. For instance, almost half of Angnew's, Vokin's and Permain's acquisitions consisted of Landscape paintings. Another commercial reason why it was important to acquire popular contemporary artworks was that it allowed to secure the copyrights on the prints of these artworks (Cooper, 1977, p.19). All other genres (Animal, History, Marine, Mythology, Religion, and Still Life) can in most cases be attributed to Old Master themes and were significantly less popular. There were some exception as some dealers seemed to secure some niche markets for themselves by acquiring larger than average shares of less popular genres. For instance, 11% of the dealer Tooth's acquisitions consisted of Animal paintings; the dealer Wertheimer concentrated 9% of his purchases in History paintings, while the dealer Lesser focused 12% of his purchases in Religion artworks. Overall, this breakdown confirms, on the one hand, the large interest in contemporary local artists and, on the other hand, the low degree of specialization or diversification among the largest dealers in our data set.

[15] The Low Countries include the Netherlands, Belgium and Luxemburg.

TABLE 2.2: Top 10 dealers with share of acquisitions by school (in %)

Rank	Dealer	Modern British	Modern Continental	Old Master Continental	Old Master Low Countries
1	Agnew	83.5	9.3	2.2	4.6
2	Colnaghi	45.1	14.3	9.6	29.0
3	Vokins	88.0	9.3	1.3	1.1
4	Tooth	69.6	27.0	0.6	2.7
5	Wallis	61.5	31.4	1.4	5.2
6	McLean	81.9	14.4	0.8	2.4
7	Gooden & Fox	76.1	13.8	3.1	5.9
8	Permain	90.8	5.5	1.0	2.3
9	Wertheimer	52.6	21.4	3.4	21.7
10	Lesser	28.6	14.8	12.8	43.4
11-138	Others	64.6	16.0	4.8	14.2
Total		71.5	14.2	3.6	9.9

Percentages do not some up to 100 as artworks which could not be attributed to a school (others). were excluded.

In this section, we have illustrated the structure of the dealer industry throughout in the 19th century. The market initially consisted of a handful of dealers who dominated the market and captured high market shares in addition to a larger mass of dealers who were less influential with a significantly lower market share. There seem to be significant differences between art dealers and their attributes which determine success and survival in the market. In the following empirical analysis, we will focus in a multivariate setting on the life cycle of art dealers throughout the evolution of the art market.

TABLE 2.3: Top 10 dealers with share of acquisitions by genre (in %)

Rank	Dealer	Animal	Genre	History	Landscape	Marine	Mythology	Portrait	Religion	Still life
1	Agnew	6.0	17.7	5.2	41.1	3.1	3.3	14.9	4.3	2.0
2	Colnaghi	4.5	14.7	8.7	26.2	2.2	1.5	29.5	8.9	1.7
3	Vokins	6.2	18.5	5.8	41.3	3.3	3.6	10.5	3.7	4.6
4	Tooth	10.9	23.4	4.6	34.1	3.1	3.2	12.6	2.6	2.2
5	Wallis	5.8	25.5	5.9	32.7	2.4	1.1	17.0	4.3	1.3
6	McLean	5.7	20.9	6.6	38.9	2.1	2.9	13.5	3.6	2.3
7	Gooden & Fox	5.6	18.7	5.1	38.1	2.1	3.8	17.8	3.1	2.5
8	Permain	6.5	15.0	4.3	45.1	3.0	3.8	11.3	3.8	3.3
9	Wertheimer	2.8	17.7	9.3	11.5	0.9	1.9	46.4	3.4	1.9
10	Lesser	5.6	19.1	4.0	24.0	1.0	1.3	28.0	11.5	1.0
11-138	Others	7.9	17.9	9.1	27.1	2.4	3.7	21.3	6.1	2.1
Total		6.7	18.4	6.8	33.9	2.6	3.2	18.4	5.1	2.2

Percentages do not some up to 100 as artworks which could not be attributed to a school (others) were excluded.

2.4 Empirical Analysis

2.4.1 Entry

What motivates dealers to enter into the art market? In particular, we aim to identify the factors that drove the evolution of the art dealership industry resulting in such a heterogeneous group of dealers. In the spirit of Rosenthal and Strange (2003) and Berry and Reiss (2007), we assume that entrepreneurs will enter the market as long as their expected profits are non-negative. Hence, we empirically estimate the expected number of entrants per year using a count model controlling for competition and other market conditions. We assume that the number of entrants will have a Poisson distribution. Note that a standard Poisson model assumes equality between the mean and variance of the dependent variable, conditional on explanatory variables. If the assumption is violated, the maximum likelihood estimator will lead to inconsistent results. Hence, we employ a Poisson pseudo-maximum likelihood (PPML) estimator which is particularly efficient and robust. For PPML estimation, the data does not have to follow a Poisson distribution to produce consistent estimates. The only condition required for consistency is the correct specification of the conditional mean of the independent variable (see Silva and Tenreyro (2010), Wooldridge (1999). In this setting, our dependent variable is the number of dealers entering in a given year and its conditional mean is given by:

$$E[y_t|A_t, K_t, X_t] = exp(A'_t\alpha + K'_t\beta + X'_t\gamma). \tag{2.1}$$

To explain the number of entrants in the market, we include trading activity as an independent variable (represented by A). We use both the number and the value of artworks bought by dealers in a given year t. Note that information on upcoming auctions is known well in advance. Our expectation is that, with higher trading activity, new players will be incentivized to enter the market.[16] The descriptive statistics in Table 2.4 show that the average annual number of artworks bought by dealers during this time period is between five and 603 with an average of 205 artworks. The mean of the dealer acquisitions reaches a value of £58,658. Additionally,

[16] We do not lag the number of artworks as it is known to the dealers ex-ante how many objects are sold in the market. Hence, they can incorporate this information when making the decision about whether to participate in the market or not.

we include the number of existing dealers to control for market competition as an explanatory variable (denoted by K).

As the overall national economy may have an effect on entry, we include a set of market characteristics (denoted by X) including the population, per capita income and the bond yield.[17] These variables control for similar characteristics of the market and, thus, we include them separately in the regressions. Our expectation is that a growing population and more disposable income will have a positive effect on the demand for artworks and will create space for more players in the market. Further, we include the lagged annual bond yield as an explanatory variable to proxy opportunity costs. When interest rates are high, potential entrants may divert their excess financial capacity to bonds rather than art. As presented in Table 2.4, the average bond yield is around three percent. The population is about 12 million in 1828 and grows to 33.9 million by the end of the period. The real per capita income more than doubles during the time period from £2,870 to £6,530 per year.

TABLE 2.4: Summary statistics for market characteristics between 1830-1913

Variables	Summary statistics	
	Mean	Sd
Average number of artworks bought by dealers per year	205.3	181.4
Average value of artworks bought by dealers per year	58,657.9	58,685.0
Annual bond yield (in %)	3.0	0.4
Population (in mn)	2.20	0.68
Real per capita income (in £)	43.2	11.6

Only the dealer sample is considered for the analysis. All prices are in constant £1850.

As the art market matured, dealers started to act as principals instead of agents, buying for their own stock after 1850. Thus, we include a dummy for the years after 1850. We expect the coefficient of the after-1850 variable to have a positive effect on entry. For the analysis, we use the time period between 1830 and 1913 as data on per capita income was available only for the years after 1829.

The entry results are presented in Table 2.5 and provide evidence that the increase in the number of entrants is mainly driven by higher trading activity. The number and the value of artworks bought by dealers have both a positive and statistically significant effect on entry. Another important factor explaining entry is the current level of competition. As expected, the number of incumbents, a proxy for market competition, has a deterring effect on entry. The coefficient is highly significant in

[17] The data on the per capita income and population was not part of the original data set and was extracted from the Bank of England and the UK Office for National Statistics.

all regression specifications. However, none of the economic conditions show significant effects on dealer entry. Moreover, contrary to expectation, the post-1850 period does not seem to have any significant effect on entry. Additionally, to have a complete picture of the full period from 1800 until 1913, we run a separate regression including only the variables for which we have complete data (column 7). The results are qualitatively consistent with the findings in columns 1 to 6, namely that trading activity is positively correlated with entry, while competition discourages it. As entrants may need more time to adjust to increasing trading activity, we have repeated the regressions using lagged values of the number and value of artworks bought by dealers. The results can be found in the Appendix in Table A2.3 (columns 1 to 6). Even though the coefficients slightly lose their magnitude, the qualitative results remain the same.

TABLE 2.5: Entry results

Variables	Number of entrants						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Number of artworks	0.767***	0.712***	0.668***				0.641***
bought by dealers (log)	(0.131)	(0.110)	(0.105)				(0.125)
Value of artworks				0.465***	0.445***	0.383***	
bought by dealers (log)				(0.096)	(0.078)	(0.074)	
Number of incumbents	-0.048***	-0.049***	-0.051***	-0.022***	-0.024***	-0.026***	-0.061***
	(0.010)	(0.010)	(0.012)	(0.008)	(0.007)	(0.009)	(0.011)
Lagged population (log)	-0.688			-0.683			1.023**
	(0.490)			(0.544)			(0.464)
Lagged real per capita		-0.414			-0.578		
income in £ (log)		(0.349)			(0.358)		
Lagged annual bond yield			0.026			0.065	
			(0.219)			(0.224)	
After 1850	0.221	0.102	0.116	0.024	-0.100	-0.044	0.215
	(0.191)	(0.173)	(0.177)	(0.233)	(0.228)	(0.222)	(0.280)
Observations	83	83	83	83	83	83	113
Pseudo log-likelihood	-144.3	-143.8	-145.7	-146.9	-146.8	-147.8	-190.3

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
All prices are in constant £1850.

Overall, we can infer that entry was driven by the increasing trading activity and was curbed as competition increased. This finding hints at the competitive dynamics of the art dealership industry. New, less experienced dealers might already anticipate that they cannot compete against more expert dealers and decide to stay out of the market. In the subsequent part of the empirical analysis, we will investigate differences in the bidding strategies of non-expert and expert dealers.

2.4.2 Bidding Strategies

As previously described, in this study, our key interest is expertise, as proxied by market share, and how bidding strategies differ between dealers who vary on this characteristic. Based on the previous year's accumulated market shares of the individual dealers, we distinguish between non-expert and expert dealers. While expert dealers have an accumulated market share of 10% or more, the rest of the dealers are defined as non-expert dealers. We expect expert dealers to pay higher prices than non-experts, on average, due to larger accumulated experience and knowledge. This expertise should translate into a better capacity to push and promote an artist in the market improves relative to other dealers. Thus, the dealer creates value through expertise in the form of reduced information asymmetries. This value added is intangible in nature but feeds back into the resale price as collectors are willing to pay a premium for alleviating uncertainty. Consequently, the dealer can extract higher profits from the artworks he sells on to collectors. Crucially, therefore, dealers with more expertise are able to pay higher prices for the artworks they acquire, which should be reflected in their bidding strategy at auction. A first look at the summary statistics (Table 2.6) lends support to our hypothesis. Table 2.6 shows the level of prices paid and number of artworks acquired for different dealer types along different quantiles of the price distribution over the sample period 1850 to 1913. While Panel A presents summary statistics for expert and non-expert dealers defined by number of acquisitions, Panel B shows summary statistics for both groups when market shares are calculated based on the value of acquisitions. Independent of how market shares are defined, on average, expert dealers seem to pay higher prices in every quantile of the price distribution. The difference becomes more pronounced for higher priced artworks. This makes intuitive sense as non-expert dealers might have fewer funds, which restricts them when competing with expert dealers for lower priced items.

Figures 2.5 and 2.6 present the corresponding unconditional densities for different distributions of the prices for expert and non-expert dealers. Figure 2.5 depicts the density function when market shares are defined by the number of acquisitions and Figure 2.6 shows the respective graph when market shares are defined by the value of acquisitions. In both representations, the price distribution of expert dealers is shifted to the right. The differences in prices paid by both dealer types are especially pronounced in higher price segments. The clear representation in these density functions confirms our findings in Table 2.6 and means that the distribution of

winning bids of expert dealers stochastically dominates the distribution of winning bids of non-expert bidders. As a result, both the table and its graphical representations outline the same pattern, namely that expert dealers appear to bid more aggressively than non-expert dealers over the whole distribution of prices. Furthermore, Figures A2.1 and A2.2 in the Appendix show the development of average real prices paid for artworks by expert and non-expert dealers over time. We see an increase trend in averages prices for both dealer types. Nevertheless, in almost every year, expert dealers appear to pay higher average prices than non-experts. This time trend perspective confirms our conjecture that expert dealers have a higher value distribution than non-expert dealers.

TABLE 2.6: Prices paid by dealers types between 1850-1913

Panel A: Dealer type defined by number of acquisitions				
Quantiles	Expert dealers		Novice dealers	
	N	Average price	N	Average price
q10	705	56.74	953	50.21
q25	1,056	89.19	1,442	76.88
q50	1,758	163.60	2,369	124.48
q75	1,764	348.85	2,389	239.22
q90	1,056	771.05	1,431	480.88
Panel B: Dealer type defined by defined by value of acquisitions				
Quantiles	Expert dealers		Novice dealers	
	N	Average price	N	Average price
q10	657	60.00	997	47.84
q25	985	91.66	1,499	76.63
q50	1,641	167.37	2,515	124.23
q75	1,643	354.65	2,501	241.70
q90	985	784.73	1,500	487.02

All prices are in constant £1850.

We expected expert bidders to exert a different influence on auction prices for artworks than non-expert bidders. In particular, we expect that expert bidders will bid more aggressively than non-expert bidders. The former are able to accumulate market expertise which enabled them to better promote artists and extract higher profits from their acquisitions. Accordingly, expert dealers had a higher value distribution than non-expert dealers. Our summary statistics reveal that expert dealers pay higher prices for artworks across the whole distribution of winning bids. Given that artworks are very heterogeneous, it may, therefore, be that expert dealers simply acquire artworks of higher quality than non-expert dealers. In order to rule out this alternative interpretation, we continue with further testing the robustness

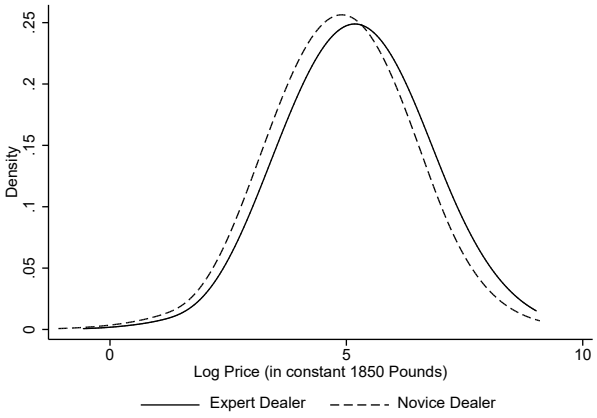


FIGURE 2.5: Expert and Novice Dealers (by number of acquisitions)

FIGURE 2.6: Expert and Novice Dealers (by value of acquisitions)

of our results conditioned on the idiosyncratic characteristics of the artwork in a multivariate setting.

To estimate the influence of the dealer type on price, we regress the price of an artwork on dealer types; we include a dummy variable that equals one for expert dealers and zero otherwise (based on the 10% market share threshold mentioned above). Note that the bidder status, expert or non-expert, is not permanent and varies across time in our sample. As the dealer's expertise might not only be reflected in the level of her market share, captured by the expert dealer dummy, we are able to also control for other dealer characteristics in a direct way. We expect that a higher availability of funds will enable the dealer to afford more expensive artworks. Hence, we control for dealers' financial resources. The variable capacity is defined as the maximum total amount spent in a year before the current acquisition period. Further, to have a proxy for the dealer's experience, apart from her market share, the number of years of experience in the market up to the current transaction is controlled for. All three dealer characteristics are highly correlated with one other and are, therefore, included in separate regression specifications.[18]

Furthermore, we are controlling for other factors related to the competitive landscape. First, we control for auction characteristics. These include the number of bidders and the lot sequence within a single auction sale. A single auction sale involves all transactions that were sold during one day in the same auction house with artworks commissioned by the same seller. As mentioned before, we cannot directly observe the number of bidders that were present at a sale. Therefore, we proxy them with the number of lots that were up for sale during a single auction event. In cases where the number of bidders was smaller than three, the value was replaced by number of lots sold during that day independent of the identity of the seller. As observed by Li and Zheng (2009), a higher number of competing bidders drive up the price. We also control for the lot sequence of an artwork. The timing when an item is sold can influence its price. Empirical studies provide evidence for both directions with respect to the expected effect of the lot sequence. While Ashenfelter (1989), Ginsburgh (1998), Ginsburgh and van Ours (2007) show that earlier lots fetch higher prices than later lots, Chanel and Gerard-Varet (1996), Deltas and Kosmopoulou (2004), Pesando and Shum (1996) illustrate that later lots yield higher prices at auction. Second, we control for rival characteristics. The attributes of rivals a dealer is faced with at auction, can affect her bidding behavior which in turn will

[18] The correlation between the expert dealer dummy, the capacity variable and the experience variables ranges from 48% to 77%.

influence prices. In particular, the presence of wealthier bidders or bidders with a lot of market expertise can drive up prices. We control for the rival's maximum capacity as well as the rival's maximum market share in terms of volume and value. The rival's maximum capacity equals the capacity of the bidder who displays the highest capacity among all bidders present in one auction sale. Similarly, a rival's maximum share equals the market share of the competing bidder who accumulated the largest market share among all rivals present in one auction event. All variables are lagged by one period to exclude the current sale.

Additionally, to control for the quality of the artwork, we include its observable characteristics. We follow the literature on hedonic pricing which assumes that it is possible to correctly estimate the price of every characteristic and that their sum equals the final sales price of the artwork. The size of an artwork significantly contributes to its price (Etro & Pagani, 2012; Ashenfelter & Graddy, 2003). However, this variable is not always recorded in the data, particularly for objects such as sculptures. To avoid loss of statistical power due to a reduced sample size and simultaneously remain conservative, we estimate every regression, both including as well as excluding the artwork size. Our basic regression model has the following specification,

$$lnP_{ijt} = D'_{jt}\beta + M'_{jt}\eta + X'_{it}\theta + \tau_t + \epsilon_{ijt}, \tag{2.2}$$

where lnP indicates the log of the real price of an artwork, i, bought by dealer j in a given year t. All dealer characteristics are captured in D, while rival characteristics are subsumed under M. X denotes the artwork's and auction characteristics.τ_t represents the time fixed-effects. Lastly, ϵ_{ijt} denotes the error term.

Table 2.7 reports the descriptive statistics for expert and non-expert dealers for the time period under investigation: 1850 to 1913. While panel A shows descriptive statistics by dealer types when dealers market share is calculated using the number of acquisitions, Panel B reports the same information when dealers market shares are based on the value of acquisitions. We can see that expert dealers are responsible for 6,967 sales out of 16,360 total dealer transactions. This is about 43% of the dealers' market.[19] However, the total value of these expert dealers' transactions accounts for 40% of the dealers' market share. A comparison of the past market shares, which were used to define expert/non-expert dealers, shows that our threshold of

[19] Out of the 16.581 observations available for the years 1850 to 1913, we lose 221 observations due to missing values for the variables artist age and artist living status. The living status refers to whether an artist was alive at the time when the transaction took place.

10% offers a very clear-cut distinction. While expert dealers reach, on average, between 24.1% and 31.3%, non-expert dealers have a mean past market share of between 3.4% and 4.0%. From a total market value of about £4.8 million, non-expert dealers obtain a share amounting to a sum between £163,200 and £192,000. It is important to note that the expert dealer dummy is a dynamic variable and, hence, the expert or non-expert status is not permanent for a given bidder. Hence, the number of distinct non-expert and expert dealers and, consequently, the amount of transactions by these two dealer types changes from year to year. While Agnew, for instance, dominates the market most of the time, the positions of the other key players are less stable. When market share is defined by the number of transactions, there are, on average, five expert dealers and 41 non-expert dealers per year. Similarly, when market share is defined by the value of completed transactions, we have a mean of four expert dealers and 42 non-expert dealers per year (see appendix Table A2.4). The capacity of expert dealers reaches, on average, almost ten times the capacity of non-expert dealers (£11,370 and £96,363). This outlines the financial constraints of non-expert dealers. Also, with respect to experience, expert dealers have, on average, approximately twice as many years of experience (44 versus 24 years) as non-expert dealers. From the descriptive statistics, we can infer that expert and non-expert dealers differ in their characteristics which will have an influence on their respective market expertise stemming from accumulated market share. Furthermore, there are on average 28 rival bidders present at auction with a mean capacity of £1,126. The average market share of rivals is 23% in terms of volume and 25% in terms of value.

In Table 2.8 we present the regression results for the influence of dealer type on price. Columns 1 and 2 show the effect of expert dealers on price when market shares are calculated based on number of acquisitions. Columns 3 and 4 present the results when market shares are based on value of acquisitions. In all four regression specifications, the expert dealer dummy coefficient is positive and statistically significant. The interpretation of this result is that when the buyer is a expert dealer, the expected estimated price is approximately 21% higher than if the buyer were a non-expert dealer. The magnitude of the coefficient is similar when we use the value instead of the number of acquisitions to calculate market shares (21.2% and 23.2 %). Another way to interpret this result is that an expert dealer estimates the additional value he can create in his role as a taste-maker at about 21% higher than what a non-expert dealer could create in value given the characteristics of the artwork. As

TABLE 2.7: Summary statistics for expert and novice dealers between 1850-1913

Panel A: Dealer type defined by number of acquisitions						
Variables	Expert dealers			Novice dealers		
	N*	Mean	Sd	N*	Mean	Sd
Past market share	6,967	0.241	0.071	9,393	0.040	0.028
Capacity	6,967	96,363	52,091	9,393	11,370	9,085
Experience	6,967	43.7	14.9	9,393	24.2	14.8
Panel B: Dealer type defined by value of acquisitions						
Variables	Expert dealers			Novice dealers		
	N*	Mean	Sd	N*	Mean	Sd
Past market share	6,503	0.313	0.108	9,857	0.034	0.026
Capacity	6,503	101,913	49,356	9,857	11,709	9,303
Experience	6,503	44.0	14.9	9,857	24.9	15.1
Panel C: Control variables						
Variables				Mean		Sd
Number of bidders				28.215		24.989
Lot sequence				17.864		17.682
Rival's past maximum capacity (in £)				1,126		4,911
Rival's past maximum share by volume				0.232		0.214
Rival's past maximum share by value				0.254		0.249

All prices are in constant £1850.
*Values correspond to number of art works bought.

a result, expertise plays a substantial role in price. When size is added as an additional explanatory variable, the magnitude of the expert dealer coefficient declines by two percentage points. However, it is still very important with an impact of about 1%. Experience, which is defined as the number of years in business, also has a statistically important effect on the expected price of the artwork. The coefficient indicates that an additional year of experience increases the expected price by about 10% (columns 5 and 6). In columns 7 and 8, we use capacity as the main explanatory variable. The coefficient on capacity is positive and statistically significant. It shows that dealers with high financial resources pay, on average, about 8.5% more. Moreover, the competitive landscape has important effect on price. Every additional bidder increases the price by 4% to 6%. In particular the presence of wealthy rivals outs upward pressure on price as can be seen by the positive and statistically coefficient on rival's past maximum capacity. Lastly, it appears that lot which are sold later within the auction sale fetch higher prices. This could be explained by the fact that dealers do not want to leave the auction sale empty-handed and thus increase their bids towards the end.

TABLE 2.8: Influence of dealer type on price

Variables	Log of price							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Expert dealers	0.212***	0.189***						
(*Top 10% by number*)	(0.066)	(0.068)						
Expert dealers			0.232***	0.203***				
(*Top 10% by value*)			(0.063)	(0.068)				
Experience (log)					0.099**	0.092*		
					(0.043)	(0.047)		
Dealer capacity (log)							0.085***	0.084***
							(0.013)	(0.014)
Number of bidders (log)	0.039*	0.057***	0.039*	0.058***	0.040**	0.056***	0.036*	0.054***
	(0.020)	(0.021)	(0.021)	(0.021)	(0.019)	(0.021)	(0.019)	(0.020)
Log of lot sequence (log)	0.153***	0.058***	0.153***	0.059***	0.153***	0.058***	0.151***	0.056***
	(0.030)	(0.017)	(0.030)	(0.017)	(0.030)	(0.017)	(0.031)	(0.018)
Rival's past maximum capacity (log)	0.013**	0.027*	0.013**	0.027**	0.013**	0.027*	0.016**	0.031**
	(0.006)	(0.014)	(0.006)	(0.013)	(0.006)	(0.014)	(0.007)	(0.014)
Rival's past maximum share (log)			-0.004	0.078	-0.258	-0.139	-0.042	0.035
(*By volume*)			(0.056)	(0.060)	(0.159)	(0.132)	(0.056)	(0.062)
Rival's past maximum share (log)	0.048	0.101**			0.309*	0.262**		
(*By value*)	(0.061)	(0.051)			(0.156)	(0.124)		
Size (log)		0.405***		0.405***		0.405***		0.406***
		(0.038)		(0.038)		(0.038)		(0.037)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Season effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Auction house effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Artist effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Seller effects	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Observations	16,360	5,842	16,360	5,842	16,360	5,842	16,360	5,842
R^2	0.515	0.577	0.515	0.577	0.512	0.575	0.519	0.582

Standard errors clustered by dealers in parentheses. *** p<0.01, ** p<0.05, * p<0.1
All prices are in constant £1850.

All results are robust for the inclusion of size as a control variable. As mentioned above, we examine bidding strategies after the year 1850 as this was the time when dealers started acting as principals, buying artworks for their own inventory. To ensure robustness, we repeat these regressions while extending the sample period from 1828 to 1913. The regression results can be found in the appendix in Table A2.5. The results, remain qualitatively the same. The coefficient of the expert dealer dummy increases in magnitude, lending further support to our hypothesis that these dealers pay, on average, higher prices for their acquisitions given the quality of the artwork.

So far, the results strongly support our conjecture that expert dealers pay higher prices at auction, which can be explained by their superior ability to promote artists in the market and access clients more easily. The expert dealer dummy, our proxy

for the dealer's overall expertise, financial capacity, and years of market experience, all confirm that these dealers, on average, pay more for an artwork given its quality.

To see if these results also hold over the entire distribution, we estimate the above model using the quantile regression approach proposed by Koenker and Bassett Jr (1978). Panel A in Table 2.9 presents the results when expert dealers are defined based on number of acquisitions. Panel B shows the results when the market share is calculated based on value of acquisitions. In both specifications, results indeed confirm that, at the more expensive end of the distribution, non-expert bidders are less able to compete with expert bidders. In the lowest quantile of the price distribution, expert dealers pay, on average, between 14% and 19% more than non-expert dealers (depending on how market share is defined). Interestingly, the difference in prices paid by the two dealer types is lowest in the 25th quantile of the price distribution (10% and 15%). This may indicate that, even if a dealer is smaller, he may be more competitive in the lower-mid-quality range than for the lowest quality artworks. From the 50th percentile onward, the difference becomes even more pronounced, peaking in the 90th percentile where expert dealers pay about 35% more than non-expert dealers given the characteristics of the artwork. Generally, the difference between the two dealer types with respect to their influence on price is slightly larger when the value of transactions is used to construct market shares. However, coefficients in Panels A and B get very close to each other in the upper part of the distribution of the price.

Note that, in all regressions, we have not used a full set of dealer fixed effects. The reason for this decision is that there is not enough variation within individual dealers with respect to the dealer type. As such, the dealer type is sticky, meaning that a dealer who is considered an expert does not often switch her status to that of a non-expert dealer.[20] As a robustness check, we repeat the regression models controlling for the top 10 dealers versus other dealers. These results are presented in Table A2.6 in the Appendix. The findings are consistent with expert dealers paying higher prices than non-expert dealers. For example, we see that Agnew bids on average 41% more than other dealers.

In summary, the results in this section provide strong statistical support to the conjecture that expert dealers pay higher prices in auctions than non-expert dealers

[20] The average variation of the dealer type change per dealer is 0.7 when market share is defined by number of acquisitions and 0.6 when market share is defined by value of acquisitions. Out of 130 dealers, there are 86 dealers (100 when market share is calculated by value of acquisitions) who have never changed dealer type at all over the whole sample period.

TABLE 2.9: Quantile regression results

Panel A: Dealer type defined by number of acquisitions					
Variables	Log of price				
	q10	q25	q50	q75	q90
Expert dealer	0.135***	0.104***	0.192***	0.275***	0.336***
(*Top 10% by number*)	(0.032)	(0.019)	(0.016)	(0.026)	(0.049)
Number of bidders (log)	0.159***	0.083***	0.064***	0.057***	0.059***
	(0.017)	(0.007)	(0.010)	(0.011)	(0.021)
Log of lot sequence (log)	0.074***	0.085***	0.144***	0.223***	0.275***
	(0.014)	(0.007)	(0.007)	(0.007)	(0.017)
Rival's past maximum capacity (log)	0.099***	0.049***	0.028***	0.010**	-0.005
	(0.008)	(0.006)	(0.004)	(0.005)	(0.006)
Rival's past maximum share (log)	0.168***	0.085***	0.042	0.029	0.092
(*By value*)	(0.064)	(0.031)	(0.026)	(0.051)	(0.069)
Other characteristics	Yes	Yes	Yes	Yes	Yes
Observations	16,360	16,360	16,360	16,360	16,360
Panel B: Dealer type defined by value of acquisitions					
Variables	Log of price				
	q10	q25	q50	q75	q90
Expert dealer	0.187***	0.148***	0.214***	0.286***	0.364***
(*Top 10% by number*)	(0.023)	(0.014)	(0.018)	(0.026)	(0.047)
Number of bidders (log)	0.155***	0.083***	0.060***	0.057***	0.054*
	(0.027)	(0.015)	(0.014)	(0.019)	(0.031)
Log of lot sequence (log)	0.074***	0.085***	0.145***	0.224***	0.275***
	(0.012)	(0.006)	(0.006)	(0.010)	(0.009)
Rival's past maximum capacity (log)	0.098***	0.049***	0.026***	0.010*	-0.008
	(0.010)	(0.005)	(0.003)	(0.006)	(0.009)
Rival's past maximum share (log)	0.085	0.003	-0.009	-0.017	-0.062
(*By volume*)	(0.058)	(0.032)	(0.035)	(0.051)	(0.072)
Other characteristics	Yes	Yes	Yes	Yes	Yes
Observations	16,360	16,360	16,360	16,360	16,360

Bootstrapped standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$
All prices are in constant £1850.

given the characteristics of the artwork. This is especially the case for higher priced artworks. Moreover, expert dealers do not seem to simply recognize and buy artworks of better quality. Instead, they appear to have accumulated knowledge which enable them to do a better job of promoting artists in the market and, thereafter, when reselling, can charge higher prices. Thus, expert dealers appear to act as tastemakers who can make the market. The higher prices paid at acquisition indirectly reflect expertise, which then feed back into the market as an intangible value for which a premium can be charged on resale. In the next section, we aim to underpin this hypothesis even further by analyzing the survival rates of expert and non-expert dealers.

2.4.3 Exit Patterns

We are also interested in learning whether the expert dealers' strategy of acquiring artworks at higher prices is sustainable. If expert dealers indeed pay higher prices, as they possess have a more expertise which enables them to promote artists in the market more effectively and extract higher profits from their acquisitions, we expect them to survive longer than non-expert dealers. In this case, non-expert dealers, should leave the market as they fail to generate sufficient profits to sustain the dealership. However, if expert dealers consistently overpay and cannot recover the amount spent on the acquisition of artworks, we should observe them exiting the market with a higher probability than non-expert dealers.

To investigate which dealer type has a relatively higher chance of survival in the market, a simple probit model is employed. The binary dependent variable, exit, takes the value of one if the dealer exits the market in a given year and zero otherwise. We consider market inactivity of a dealer as an exit if there were no purchase or sale transactions for three consecutive years. We allow for a break of three years before we define dealer inactivity (buyer or selling) as an exit. This allows for the possibility that dealers remain active elsewhere and may replenish supply either through private acquisitions or in other public sales outside of London. A period of three years was selected based on the distribution of the years of market absence among dealers in the sample.[21] In the case of an exit, we still cannot exclude the possibility that the dealer is still active as an art dealer in a different market or auction

[21] In our sample, 98% of dealers did not have more than three consecutive years of inactivity between their first and their last observation.

house. Nevertheless, as the London auction market was considered the most important art market at the time, we interpret an exit as a sign of market failure. Dealers are considered re-entrants when they exit the market and make a first acquisition upon their return. Therefore, re-entrants are considered as entrants with past experience.[22] Our definition of firms with past experience is similar to Dunne, Klimek, and Roberts (2005), where they examine the exit patterns of firms with past experience in the manufacturing industry. Entry status is not permanent and all dealers are considered incumbents after the initial year of entry or re-entry. While most of the dealers entered after 1850, many dealers exited and re-entered the market several times. We identify re-entrants using a dummy variable that takes the value of one if a dealer was active in the market before and zero otherwise. If a dealer was active in the market in the past, it should help her to survive in the market due to more accumulated information. Hence, he should have a lower likelihood of exit. Furthermore, we control for market conditions and year effects. Similar to the entry analysis, we expect that favorable market conditions (i.e., more trading activity, higher artwork prices, a prospering population and low opportunity costs) should increase survival probability. Due to the fact that all market condition variables exhibit a high correlation with each other, we include them separately in different regression specifications. Note that, as we are interested in the full life-cycle of the dealers, we use only firms that entered or re-entered from 1828 to 1910. We do not use entrants or re-entrants after 1910 and this gives us an opportunity to track dealers for at least three years since they last participated in the market. This ensures that they are not active again within at least three years. We use a simple probit model to analyze exit and the empirical specification has the following form:

$$Pr(Exit = 1|Z) = \Phi(Z'_{jt}\lambda), \tag{2.3}$$

where the independent variables Z can be classified into three main groups D, E, and M. D denotes the dealer j's type at exit, E represents whether dealer j is a firm with past market experience, and M includes proxies for the market conditions. Φ is the cumulative normal distribution.

Table 2.10 shows the descriptive statistics for the main explanatory variables for expert and non-expert dealers used in our exit analysis. While Panel A presents the descriptive statistics when market share is defined by number of acquisitions, Panel

[22] In order to define exit and re-entry, we count the number of inactive years per dealer. We define years of inactivity as years in which neither sale nor purchase transactions were completed by the dealers. However, only purchase transactions are considered to define entry.

B shows the values when market share is determined using the value of acquisitions. The most important insight that can be inferred from Table 2.10 is that the probability of exit is much higher for non-expert dealers (12%) than for expert dealers (4%). As before, and subject to our definition, expert dealers have a much larger market share (19% to 23%) than non-expert dealers (one percent). There are also more dealers with past experience among expert dealers (87%) than among non-expert dealers (69%). Furthermore, the financial resources of expert dealers exceed non-expert dealers' funds fivefold.

TABLE 2.10: Summary statistics for expert and novice dealers between 1850-1913

Panel A: Dealer type defined by number of acquisitions				
Variables	Expert dealers		Novice dealers	
	Mean	Sd	Mean	Sd
Probability of exit*	0.040	0.197	0.116	0.320
Past market share	0.190	0.071 4	0.014	0.022
Dealers with past experience	0.874	0.333 2	0.687	0.464
Capacity	18,068.9	37,075.4	3,779.9	5,402.4
Panel B: Dealer type defined by value of acquisitions				
Variables	Expert dealers		Novice dealers	
	Mean	Sd	Mean	Sd
Probability of exit*	0.028	0.165	0.116	0.320
Past market share	0.234	0.112	0.014	0.023
Dealers with past experience	0.846	0.362	0.695	0.461
Capacity	20,723.1	40,309.2	3,839.7	5,528.1

All prices are in constant £1850.
*Multiple entries and exits by dealers are possible during the sample period.

The results of the probit regression are reported in Tables 2.11 and 2.12. Table 2.11 reports the regression coefficients when market share is defined by number of acquisitions and Table 2.12 shows the results when market shares are determined using value of acquisitions. For all regression coefficients, we report the marginal effects. The results indicate that, independent of the inclusion of market condition variables, both tables show consistent effects for the expert dealer dummy. The probability of exiting the market is between 6.7% and 8.2% lower when a dealer is defined as expert rather than non-expert. As expected, previous market experience alleviates the probability of exit. A dealer with past experience is between 7.6% and 7.8% less likely to exit the market than a dealer who has no previous experience. Both results are statistically significant. The coefficients of the market condition variables have the expected signs and are all statistically significant. For instance, higher average prices for artworks decrease the probability of exit as a booming market provides more profits. Higher bond yields, on the other hand, increase the probability of exit

TABLE 2.11: Exit probabilities - Dealer type defined by number of acquisitions

Variables	Exit				
	(1)	(2)	(3)	(4)	(5)
Expert dealer (*top 10% by number*)	-0.067***	-0.067***	-0.067***	-0.067***	-0.068***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Dealer with past experience	-0.076***	-0.077***	-0.076***	-0.076***	-0.076***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Value of artworks bought by dealers (log)	-0.011**				
	(0.005)				
Number of artworks bought by dealers (log)		-0.012**			
		(0.006)			
Average price per art work (log)			-0.045***		
			(0.016)		
Real per capita income in £ (log)				-0.055**	
				(0.027)	
Annual bond yield					0.078***
					(0.027)
Year effects	Yes	Yes	Yes	Yes	Yes
Observations	3,098	3,098	3,098	3,098	3,098
Wald χ^2	113.1	112.6	113.2	112.8	116.6

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
All prices are in constant £1850. The regression coefficients are transformed into marginal effects.

by about 8% which reflects the opportunity cost of investing in other financial assets. Since the results might only be driven by the amount of financial resources a dealer has access to, we repeated the estimation using capacity as the main explanatory variable instead of the expert dealer dummy. The results can be found in the Appendix in Table A2.7. While the coefficient of the capacity variable is statistically significant and negative, it is smaller in magnitude (minus five percent). Consequently, although financial funds are an important source for accumulating market share for dealers, it cannot solely explain them. As a result, the dealer's expertise remains an important attribute for an effective promotion of artists in the market and the establishment of large client base.

Overall, the results in this part of the analysis show that the expert dealers' strategy of paying higher prices indeed seems to reflect their higher expertise and standing in the market. This can be explained by their superior ability to promote an artist in the market and eventually extract higher rents on future re-sales. Expert dealers are able to create a higher intangible value by guaranteeing the quality of the artworks they purchase. Clients seem to be willing to pay for this information production in the form of higher premiums. Furthermore, our findings provide evidence that dealers are more likely to fail to compete in the market unless they manage to build up sufficient financial capacity and experience to become an expert dealer. This highlights

TABLE 2.12: Exit probabilities - Dealer type defined by value of acquisitions

Variables	Exit				
	(1)	(2)	(3)	(4)	(5)
Expert dealer (*top 10% by value in £*)	-0.082***	-0.082***	-0.082***	-0.082***	-0.082***
	(0.010)	(0.011)	(0.010)	(0.011)	(0.010)
Dealer with past experience	-0.077***	-0.078***	-0.077***	-0.078***	-0.077***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Value of artworks bought by dealers (log)	-0.011**				
	(0.005)				
Number of artworks bought by dealers (log)		-0.013**			
		(0.006)			
Average price per artwork (log)			-0.046***		
			(0.016)		
Real per capita income in £ (log)				-0.056**	
				(0.027)	
Annual bond yield					0.077***
					(0.027)
Year effects	Yes	Yes	Yes	Yes	Yes
Observations	3,098	3,098	3,098	3,098	3,098
Wald χ^2	119.4	118.7	119.6	118.6	122.2

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
All prices are in constant £1850. The regression coefficients are transformed into marginal effects.

the importance of size and market expertise for maintaining a competitive position.

2.5 Concluding Remarks

We quantify the value of expertise within the course of the evolution of a new industry characterized by uncertainty and product heterogeneity. Having access to a unique data set, which covers the period of the formation of the contemporary art market at the time and the emergence of art dealership as an entrepreneurial activity in the United Kingdom, gives us the opportunity to use the art market as a case study. Due to the heterogeneous nature of art as a good and the resulting importance of experts to add value, the art market provides an interesting example to study the value added by these intermediaries. We use the evolution of the art dealership industry to illustrate how dealer expertise, as a result of accumulated market share, affects market dynamics that govern entry, exit and growth.

We show that sales of artworks at auction exponentially increased over the market evolutionary period from 1800 to 1913. At the same time, the number of art dealers multiplied four-fold within the period 1850 to 1913. During this time, dealers became the dominant buyers at auction. Dealer entry was primarily motivated by an increased trading activity. We also find that entry was curbed by a higher level of competition. Additionally, we provide insights on the strategic acquisition behavior of dealers who differ in their level of expertise. In particular, our evidence suggests that dealers with a higher market share have a positive effect on the auction price beyond what is predicted by the characteristics of an artwork. These expert dealers tend to pay about 21% more than non-expert dealers. This effect is valid for the whole distribution of prices. We further show that expert dealers are about 7.5% more likely to survive in the market than non-expert dealers. Our results are robust for market shares specified by the number, or value, of total acquisitions.

Our results support the conjecture that auctions provide an advantage to expert bidders with more experience for heterogeneous objects whose value is uncertain. We provide support for the findings in the area of financial intermediation, namely that firms with more expertise and higher capability to resolve information asymmetries perform better in the market as among others presented by Ertugrul and Krishnan (2011), Golubov et al. (2012), Song et al. (2013). In addition, we contribute to the field of industry evolution research by demonstrating firm-level dynamics in an industry characterized by heterogeneity. The most revealing finding in this analysis is that we can put a value on expertise and show how it helps sustain performance as the market evolves.

Our paper provides a useful empirical study that observes an industry characterized by uncertainty surrounding the value of a good. Insight into historical information of dealers helps us to quantify the value of expertise and explain how market share affects dealers' bidding behavior and their subsequent survival in the market over its evolution. Our findings can be widely applied to other industries where expertise is a vital element and can yield substantial advantages such the market for collectibles, the venture capital industry as well as merger and acquisition advisory.

2.6 Appendix

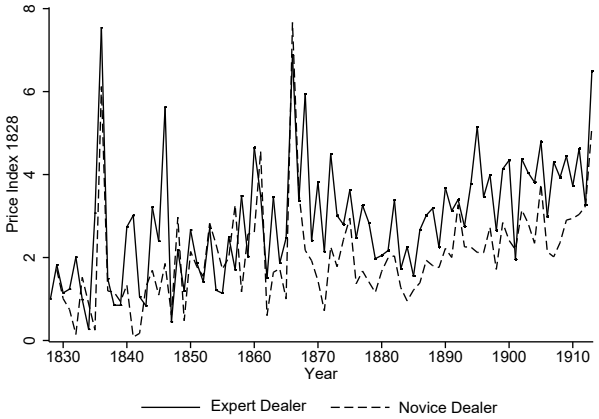


FIGURE A2.1: Average prices paid by expert and novice dealers (by number of acquisitions)

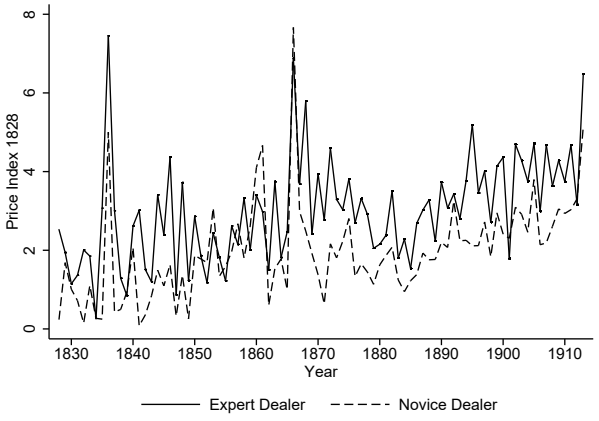


FIGURE A2.2: Average prices paid by expert and novice dealers (by value of acquisitions)

TABLE A2.1: Top 10 dealers with most popular acquisitions by artist

Rank	Dealer	Top 5 artists acquired	Number of acquisitions
1	Agnew	William Turner	543 (9.9%)
		David Cox	227 (4.1%)
		Edwin Henry Landseer	121 (2.2%)
		John Linnell	121 (2.2%)
		Copley Fielding	118 (2.2%)
2	Colnaghi	Joshua Reynolds	52 (4.5%)
		Thomas Gainsborough	51 (4.1%)
		George Romney	41 (3.6%)
		Francesco Guardi	33 (2.9%)
		Jacob van Ruisdael	27 (2.4%)
3	Vokins	William Turner	90 (8.9%)
		William Holman Hunt	46 (4.6%)
		Copley Fielding	41 (4.1%)
		Myles Birket Foster	34 (3.4%)
		Peter De Wint	30 (3.0%)
4	Tooth	Myles Birket Foster	29 (3.2%)
		John Linnell	28 (3.1%)
		Benjamin Williams Leader	27 (3.0%)
		Joshua Reynolds	22 (2.4%)
		Eugène Joseph Verboeckhoven	20 (2.2%)
5	Wallis	William Turner	43 (5.2%)
		Joshua Reynolds	29 (3.5%)
		Henry Raeburn	26 (3.1%)
		John Linnell	24 (2.9%)
		Jacob Maris	24 (2.9%)
6	McLean	William Turner	43 (5.7%)
		John Linnell	29 (3.4%)
		William James Mueller	25 (3.3%)
		Joshua Reynolds	22 (2.9%)
		Thomas Sidney Cooper	19 (2.5%)
7	Gooden & Fox	William Turner	27 (4.4%)
		Lawrence Alma-Tadema	14 (2.3%)
		Joshua Reynolds	14 (2.3%)
		George Frederic Watts	12 (2.0%)
		Thomas Sidney Cooper	11 (1.8%)
8	Permain	David Cox	19 (4.8%)
		William Turner	19 (4.8%)
		Thomas Sidney Cooper	17 (4.3%)
		Myles Birket Foster	16 (4.0%)
		Copley Fielding	13 (3.3%)
9	Wertheimer	Henry Raeburn	18 (5.6%)
		Charles Marion Russell	18 (5.6%)
		George Romney	16 (5.0%)
		Thomas Gainsborough	13 (4.0%)
		Joshua Reynolds	13 (4.0%)
10	Lesser	Joshua Reynolds	23 (7.6%)
		Jacob van Ruisdael	17 (5.6%)
		Rembrandt van Rijn	14 (4.6%)
		David Teniers	11 (3.6%)
		Peter Paul Rubens	8 (2.6%)
11-138	Others	Joshua Reynolds	385 (6.5%)
		Thomas Gainsborough	235 (4.0%)
		William Turner	180 (3.1%)
		Edwin Henry Landseer	112 (1.9%)
		Thomas Sidney Cooper	111 (1.9%)
Total		William Turner	981 (5.7%)
		Joshua Reynolds	671 (3.9%)
		Thomas Gainsborough	468 (2.7%)
		David Cox	339 (2.0%)
		Edwin Henry Landseer	316 (1.8%)

TABLE A2.2: Overview of artwork characteristics

Variable	Definition/ unit
Personal characteristics of the artist	
Name	First and last name of the artist
Living status	Dummy indicating if artist was dead or alive at the date of sale
School	Indicates whether artwork was modern British, modern Continental, Old Master Continental or Old Master Low Countries
Age	Difference between birth year and date of sale
Physical characteristics of the artwork	
Size	Height times width in inches
Medium	Dummy indicating if artwork was a painting, sculpture, engraving, drawing or a copy
Transaction characteristics	
Sales price	Nominal sales price in Pounds, Sterling and Dimes
Sales date	Day, month, year when the transaction took place
Auction house name	Name of auction house that held the sale
Collection sale	Dummy indicating if artwork was part of a sale where an entire collection was sold (mostly the case for posthumous sales)
Seller name	First and last name of the seller
Buyer name	First and last name of the buyer
Lot sequence	A rank number indicating how late an artwork was up for bidding in a sequence of sales within one auction
Number of bidders	Proxied by the number of lots sold within one auction sale
Rival characteristics	
Rival's past maximum capacity	Highest financial capacity among all winners (excluding the winner of the current transaction) within a one auction sale
Rival's past maximum share by volume	Highest market share in terms of volume among all winners (excluding the winner of the current transaction) within a one auction sale
Rival's past maximum share by value	Highest market share in terms of value among all winners (excluding the winner of the current transaction) within a one auction sale

TABLE A2.3: Entry results with alternative specifications

Variables	Number of entrants					
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged number of artworks	0.351**	0.424***	0.408***			
bought by dealers (log)	(0.176)	(0.150)	(0.130)			
Lagged value of artworks				0.203*	0.266**	0.255***
bought by dealers (log)				(0.123)	(0.109)	(0.093)
Number of incumbents	-0.034**	-0.032**	-0.033**	-0.023**	-0.020**	-0.020*
	(0.014)	(0.014)	(0.015)	(0.011)	(0.010)	(0.011)
Lagged population (log)	0.368			0.432		
	(0.636)			(0.633)		
Lagged real per capita		-0.115			-0.100	
income in £ (log)		(0.392)			(0.404)	
Lagged annual bond yield			0.002			-0.005
			(0.232)			(0.239)
After 1850	0.163	0.215	0.218	0.086	0.127	0.136
	(0.249)	(0.232)	(0.235)	(0.236)	(0.245)	(0.241)
Observations	83	83	83	83	83	83
Pseudo log-likelihood	-150.1	-151.4	-154.7	-150.7	-152.3	-155.5

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
All prices are in constant £1850.

TABLE A2.4: Average number of expert and novice dealers per year between 1828-1913

Variables	Summary statistics	
	Mean	Sd
Expert dealer (*Top 10% by number*)	4.84	1.68
Expert dealer (*Top 10% by value*)	3.84	1.44
Novice dealer (*Bottom 90% by number*)	41.33	13.94
Novice dealer (*Bottom 90% by value*)	42.33	14.30

TABLE A2.5: Influence of dealer type on price for 1828-1913 sample

Variables	Log of price							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Expert dealers	0.217***	0.188***						
(*Top 10% by number*)	(0.065)	(0.068)						
Expert dealers			0.240***	0.205***				
(*Top 10% by value*)			(0.062)	(0.068)				
Experience (log)					0.098**	0.091*		
					(0.044)	(0.047)		
Dealer capacity (log)							0.082***	0.085***
							(0.013)	(0.014)
Number of bidders (log)	0.030*	0.057***	0.030*	0.058***	0.033*	0.056***	0.028	0.053***
	(0.018)	(0.021)	(0.018)	(0.021)	(0.017)	(0.021)	(0.017)	(0.020)
Log of lot sequence (log)	0.162***	0.058***	0.161***	0.058***	0.163***	0.058***	0.160***	0.056***
	(0.027)	(0.017)	(0.027)	(0.017)	(0.027)	(0.017)	(0.027)	(0.018)
Rival's past maximum capacity (log)	0.014**	0.027*	0.014**	0.027**	0.014**	0.027*	0.016**	0.031**
	(0.006)	(0.014)	(0.007)	(0.014)	(0.007)	(0.014)	(0.007)	(0.014)
Rival's past maximum share (log)			-0.009	0.078	-0.282*	-0.133	-0.038	0.035
(*By volume*)			(0.057)	(0.060)	(0.170)	(0.132)	(0.056)	(0.062)
Rival's past maximum share (log)	0.045	0.102**			0.328*	0.258**		
(*By value*)	(0.063)	(0.051)			(0.168)	(0.125)		
Size (log)		0.405***		0.405***		0.405***		0.405***
		(0.038)		(0.038)		(0.038)		(0.037)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Season effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Auction house effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Artist effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Seller effects	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Observations	16,874	5,856	16,874	5,856	16,874	5,856	16,874	5,856
R^2	0.537	0.578	0.537	0.578	0.534	0.575	0.540	0.584

Standard errors clustered by dealers in parentheses. *** p<0.01, ** p<0.05, * p<0.1
All prices are in constant £1850.

TABLE A2.6: Influence of dealers on price

Variables	Log of price					
	OLS	Quantiles				
		q10	q25	q50	q75	q90
	(1)	(2)	(3)	(4)	(5)	(6)
Agnew	0.411***	0.449***	0.307***	0.364***	0.447***	0.475***
	(0.044)	(0.040)	(0.020)	(0.028)	(0.034)	(0.048)
Colnaghi	0.228***	0.367***	0.191***	0.180***	0.246***	0.204***
	(0.055)	(0.049)	(0.033)	(0.039)	(0.039)	(0.076)
Vokins	0.321***	0.327***	0.192***	0.195***	0.219***	0.112*
	(0.048)	(0.048)	(0.020)	(0.022)	(0.043)	(0.063)
Tooth	0.149***	0.288***	0.186***	0.172***	0.177***	0.110*
	(0.044)	(0.057)	(0.035)	(0.030)	(0.060)	(0.067)
Wallis	0.010	0.297***	0.150***	0.134***	0.145***	0.010
	(0.041)	(0.062)	(0.036)	(0.035)	(0.051)	(0.056)
McLean	-0.001	0.196***	0.095**	0.074**	0.044	-0.091*
	(0.050)	(0.063)	(0.038)	(0.036)	(0.049)	(0.051)
Gooden & Fox	0.061	0.284***	0.162***	0.127**	0.080*	-0.084
	(0.043)	(0.050)	(0.031)	(0.051)	(0.045)	(0.063)
Permain	-0.073*	0.073	0.002	-0.017	-0.073	-0.232***
	(0.044)	(0.050)	(0.045)	(0.051)	(0.078)	
Wertheimer	0.625***	0.607***	0.635***	0.752***	1.188***	1.148***
	(0.091)	(0.112)	(0.049)	(0.086)	(0.120)	(0.082)
Lesser	0.126**	0.398***	0.208***	0.137***	0.063	-0.086
	(0.049)	(0.139)	(0.053)	(0.041)	(0.065)	(0.139)
Years	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,360	16,360	16,360	16,360	16,360	16,360

All regressions include the standard control variables listed in Table A3.1.
Standard errors clustered by dealers in parentheses in column (1).
Bootstrapped standard errors in parentheses for columns (2)-(7).
*** $p<0.01$, ** $p<0.05$, * $p<0.1$. All prices are in constant £1850.

TABLE A2.7: Exit results with Capacity as proxy for dealer type

Variables	Exit				
	(1)	(2)	(3)	(4)	(5)
Capacity (log)	-0.026***	-0.026***	-0.025***	-0.026***	-0.025***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
Dealer with past experience	-0.027**	-0.027**	-0.027**	-0.027**	-0.027**
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Value of artworks bought by dealers (log)	0.006				
	(0.005)				
Number of artworks bought by dealers (log)		0.010			
		(0.006)			
Average price per art work			-0.005		
			(0.016)		
Real per capita income in £ (log)				0.041	
				(0.028)	
Annual bond yield					-0.003
					(0.027)
Year effects	Yes	Yes	Yes	Yes	Yes
Observations	3,098	3,098	3,098	3,098	3,098
Wald χ^2	232.6	233.5	230.4	233.2	229.9

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
All prices are in constant £1850. The regression coefficients are transformed into marginal effects.

Chapter 3

Dealer Networks in the World of Art*

We apply network theory to study auction outcomes in the fine art market. Using a unique historical data set, of London-based art auctions that took place between 1741 and 1913, we investigate the drivers of strategic network formation for dealers (buyers) and the effect of network structure on artwork prices and market exit. We find that the network size and depth as well as similarities in art specialization between trading partners strongly influence the decision to form links. Furthermore, a larger and deeper network exacerbates informational asymmetries across buyers, leading to higher rents through lower prices. For smaller dealers, the development of a strong network facilitates longer market presence.

3.1 Introduction

An agent's superior market performance is typically the result of privately held information. In addition to accumulated experience, the professional network that surrounds an agent can contribute to heterogeneity in proprietary knowledge. The quantity and exclusivity of information delivered by a network ultimately depends on its topology and the relative position assumed by the agent. This paper employs

* This chapter is co-authored with Dakshina G. De Silva (Lancaster University), Georgia Kosmopoulou (University of Oklahoma) and Rachel A.J. Pownall (Maastricht University)

network analysis to investigate the drivers of network formation and the effect of network structure on bidding behavior within the context of fine art auctions. We analyze strategic link formation created through transactions at auction events. Our focus is on professional art dealers who mainly assume the role of buyers. Through this analysis, we are interested in answering three questions. What drives link formation choices of art dealers? How does a dealer's network affect the price of an artwork? What is the influence of the network on the dealer's likelihood to sustain an active presence in auction markets?

In this study, we use a rare London-based fine art auction data set spanning the period from 1741 to 1913. The data provides us with a unique opportunity to analyze a network evolving through trades over a period of 150 years, in London, a city that was the central hub of economic activity at the time (Bayer, 2015). We capture auction trades since the emergence of the market focusing on professional buyers (art dealers) who bought artworks for their resale value and dominated the market in terms of purchased volume. Art dealers built deeper connections and had longer market presence which allows us to study market dynamics. The most revealing result of the study is how the relative size and depth of a dealer's network is shaping competitive outcomes. The number of direct links, frequency of interaction with the same trading partner, the significance of a network based on the trading flows of partnering sellers as well as similarities in product specialization between buyers and sellers are strong predictors of both the formation of future links as well as the prices of artworks. Those links can produce advantages leading to the propagation of a dealer's success.

It is well established that, in common value auctions with asymmetric information, the expected rent a bidder can extract depends on her level of information (Milgrom & Weber, 1982). Further, it is the privacy and exclusivity of information that are regarded as key explanatory factors in the observed heterogeneity of profits among bidders at auction (Engelbrecht-Wiggans, Milgrom, & Weber, 1983).

A network characterized by many linkages among agents and a high density can lead to more efficient information diffusion resulting in dissipation of profits as the quantity of privately held information is diminished (Colla & Mele, 2010; Ozsoylev & Walden, 2011). However, when agents are not well connected through linkages, information asymmetries arise. Agents who have a central position in these networks have preferential access to information as it reaches them easier and faster. For instance, in the market for artwork, a larger network would lead to better knowledge of the value of art in its different forms and the competitive landscape. In the

finance literature, Ozsoylev, Walden, Yavuz, and Bildik (2014) empirically show that the topology of a network influences information diffusion among equity investors at the Istanbul Stock Exchange which, in turn, influences their returns. Centrally located investors earn higher returns and trade earlier than peripheral investors upon the arrival of new information. Li and Schürhoff investigate the dealer network in the municipal bond market over a time period of 13 years and find that a central dealer's position improves access to investors. This leads to higher competition among peripheral players than among centrally located agents who charge higher premiums. Brancaccio, Li, and Schürhoff find that dealers in the municipal bond market increase trading activity with other dealers in order to increase the precision of their information on asset values.

In addition to the size of the network, the quality of established connections can impact the type of acquired information. While links with diverse agents may increase the variety of information, homogeneous relationships can increase the depth of information and yield other type-dependent benefits (Ioannides & Datcher Loury, 2004; McPherson, Smith-Lovin, & Cook, 2001). Moreover, the frequency of interaction can increase the quality of information and result in better trade conditions (Cocco, Gomes, & Martins, 2009; Karlan, Mobius, Rosenblat, & Szeidl, 2009). Such a diversified and well-connected network increases the set of options for exchange resulting in greater bargaining power for the agent (Corominas-Bosch, 2004). Consequently, the formation of links becomes an imperative strategic consideration for market participants as the resulting relative position in the network will influence the level of rents that can be extracted.

A number of studies in the economics and finance network literature focus on how different characteristics might affect link formation and result in preferential attachment. For instance, Lux (2015) provide a dynamic model of interbank credit relationships. The author demonstrates that while, at first, formations are random, preferential relationships develop over time due to a learning mechanism.[2] Commonly studied factors that induce preferential attachment are, among others, demographic characteristics, trust, and performance indicators. Currarini, Jackson, and Pin (2009) develop a model for friendship formation and show that, independent of group structure, there is a bias towards same-type relationships with respect to demographics. The theoretical paper of Iori et al. (2015) uses memory to proxy trust

[2] Preferential attachment is the tendency to condition random link formation on characteristics of the nodes, making it more likely to create links with certain agents than with others.

in repeated pairwise interaction between borrower and lender in the setting of intrabank lending. Cocco et al. (2009) provide evidence from the Portuguese short term intrabank lending market showing that small banks are more likely to replenish liquidity through loans from banks they have established a relationship with in the past resulting in better loan conditions. This indicates that evolving trust in established relationships can reduce information asymmetries. However, the authors focus on direct pairwise exchanges as opposed to the overall nexus of indirect relationships. Our analysis extends this literature by demonstrating how node- and link-specific characteristics affect the strategic behavior of market players who share trading partners within the context of a newly evolving network over the time span of a century and a half.

Few theoretical studies have explicitly investigated networks of sellers and buyers through bipartite graphs (Corominas-Bosch, 2004; Kotowski & Leister; Kranton & Minehart, 2000, 2001; Uzzi, 1996) and their focus has not been on network structures varying by the degree or strength of connection. We provide empirical evidence for the effect of a comprehensive number of such network measures on the probability of link formation and the bidding strategies of agents in a real-life auction network.

Our analysis is conducted in three parts. First, we investigate the determinants of link formation between buyers and sellers at auction using Bayesian methods. Bayesian analysis allows us to incorporate information on prior link formation choices in agents' decisions. In the spirit of Jackson and Wolinsky (1996), the utility of a new connection depends on the size of the buyer's direct network, the prominence of a dealer's network from the perspective of the flow of past transactions made by trading partners, and link-specific characteristics. The latter includes the number of times the buyer and seller have interacted with each other in the past, and the similarity in terms of their respective product specializations (artistic genre) throughout their trading history.

Second, we analyze the effect of a dealer's individual network on the price of the artwork at auction. We employ the posterior Bayesian estimates derived in the first step of the analysis to address endogeneity concerns by estimating the number of competitors.

In the last part of our analysis, we investigate how a dealer's position in the network affects her ability to maintain market presence. In the entrepreneurship literature, research has shown that start-ups with better informal and formal networks

are more likely to survive in the market (Brüderl & Preisendörfer, 1998; Dubini & Aldrich, 1991; Hoang & Antoncic, 2003; Raz & Gloor, 2007).

Our results provide strong empirical evidence that the network structure plays an important role in the link formation decision, the price, and survival in the market. Dealers are more likely to form a new link if they have established a higher number of distinct connections in the past. Further, the probability of a link formation increases in proportion to the past frequency of repeated interaction between the same pair of agents. The centrality of the dealer in a trading network, measured by links weighted by volume of sale activity of their past trading partners, is critical in the formation of new links. Dealers who have limited exposure to the auction market, based on their past record of activity, are more eager to purchase artworks while experienced dealers are more selective in their investment choices. Lastly, our results show that a connection between two agents becomes more probable, the more similar the buyer and seller are in their trading patterns and specializations in terms of artistic genre.

With respect to the effect of the dealer's network on price, we find that the number of distinct networks is one of the most important predictors of the dealer's winning bid. Having a relatively high number of distinct network connections to sellers can amplify informational asymmetries, thus increasing one's market power leading to lower prices and higher returns (consistent with Engelbrecht-Wiggans et al. (1983)). Further, repeated interactions with the same seller have a decreasing effect on price as an established relationship may lower information barriers and create profitable opportunities. Experiencing a network developed by linking to well-connected, popular sellers raise the auction price. Higher specialization in a traded genre allows the dealer to acquire artworks at lower prices. A rival's network size and thus their market power raises the price for a winning bidder.

Finally, we show that both the level of market exposure and the market share exert a positive effect on a dealer's likelihood to stay active in the market. We find that the number of competitors at auctions has no significant effect on market exit. It is rather the size of the rivals' networks that matters. We find that dealers are more likely to form links early on, but are more reluctant to bid aggressively.

Overall, these findings suggest that a dealer's position in a network is key to market success as it facilitates information flow, which, in turn, improves strategic link formation resulting in superior conditions of exchange. We show that the link formation process in art auctions is not random, but dependent on the structure of

the prevalent network and the competitive considerations of its participants, thus highlighting network paths that may lead to a dealer's success. Bipartite network structures have not been investigated before in auction markets.[3] Contemporaneous studies which focus on bank relationships or social media networks are often not able to directly observe the formation of a connection between two agents.[4] The sheer volume and frequency of trade and interactions in many markets contribute to complexity and create opaqueness with respect to trading relationships. While it is well established in the auction literature that agents with superior information can extract higher rents in auctions (Engelbrecht-Wiggans et al., 1983; Hendricks & Porter, 1988), we illustrate how an agent's network can constitute the source of superior information.

The paper proceeds as follows. In Section 2, we present a modeling framework which guides predictions with respect to prices and link formation at auctions. The data set is described in Section 3. Section 4 is dedicated to the empirical analysis and details the methodology and results with respect to network formation, bidding implications and exit patterns. We finish with some concluding remarks and implications for the art market as well as similar network structures in general in Section 5.

3.2 Modeling framework

In any time period t, n individuals are active in the art market and are considering the possibility of engaging in transactions thus forming links. Links offer learning opportunities, allowing the formation of a network among market participants. There are T periods in the network formation and individuals can engage in market transactions more than once via an auction. The value $V_{ij,t}$, of artwork, i, offered to a prospective buyer j at time t is not observed directly at the time of the auction. The expected value of the artwork, and the decision on how much to bid by a bidder, j, depend on the characteristics of the artwork on sale, X_i, the state of the existing network, N at $t-1$, and the information revealed through the auction process. The

[3] Kotowski and Leister consider in a theoretical study the network of buyers and sellers within an auction context. However, in their contribution the focal point is the optimal number of intermediaries as opposed to the buyer-seller relationship.

[4] Jackson, Rogers, and Zenou (2017) provide an excellent survey article on the current state of network analysis within the sphere of social networks.

adjacency matrix, $\mathcal{N}_{t-1}$, provides information on the state of the network in period $t-1$, with $\mathcal{N}_{jk,t-1} = 1$ for all (j,k) that have formed links up until period $t-1$ and $\mathcal{N}_{jk,t-1} = 0$ if no link has been formed up to this period. For bidder j, the network structure until time $t-1$, N_{t-1}, compiles information about all prior connections and allows a mapping of artwork characteristics to form value estimates in period t. In particular, the distribution of estimates $Z_{ji,t}= f_j(N_{t-1}, X_i)$ reflects the asymmetries across bidders through a varied network structure. The broader the network, the less noisy the signal received that is linked to the value of the artwork for sale. The artwork characteristics and network structure are common knowledge but the information filtering through the network is essential in determining the value estimates.

Expected price: The auction house uses an English auction format to sell to bidders. The auctioneer calls bids and the willing bidders indicate their desire to buy with a gesture. The auction ends when no one is willing to raise the price any further. The seller indexed by l has a reputation $R_{l,t}$ which, in our application, will reflect his volume of past sales that is common knowledge across bidders. The auction format is the asymmetric analogue of the irrevocable dropout auction described in Milgrom and Weber (1982). The asymmetric version was first presented in Wilson (1998) and generalized in Hong and Shum (2003) (HS thereafter) to encompass the common and private value frameworks as in Milgrom and Weber (1982). Assuming that the expected value of an object is strictly increasing in $Z_{ji,t}$ for all $j = 1, \ldots, n$ and, the bidding strategy is monotonic in $Z_{ji,t}$ for any individual j, equilibrium prices increase in the value of a rival's estimate. The introduction of a network into the model introduces the element of asymmetric information across bidders. In the spirit of Engelbrecht-Wiggans et al. (1983) and Hendricks and Porter (1988), the most informed bidder who has superior information to everyone else enjoys higher profit margins. The impact of the network structure on the mapping of X_i into $Z_{ji,t}$ is critical for the formation of prices.[5]

[5] HS presented an example of a parametric family of distributions for which the conditional expectation functions describing equilibrium bidding have closed form solutions. In this example, bidder valuations are log-normally distributed and, in a common value context, better information leads to higher information rents. In the context of our empirical framework, the broader the network is, the more informed the bidders are expected to be (relative to their competitors) leading to higher profit margins and higher likelihood of forming new links. A challenge in our empirical application is the lack of information on the losing bids within an auction that would provide direct signaling information on competitors. We proxy competitor signals by the past network size, maximum capacity and market share of all potential rivals in the same auction sale. We have information on the identity of all winners who were present in an auction sale and we utilize this information in our analysis of competitive effects.

Link formation: Every period, the seller selects an auction house that will maximize her return and then the bidders decide on whether to buy her artwork advertised in the auction catalog. Christie's auction house had nearly or effectively a monopoly position in the trade of fine art during our period of analysis, capturing 97% of the market by number and by value of acquisitions. In that sense, the sellers' choices of auction house had almost no variation.

A bidder's decision to form a link depends on the expected utility from purchasing the artwork. Denoting the unconditional utility of buyer j as $U_j(l)$, a link is formed if $E(U_j(l|D_{j,t},$
$R_{l,t}, N_{t-1}) \geq 0$. The utility depends on the bidder's characteristics, $D_{j,t}$, the reputation of the seller, $R_{l,t}$, and the network structure, N_{t-1}, which includes information on competitors. The parametric form introduced in section 4.1 will explore the nature of those connections focusing on the buyer's decision to buy from one specific seller among those who compete to sell their artwork. In other words, we explore the buyer's probability to form a link considering the landscape of possible options to connect with sellers.[6] In our empirical section, we will assume that bidders form expectations about the structure of the network up until time $t-1$ following this framework, and based on that expected network structure they formulate their bidding strategies that determine the price at auction in period t taking into account the current level of competition.

3.3 Data

3.3.1 Description

The basis for our empirical network study is a unique historical data set on fine art auction transactions taking place in London-based auction houses between 1741 and 1913. The transactions were recorded in three volumes by the former art dealer Algernon Graves (Graves, 1918). We retrieved these three volumes from the Victoria and Albert Museum Library in London. The sample period is very important for

[6] The number of artworks that were buy-ins in our sample is in fact limited to 5.6% of all transactions and we don't have any bid information on those auctions. Therefore, we do not consider the seller's decision to form a link as there is limited information on the few unsold works of art.

the global art market as it marks the time span over which the market evolved to maturity (as we know it today). London was the focal trade location for artworks in the 19th century and the beginning of the 20th century in particular for professional art traders. Further, it also constitutes the period when the profession of art dealer emerged. Next to direct patronage of artists, auctions constituted the most important source of artwork supply for art dealers. Their purchase volume and frequency at auction by far exceeded the trading activity of non-professional buyers such as collectors who in turn acquired artworks from these dealers in the private market (Bayer, 2015).

Overall, the data set comprises 37,640 transactions. Historical records indicate that the data set is a representative sample of auction sales over this period (Bayer, 2015). All transactions took place in an English auction format in which the buyer with the highest bid receives the item. Only the final hammer prices are observed. The unique feature of the data set is the availability of the original seller's and buyer's identities in the transaction. Besides this, we have information on the name and living status of the artist, the name of the artwork, its size and genre attribution. In addition, transaction data are available, including the name of the auction house where the sale took place, whether the transaction was part of a collection sale, the date of sale and, lastly, the nominal sales price in pounds, shillings and pence. We do not have information on either the number or the identities of losing bidders at these auctions but we have information on rival winners in the same auction sale who were present on the floor and likely competitors. This will allow us to control for competitive dynamics between buyers in the auction room. A number of the aforementioned artwork characteristics are used to control for the quality of artworks. Detailed description of some of these variables can be found in Table A3.1, in the Appendix. Another virtue of the data is that during that time the order of sale was alphabetical based on the name of the artist as opposed to the popularity or the value of an artwork which is common nowadays. As a result, lot allocation is random in our data set reducing the impact of the auctioneer on bidding dynamics. Moreover, all bidders had to be physically present to participate in the auction sale. Therefore, all auction participants were aware of the identities of their competitors which should have impacted their bidding strategies. These identities are known to us and controlled for, in the analysis.

We restricted our analysis to buyers who were professional art dealers and we use the term dealers and buyers interchangeably. Besides exploring their rich and variable trading history, we focus intentionally on the behavior of dealers who acquire

artworks with the goal of reselling for a profit in the future. Whereas emotional and aesthetic aspects may drive purchases of private collectors, we wanted to focus on buyers who did not derive non-pecuniary utility from holding an inventory of artworks and whose long history of transactions influence market prices the most. Furthermore, private buyers who typically make a single appearance at auction do not contribute actively to network dynamics through repeated interactions. As the data do not provide any biographical information on the buyers, we used museum archives to identify professional art dealers.[7] Further, we excluded observations in which the sales price was missing (buy-ins[8]) as well as transactions in which the buyer and seller were the same person.[9] This left us with a sample size of 17,479 observations spread over the period March 1741 to December 1913. The sample consists of 25 auction houses, 1,099 artists, 3,187 sellers and 137 buyers who were identified as art dealers.[10,11] Our variables were consolidated on a monthly basis to study link formation and pricing and on a yearly basis to study market exit. In some months no auction was held, so we end up with 811 monthly entries in our sample.

Art auctions represented an important source of supply for art dealers who were often seeking to replenish their inventory in those sensational public events. Overall, art dealers purchased 46.4% (17,479) of all artworks traded at auctions in terms of volume but it was unusual for them to sell at auctions.[12] A large fraction of sales comprised of estate sales. Many of these were prestigious collections (e.g. the Orlean's collection) which were owned by influential personalities; among them many

[7] The historical nature of the data set limits how much information could be extracted on the identities and biographies of the individual buyers. For instance, we cannot distinguish between full-time and part-time dealers. Moreover, we could not always distinguish businesses that discontinue due to mergers or partnerships. In cases in which dealerships were held by families over generations, we do not distinguish between different family members who managed the business in different ownership periods.

[8] In auctions, a buy-in takes place when an artwork is not sold as it fails to meet the seller's reserve price. In our data set, buy-ins represent only 5.6% of all transactions. This is low compared to the buy-in rates that are common nowadays which reach about 30% and should therefore not bias the results.

[9] Instances where buyer and seller were listed as the same person are difficult to interpret. These could be related to cases where a seller is submitting phantom bids or intervenes in the process to buy-in.

[10] Overall, there are 138 art dealers in the sample. However, we dropped the observation of a dealer who had a single sale through the period with an incomplete transaction record missing seller identity information.

[11] As mentioned earlier, Christie's auction house is capturing 97% of the market by number and by value of acquisitions.

[12] Most instances in which art dealers acted as sellers at auction were instances of business liquidation. Out of 37,640 artworks that were transacted at auction 1,613 (4.3%) were sold by art dealers.

aristocrats and members of the high society. Thus, sellers mainly consisted of non-professional traders who used auctions to liquidate property. However, while sellers used auctions as a sales platform, their purchases were rather made through art dealers. Therefore, even though individuals can in theory participate in auctions as buyers and sellers, historical records as well as our data clearly show that they assumed either of these roles from the onset. For this reason, the network can be represented by a bipartite graph as described in Wasserman and Faust (1994) where nodes can be partitioned into different subsets. For a comprehensive overview of the art market of that time, the functioning of art auctions, as well as the profession of art dealers, see De Silva et al.

It is worth mentioning that we conducted research to identify references to potential collusion between art dealers throughout the sample period as it could impact the interpretation of our results. Dealers with a large network could also have more chances to collude with each other, creating added opportunities for profit. However, we could not find any anecdotal evidence of such cases in the historical records. In Cooper (1977) there is a discussion of ring activity in the 1920s but this discussion does not cover our sample period. Even though we cannot rule out the existence of instances of collusion, the possibility of such activity in our extensive data set may point to an alternative channel by which a network provides benefits but does not alter the conclusion that developing a network is beneficial to the dealer. In our analysis, we use a different approach and identify large and small dealers by their volume of transactions to study the relative impact of a connected dealer on auction prices.

Our data set, comprised of fine-art auction transactions spanning a period of a century and a half, offers a valuable real-life application for network analysis. Using the emerging art market network as a case study, we can learn about the competitive strategies of professional dealers that lead to sustained market success. The following two subsections will detail our constructed network measures, the characteristics of the network structure, as well as individual dealer characteristics.

3.3.2 Network Measures

Given the data set, we have a link formation setting where a buyer can decide to form a link with a seller resulting in a bipartite network. In order to define the

structure of the dealer network in more detail, four different measures were constructed which are derived from the trading intensity of the network participants. The measures include the number of direct links for buyers and sellers, the degree centrality as an alternative weighted representation of direct links, the number of same-pair transactions, and hub centrality that allows us to bring in the importance of a dealer's network from the perspective of her sellers' flow of transactions. While the number of direct links, the degree centrality and hub centrality are individual-specific counts, the number of same-pair transactions is link-specific. In order to avoid underestimating the size of the network, all measures were constructed using the full sample which also includes buyers not identified as professional dealers.

For our first measure, the number of direct links, we counted the number of transactions with distinct trading partners per month and let it accumulate over time. This measure is individual-specific, meaning that her connections were counted independent of whether she assumed the buyer or seller side in a transaction. Our second network measure, the degree centrality, is the count of direct links weighted by the number of artwork bought. The third measure is hub centrality. It is calculated as the eigenvector that corresponds to the largest eigenvalue of $N_{t-1}XN_{t-1}^{T}$ where N_{t-1} is the adjacency matrix incorporating information on network connections up to period $t-1$. This measure captures the influence of a link in a network, weighing higher connections made to sellers who have had a large number of links to distinct buyers. The last measure is the number of same-pair transactions. The measure was constructed by counting the monthly number of transactions per buyer-seller pair and letting it accumulate over time. Given the long sample period as well as the fact that professional art dealers were smaller in number (137 distinct dealers) as opposed to sellers (3,187 distinct sellers), we expect an overall higher number of direct links for buyers than for sellers. There is still, however, a considerable number of instances of sales by individual sellers. In particular, a seller appears on average in two different periods (months) at auction and, out of 3,187 sellers, 1,924 (about 60%) submitted at least two artworks for sale. Moreover, as mentioned before, many sellers were influential members of society. Therefore, established links to these individuals could provide art dealers with further opportunities for information and profit. Additionally, since some of the dealers but not all had a presence in the market that extended back over many decades, we limit attention to the last 10 years of transactions and assume that a network connection lasted for a shorter period than the dealer's duration in business.

Table 3.1 lists the number and value of acquisitions as well as the counts for the

network measures for the top twenty-five dealers for the entire period.[13] We can see that the dealer Agnew is by far the largest dealer in the sample in terms of all measures. He captures 34% of sales by the number of acquisitions and 44% in terms of the value of acquisitions. Moreover, his number of direct links (938) is more than double the amount of the dealer with the second largest number of direct links (Colnaghi with 413 connections). As a result, Agnew forms the center of the dealer network. Overall, the twenty-five largest players account for 75% of all connections in the network. Further, repeated exchanges among the same pair have a moderate frequency. Agnew interacts on average 5.3 times with the same seller, while the average dealer interacts 1.7 times with same trading partner at auction.

TABLE 3.1: Top 25 dealers with averages of transaction and network variables

Rank	Dealer	Total number of transactions	Total value of transactions	Total number of direct links	Average number of same-pair transactions
1	Agnew	4988	2,623,168.00	938	5.31
2	Vokins	910	274,028.40	350	2.61
3	Colnaghi	862	394,088.70	413	2.08
4	Tooth	743	274,173.00	336	2.21
5	Wallis	670	255,554.70	276	2.41
6	McLean	609	151,368.40	299	2.03
7	Gooden & Fox	476	178,666.00	211	2.26
8	Permain	359	75,838.34	191	1.88
9	Smith	284	62,028.69	161	1.77
10	Lesser	245	64,805.10	174	1.40
11	White	230	55,267.03	136	1.70
12	Graves	229	38,946.65	139	1.65
13	Wertheimer	221	239,346.50	126	1.75
14	Sampson	215	47,286.80	125	1.72
15	Leggatt	145	23,253.23	101	1.44
16	Polak	141	18,176.68	109	1.29
17	Shepherd	139	25,240.32	105	1.32
18	Lawrie	122	71,849.11	66	1.85
19	Nieuwenhuys	118	33,451.45	67	1.76
20	Gambart	114	23,599.48	52	2.24
21	Grindley	112	15,797.36	66	1.70
22	Sedelmeyer	107	47,850.61	46	2.33
23	Pilgram & Lefevre	103	40,967.01	44	2.34
24	Rutley	100	14,279.97	65	1.54
25	Col	100	18,756.38	42	2.38
26-137	Others	2,407	839,861.98	13.88*	1.62
Total		14,749	5,907,650.89	45.20*	1.70*

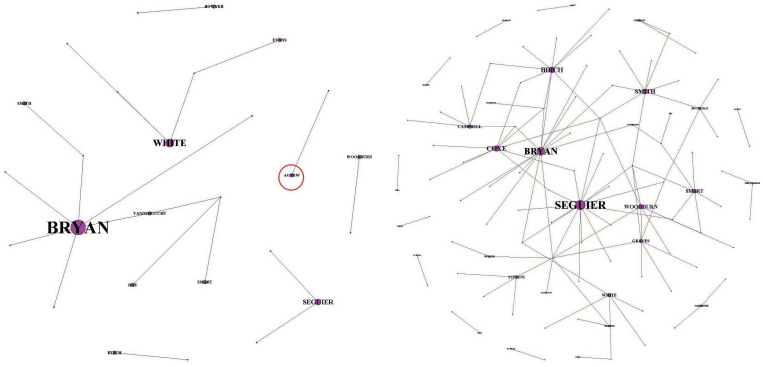
All prices are in constant £1900 and were converted using the UK CPI provided by the Bank of England.
*Numbers correspond to average values.

[13] All prices are in constant £1900 and were converted using the UK CPI provided by the Bank of England.

Figure 3.1 visualizes the development of the whole dealer network from 1800 until 1880 which represents the peak of the market in terms of market volume and number of dealers. Figure 3.1(a) depicts the network at its outset in 1800. Overall, there are only a few dealers with a few interactions. Its structure is clustered, with one large network in its center (headed by the dealer Bryan) surrounded by a handful of peripheral smaller networks. The future market leader, Agnew, is already present in the market but, with one link, is still a small player. In Figure 3.1(b) we can see how the dealer network evolved after 20 years. The number of market participants and the number of dependencies between individual players have increased. While we are facing a bipartite graph, some dealers are indirectly connected to each other through trades with the same sellers. Figure 3.1(c) presents the network in 1850, before its peak.[14] The complexity of the network increased. All three future top dealers, Agnew, Colnaghi, and Vokins are now in the market. The number of larger players grew within an emerging dynamic market structure which was also a result of a rapidly growing demand for artworks. Lastly, Figure 3.1(d) shows the network at its peak, in 1880. The network is much more complex. There are several hubs and a very large number of peripheral players. Agnew has developed into the largest dealer in the market followed by Vokins, Graves, Smith, and Colnaghi. Dealers establish mostly indirect connections to one another through common sellers, whom they interact with.

Eventually three players, namely Agnew, Colnaghi, and Vokins, form the central hubs of the network with a very large number of connections. Figure 3.2 shows the overall number of dealers in the market over time as well as the evolution of the network for the three largest players compared to the other dealers. Figure 3.3 depicts the number of dealers in terms of the years of market exposure. The distinction between time and years of market exposure is important as the three key dealers did not emerge at the same time. Also, while the number of dealers sharply increased over time (Figure 3.2(a)) few dealers enjoyed a long market presence (exposure) (Figure 3.3(a)). The large jump in the number of dealers around 1870, observed in Figure 3.2(a) coincides with rising market prices and trading volumes of artworks sold via auctions. This was also the time when local contemporary artists gained in popularity (Bayer, 2015). Dealers, as market makers could exert more control on local living artists than trading the work of Old Masters occasionally turning out to be forgeries (Bayer, 2015). Interestingly, as shown in 3.2(b), the mean number of links starts to grow at around 1850 jumping to 64 during the period 1850 to 1913. The

[14] We show the year 1850 instead of 1840, as this is the time when the second largest player, Vokins, enters the market.



(a) Network in 1800

(b) Network in 1820

(c) Network in 1850

(d) Network in 1880

FIGURE 3.1: Network Evolution (1800-1880)

same pattern can be observed in 3.3(b). As Vokins entered the market later than Agnew and Colnaghi, his number of direct networks starts growing after a very short period in the market. This graph also indicates that the number of direct links of all other dealers remained fairly stable over time.[15] A similar network pattern was also observed by Goyal, Van Der Leij, and Moraga-González (2006) for the case of academia (journal publishing) who studied the evolution of co-authorship among economists over a time period of 30 years.

Figure 3.4 visualizes the size of the networks of Agnew, Vokins, and Colnaghi in 1850 (Figure 4.2(a)) and at the peak of the art market in 1880 (Figure 4.2(b)). All three players grew their networks substantially within 30 years. In 1850, Agnew was already the largest of the three dealers. Unlike Agnew, Colnaghi and Vokins shared one common connection. By 1880, the three agents are a lot more interconnected and Vokins overtakes Colnaghi in terms of the number of links. These three players would remain the strongest dealers in the market from the year 1880 onward.[16]

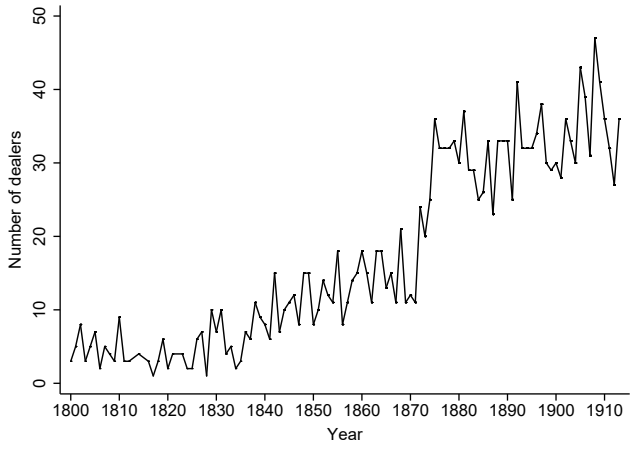
3.3.3 Homophily Measure

The similarity between two market players can influence the likelihood of an exchange as well as the conditions of trade (Currarini et al., 2009). The tendency to form connections with agents who are alike in their characteristics is termed as 'homophily' in the network literature (Jackson, 2010). Within the setting of fine art auctions, an appropriate measure on which buyers and sellers can be compared, is their trading pattern across different artistic genres. Art dealers might have aimed at developing product-specific knowledge by specializing in certain genres in order to promote particular artists and to cater to certain customer segments. Sellers were often in possession of themed collections providing them with knowledge of certain artistic styles. Overall, we identified nine different genres in our data set. The artworks that could not be attributed to any genre were subsumed under the heading 'other'.[17] All categories can be found in Table A3.1, in the Appendix.

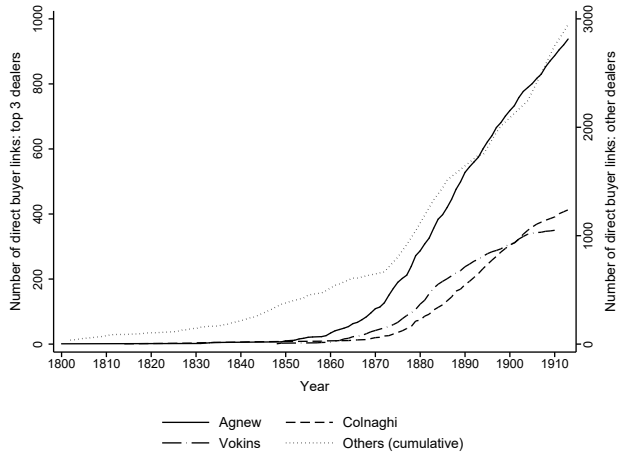
[15] Figure 3.2(b) depicts the cumulative number of direct links for other dealers, while Figure 3.3(b) shows the average number of buyer links for other dealers.

[16] Due to the historic nature of our data set and lack of information on individual transactions outside the auction market, we do not preclude the possibility that we do not capture all links and, therefore, might underestimate the extent of the network reach. We remain optimistic, however, that we are able to gain more insights in studying this market than what is possible today with the proliferation of online auctions and anonymity of transactions.

[17] This category includes, for instance, sculptures.

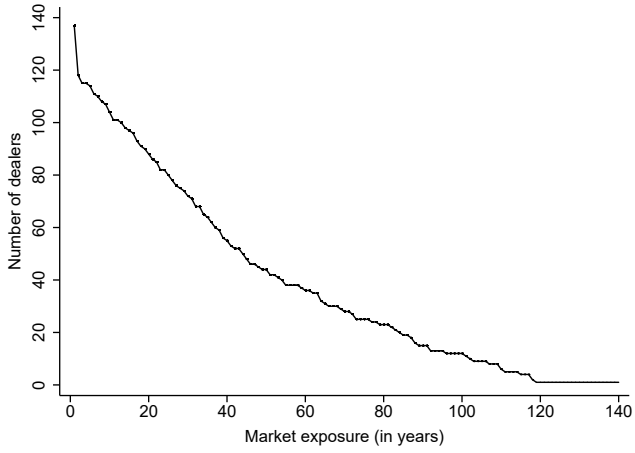


(a) Number of dealers over time

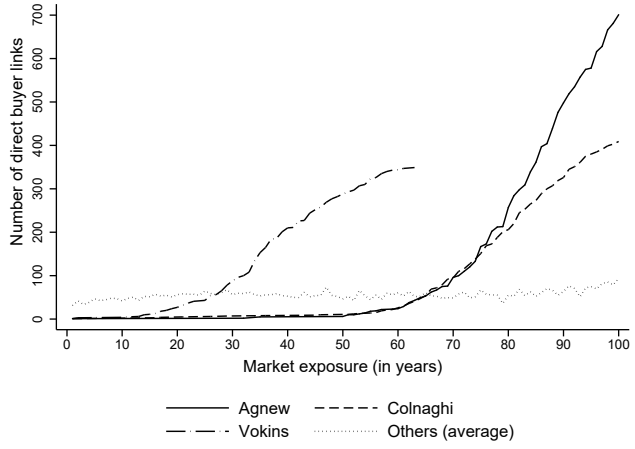


(b) Number of direct links over time

FIGURE 3.2: Evolution of dealers' network over time



(a) Number of dealers by years of market exposure

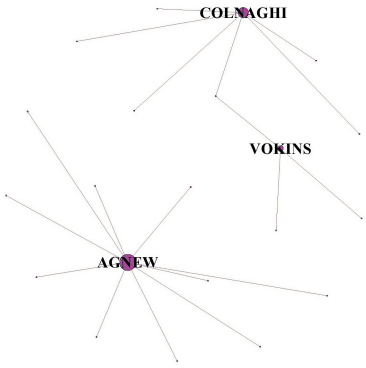


(b) Number of direct links by years of market exposure

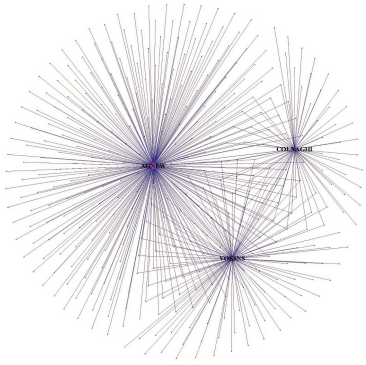
FIGURE 3.3: Evolution of dealers' network by years of market exposure

Table 3.2 shows summary statistics for the different genres.[18] In terms of volume and value of sales, the genre 'Landscape' by far outperforms all other genres. With 5,024 sales, it comprises almost twice as many sales as the second most popular theme of

[18] All prices are in constant £1900 and were converted using the UK CPI provided by the Bank of England.



(a) Network in 1850



(b) Network in 1880

FIGURE 3.4: Networks of Agnew, Colnaghi, and Vokins in 1850 and 1880

'Genre' (2,741 unit sales), closely followed by 'Religion' (2,377 unit sales).[19] 'Landscape' was a very popular genre for English contemporary artists who were heavily

[19] The genre 'Genre' includes artworks depicting scenes and activities of everyday life. Portrayed persons are not clearly identifiable or well-known individuals.

promoted by dealers at that time. A famous representative of Landscape paintings was the artist William Turner with 981 sold artworks in our dataset. Less popular themes were Marine, Mythology, and Portrait paintings. While more than £2 million worth of Landscape artworks were sold, only £149 and £140 thousand respectively were spent on Marine and Portrait artworks. Overall, average prices for Old Master genres such as Religion (£504), Mythology (£456), and Still Life (£409) are higher than the average prices for Contemporary art such as Landscape which sold for a mere £388 per artwork. This might be explained by the scarcity of paintings by Old Masters relative to contemporary artwork. At the end, the genres that are bought by almost all of the 137 art dealers in our sample are Landscape (118), Religion (107), and Genre (106). By contrast, Portraits and Marine paintings were only bought by less than half of the dealers in the sample.

These observations indicate that dealers were not highly specialized. Almost all dealers traded in Contemporary art and supplemented their portfolios with some Old Masters to hedge the risk of representing new artists.[20] In order to construct our measure of similarity, we first determine each market player's specialization by computing the share of artworks bought and sold in every genre as a percentage of overall sales and purchases in terms of volume accumulated over every period. Table 3.3 shows summary statistics for the buyer and seller specializations by genre.

We constructed three measures that capture specialization differences which will be used in different parts of our analysis. The first one is an overall homophily measure that takes into account the information on trades across all genres. It indicates how similar the buyer and seller are with respect to their purchases and sales volumes. A more similar trading pattern should result in a higher probability to form a link. The measure is defined as the root mean square deviation, i.e., the square root of the sum of the squared differences in the share between buyer and seller for all genres. The resulting value is strictly positive with a lower value indicating a higher degree of similarity between buyer and seller. The second measure relates to the buyer's and seller's specialization within one particular genre. This variable aims to compare trading partners based on their main area of expertise. For every period and agent, we determined the genre with the highest share and subtracted the trading partner's respective share in that genre. The absolute value of this number indicates the size of the distance between buyer and seller with respect to the genre they are specialized

[20] The popularity of contemporary themes is also reflected in the amount of distinct artists in each genre. Some artists were even known for a signature subject or style (e.g. William Hunt's Bird Nest). This made an artist more recognizable and competitive in the market for Contemporary art (Bayer, 2015).

TABLE 3.2: Summary statistics by genre

Variable	Animal	Genre	History	Landscape	Marine	Mythology	Portrait	Religion	Still life	Other
Total artwork volume	1,002	2,741	994	5,204	416	499	416	2,377	783	317
Total artwork value (£)	340,889.9	1,042,727.4	380,194.4	2,020,591.4	149,599.4	227,386.7	140,918.3	1,198,566.1	320,453.6	86,321.5
Average price (£)	340.21	380.42	382.49	388.28	359.61	455.69	338.75	504.24	409.26	272.31
	(589.77)	(578.23)	(709.59)	(693.93)	(468.52)	(968.80)	(1032.57)	(662.27)	(340.36)	(529.22)
Distinct buyers	89	106	91	118	58	74	61	107	81	47
Distinct sellers	530	926	492	1,158	263	300	304	992	369	199
Distinct artists	197	489	306	450	95	182	178	461	275	88

All prices are in constant £1900 and were converted using the UK CPI provided by the Bank of England.
Standard deviations are in parentheses.

TABLE 3.3: Summary statistics for buyer and seller specialization by genre

Variable	Average specialization buyer	Average specialization seller
Animal	0.065	0.063
	(0.083)	(0.083)
Genre	0.191	0.194
	(0.111)	(0.119)
History	0.069	0.062
	(0.094)	(0.091)
Landscape	0.349	0.369
	(0.171)	(0.171)
Marine	0.031	0.030
	(0.050)	(0.047)
Mythology	0.040	0.038
	(0.059)	(0.062)
Portrait	0.146	0.142
	(0.150)	(0.151)
Religion	0.056	0.051
	(0.085)	(0.084)
Still life	0.024	0.020
	(0.049)	(0.042)
Other	0.033	0.031
	(0.052)	(0.054)

Standard deviations are in parentheses.

in. The value is always positive and ranges from 0 to 1. A higher value points to a larger distance between the agents. These two measures, the homophily and genre specialization difference, will be used in the network formation analysis. A dummy variable indicating the dealer's specialization is employed in the exit analysis.

The third measure is an object-specific specialization difference. Based on the genre of the artwork that is up for sale, we subtracted the seller's share in that genre from the buyer's share in that genre. The value can range from -1 to 1. The closer the value is to 1, the large the information leap of the buyer relative to the seller. This measure is used in the bidding analysis and proxies the informational advantage of the buyer relative to the seller. All measures are dynamic and updated throughout the analysis.

3.4 Empirical Analysis

3.4.1 Network Formation

We start our empirical analysis by investigating the factors that influence the probability of link formation between buyers and sellers. In each period, a buyer has the opportunity to form a link with each seller, considering the set of all possible choices. A link is established if a buyer transacted with an individual seller at least once in a given period. A buyer is considered to be in the market from the time period of her first purchase until the time period of her last purchase even if she is not active in all periods. In our data set, we have 137 unique dealers and 3,187 unique sellers with 6,194 connections among the set of 242,145 potential links. Therefore, our data set includes all potential seller-buyer combinations in each period.

Our dependent variable is equal to 1 if a buyer, in time period (month) t, forms a link with a seller and 0 otherwise. The buyer will only form a connection if it is beneficial, which will depend on the existing links, the individual node characteristics, as well as the reputation of the seller. We assume that participants are aware of the shape of their current network but have no information with respect to its future shape.

Based on the prediction in our model related to the impact of better information on prices and profits, we expect that a higher number of direct links formed in the past will positively influence the formation of new connections. Hence, we are interested in modeling the probability, $P_{j,t}(l_t, N_{j,t-1}, D_{j,t}, R_{l,t-1}, g_j(N_t); \theta_t)$, of a link established by buyer j to seller l as a function of an unknown vector of parameters denoted by θ_t at a given time. We use observed data of the structure of the network N, bidder market exposure D, seller reputation R, and the homophily measure $g(N)$ and postulate a prior distribution for θ_t. We then derive the posterior distribution for θ_t and calculate the probability of link formation for different values of $N_{j,t-1}$, $D_{j,t}$, $R_{l,t-1}$, and $g_j(N_t)$.

The more frequent the interaction between a buyer and a seller and the larger the seller's network measured by his volume of past transactions, the higher should be the chance of forming a link. As one could question whether once established links continue to be relevant over the entire lifetime of an agent, we employ a specification of the variables "direct buyer links", "degree" and "hub centrality" in which the informational value of links ceases after a 10-year period. We include seller's

capacity and as an explanatory variable in the link formation analysis. This variable is a proxy for the reputation of a seller. Given the fact that many forgeries and artworks in poor condition were circulating around this period, the track record of a seller was of high importance.

With respect to genre specialization, we expect that the more similar the buyer and the seller are in their trading patterns and genre specializations, the more likely they are to trade with each other in an auction setting. In this part of the analysis, we use the homophily measure capturing similarities in trading patterns across genres as well as the absolute distance between the buyer and the seller with respect to their genre specializations. Lastly, we consider the level of an agent's market exposure which proxies for her market experience. The variable is defined as the number of years since her first appearance in the market. Our dependent variable is binary, indicating whether a link is formed or not.

Based on the utility of forming a link, broadly outlined in the modeling section, we consider an empirical framework defining the probability to form a link between j and l to buy artwork i at time t as

$$
\begin{aligned}
ln\left(\frac{P_{j,t}(l_t, N_{j,t-1}, D_{j,t}, R_{l,t-1}, g_j(N_t); \theta_t)}{1 - P_{j,t}(l_t, N_{j,t-1}, D_{j,t}, R_{l,t-1}, g_j(N_t); \theta_t)}\right) = \quad & \gamma + \beta' N_{j,t-1} + \delta D_{j,t} + \rho R_{l,t} \\
& -(g_j(N_{j,t-1} - N_{l,t})' \Psi (g_j(N_{j,t-1} - N_{l,t})) \\
& +\epsilon_{jl,t}
\end{aligned} \tag{3.1}
$$

where, as mentioned earlier, N is the network position, D represents bidder market exposure (age), and R is the seller's reputation as this is expressed by the value of previous transactions. The term $(g_j(N_{j,t-1} - N_{l,t})' \Psi (g_j(N_{j,t-1} - N_{l,t}))$ is the disutility of having a difference in the specialization between potential partners which relates agent j in period $t-1$ to a function of the number of previous purchases of artwork in the same genre (see Christakis, Fowler, Imbens, and Kalyanaraman (2010) for a similar measure of homophily). The measure of homophily, g, is expressed as the standard deviation of the trades across all genres and in an alternative specification as the relative buyer/seller specialization in a specific genre. Ψ is a diagonal matrix. We assume that the $\epsilon_{jl,t}$s are independent across all j and l at a given time, t, and that they follow a logistic distribution.

In the spirit of Christakis et al., 2010 for empirical link formation analysis, we used

Bayesian estimation to obtain posterior values for each network parameter based on prior information on link formation choices. Within the Markov-Chain-Monte-Carlo methods, we selected the Metropolis-Hastings algorithm to update the vector of the parameter given the sequence of link formation. Note that we use normal priors with mean 0 and variance of 100 for the regression coefficients and an inverse-gamma prior with shape and scale parameters of 0.1 and 1 for the error variance. In all of our Bayesian runs we use 12,500 iterations the first 2,500 of which are omitted to mitigate possible start up effects.

Unlike Christakis et al. (2010), we take advantage of the full data set instead of taking random draws from the samples. This is possible because, in our case, the average number of potential links is about 560 (56 dealers and 10 sellers) per period with a maximum of 2,964. Therefore, we do not encounter any computational constraints during the estimation of the model. Our analysis of link formation focuses on the buyer side. Sellers decide to sell through an auction house, almost invariably Christie's and then buyers link to one of the sellers through the auction process.[21] An independent normal distribution is specified for all parameters, with a prior mean equal to zero and a prior variance equal to one. The posterior estimates provide a distribution for every variable in our model predicting link formation. The posterior means are included in the second step of our analysis where we determine the effect of competition on price. This allows us to address endogeneity concerns related to the use of the actual number of direct buyer links in the regression. Consistent with our objective, a Bayesian approach offers the advantage of continuously updating posterior estimates given prior information on link formation and network characteristics.

Table 3.4 shows the summary statistics for the control variables used in the Bayesian estimation. The number of potential links varies from period to period and depends on the number of buyers and sellers in that period. The unconditional average probability for a buyer and a seller to form a direct link is 4.9%. A buyer's market exposure is also quite high with an average of 38.221 years. Again, the large standard deviation (29.308) accentuates the large variations in the dealer's years of participation at auction. Homophily, or the similarity in trading patterns between buyer and seller, is rather low with an average distance of 0.625. Similarly, a mean value of 0.338 for the differences in the specializations between buyers and sellers shows that the agents are only moderately alike with respect to their specializations.

[21] Our data include only completed sales with only a 5.9% of unsuccessful trades reported at auction.

TABLE 3.4: Summary statistics of control variables for network formation

Variable	Mean	Sd
Past number of direct buyer links with 10 year moving window	14.895	33.627
Hub centrality with 10 year moving window (weighted)	0.009	0.032
Degree centrality with 10 year moving window (weighted)	243.139	261.372
Buyer's market exposure (in years)	38.221	29.308
Past capacity seller (in £)	1,736.123	6,953.613
Past homophily	0.625	0.330
Past genre specialization buyer-seller: absolute difference	0.338	0.264

Seller capacity is in constant £1900.

Table 3.5 presents the means and confidence intervals of the posterior distributions of our model parameters. We utilize a different time threshold for network formation; the buyer's market exposure and same pair transaction variables are based on the entire network formed through the years a dealer was actively bidding at auctions.

The individual-specific network variables (number of direct buyer links, hub and degree centrality), and link-specific network variables are based on the last 10 years of transactions. Limiting the lifetime of a link represents a more realistic assumption with respect to the process of link formation and maintenance, limiting the capacity to retain institutional memory. Further, while the models in columns 1 and 3 include our homophily measure, in columns 2 and 4 the absolute value of the genre specialization difference is employed to proxy the similarity between a buyer and a seller.

The results across models reveal several important observations. First, the buyer-specific network variable, the number of direct links, plays a significant role in explaining link formation. In the two specifications, the mean of the posterior distribution is 0.722 and 1.049 respectively and the 95% confidence interval for the number of direct links lies strictly in a positive range of values. This indicates that a higher number of direct links increases the likelihood of forming a connection. This is consistent with the alternative weighted measure of degree centrality. The number of same-pair transactions is also predictive of link formation. The mean of the distribution of the covariate is positive, contributing to the probability of establishing a link. The 95% confidence interval for all estimates is in the positive domain. Hub centrality signifies the relative importance of connections which underlines the popularity of the sellers a dealer connects to and has a consistent positive effect on the likelihood to form a link. This variable can be regarded as a proxy for reputation of established links and it has a higher mean and standard deviation for the top

TABLE 3.5: Estimates of network formation parameters

Parameter	Variable	Mean of the posterior distribution			
		(1)	(2)	(3)	(4)
β_1	Log of past number of direct buyer links	0.722	1.049		
	(with 10 year moving window)	[0.700, 0.744]	[1.017, 1.083]		
β_2	Hub centrality (weighted)			11.398	13.585
	(with 10 year moving window)			[10.789, 11.645]	[13.367, 13.805]
β_3	Log of degree centrality (weighted)			0.429	0.447
	(with 10 year moving window)			[0.383, 0.457]	[0.436, 0.487]
β_4	Log of past number	7.373	6.073	7.909	5.998
	of same-pair transactions	[7.161, 7.630]	[5.711, 6.392]	[7.172, 8.204]	[5.828, 6.158]
δ_1	Log of buyer's market exposure	-0.278	-0.427	-0.099	-0.222
		[-0.305, -0.238]	[-0.448, -0.406]	[-0.145, -0.069]	[-0.236, -0.192]
ρ_1	Past capacity seller	-0.018	0.105	0.079	0.101
	(in £)	[-0.021, -0.012]	[0.102, 0.109]	[0.072, 0.086]	[0.095, 0.108]
ψ_1	Past homophily	-1.575		-1.872	
		[-1.643, -1.521]		[-2.234, -1.722]	
ψ_1	Past genre specialization buyer-seller		-0.981		-1.788
	(absolute difference)		[-1.147, -0.836]		[-1.896, -1.659]
Observations		242,145	242,145	242,145	242,145

95% credibility intervals are in parentheses.

three dealers than all others (the values for the mean and standard deviation are 0.182 and 0.113 for the top 3 versus 0.016 and 0.019 respectively for the others). Top dealers seem to diversify more in their choices of trading partners in terms of established reputation while the remaining dealers transact mostly with sellers who have limited prior activity. Further, a higher level of market exposure decreases the likelihood of network formation. Thus, it appears that newer dealers are more eager to build a larger network than seasoned ones, who are becoming more selective in their investment choices. This is intuitive as expanding a network might be more crucial during the establishment phase of a dealer in the market. Higher seller capacity increases the probability of link formation. A seller's capacity can be regarded as a proxy for reputation decreasing the information asymmetries with regard to the artworks she offers for sale at auction. The measure of the distance between buyer and seller, homophily, and the difference with respect to genre specialization, exhibit a negative effect on link formation. Homophily, which takes into account the distance across all genres, appears to have an even stronger adverse effect on link formation than the difference in genre specialization. Overall, in line with our expectations, it is less likely for players to form a link if they are specialized in different genres.

Figure A3.1 plots the number of direct buyer links based on the full network. The graph shows the actual versus the expected distribution of values. Further, considering the goodness of fit of the Bayesian estimates, the trace plot of the constant demonstrates good mixing. The posterior distribution of the constant is normally distributed, as is expected for the specified likelihood and prior distributions.[22]

Overall, it appears that the existing network structure and homophily are important predictors of link formation. In line with our expectations, a larger and denser dealer network increases the odds of forming a connection. The link-specific history plays an important role. More interactions among the same buyer-seller pair in the past, increase trust and lowers information barriers. The same applies to more similarities in product specializations, which make link formation more likely. Lastly, dealers with less market experience appear to be more eager to form links than more experienced ones. Having established the determinants for network formation, the next section will empirically investigate the role of network effects on the final hammer price.

[22] These figures have been omitted but can be provided upon request.

3.4.2 Bidding

In this section, we examine how the features of a network and a player's characteristics affect prices. While auction catalogs were accessible to all agents, the possibility to physically inspect the artworks prior to the auction sale was not institutionalized during this time period as it is the case today. The dealer's network and experience were crucial in assessing the artwork's value. In particular, based on the theory outlined in section 2, we expect that, with more direct links in a common value framework, a dealer should pay a lower price due to proprietary information on market conditions. Further, a well-connected buyer could have knowledge of better outside options. Once more, we use a 10-year moving window for network formation to be more realistic with respect to the time span of maintained knowledge from established links.[23]

In this part of the analysis, we introduce additional control variables related to auction and rival characteristics. What happens in the auction room between bidders might exert a considerable influence on artwork prices, that could confound the effect of network measures. Control variables related to auction characteristics include the number of bidders, and the lot sequence within a single auction sale. A single auction sale is defined as a sale that took place on one day, in the same auction house, involving sales commissioned by the same seller. As we cannot directly observe the number of bidders competing for individual artworks, we proxy competition in two ways: 1) Estimate the number of competitors in an auction by summing up the estimated probabilities of all active bidders linking to seller j to buy item i at time t and alternatively, 2) The number of bidders who bought lots within the same auction sale. These rivals had access to the same catalog that listed all the items in a single auction sale and were likely to be present throughout the duration of the auction sale on that day.[24]

The number of potential rivals can increase competition in an auction and will lead to higher prices (Li & Zheng, 2009). Moreover, the timing when an artwork comes up for bidding within a sequence of lots can influence the price. While there is empirical evidence that early lots fetch lower prices than later lots (Chanel & Gerard-Varet, 1996; Deltas & Kosmopoulou, 2004; Pesando & Shum, 1996), there is also research showing that later lots may yield lower prices (Ashenfelter, 1989; Ginsburgh,

[23] Results on the full network are available upon request.

[24] In instances where the number of bidders was smaller than three, it was replaced by the number of lots sold during one day independent of the identity of the seller.

1998; Ginsburgh & van Ours, 2007). In common or affiliated value environments, the release of information in the lot sequence reduces uncertainty and leads to higher prices (Milgrom and Weber, 1982). The attributes of the rivals faced by an art dealer at auction could also affect her strategy and, as a result, influence artwork prices. Therefore, we control for the rival's maximum capacity and market share in terms of volume. The rival's maximum capacity is determined by identifying the highest financial capacity among all winners within a particular auction sale. Again, financial capacity is defined as the highest amount ever spent by a bidder in the past. The rival's maximum share by volume is identified in the same way with the rival's accumulated market share in terms of purchased items being the value of interest. This is a more consistent measure for market power than financial capacity as it cannot be distorted by one large purchase. The rationale for both control variables is that the presence of wealthier bidders or bidders with greater market power might have a positive effect on auction prices. Alternatively, we use the average past number of distinct links of the rivals in the same auction sale. This number is an alternative measure of rival competitiveness that focuses on access to proprietary market information. They all relate implicitly to the vector of signals $\mathbf{Z}$ in the modeling section. To control for the quality of the artworks, we include their characteristics in our regression model.[25,26] Furthermore, we include buyer and year fixed effects.[27]

We run a simple linear regression with the logarithm of the price as our dependent variable. All network-related explanatory variables are transformed into their logarithms and lagged by one period. Due to endogeneity concerns in one specification we introduce the expected number of bidders obtained from the Bayesian estimation of the probabilities to form a link for all eligible bidders who could connect to a specific seller at time t. Our basic regression model has the following specification,

$$lnP_{ij,t} = \gamma' N_{j,t-1} + \vartheta D_{j,t-1} + \sigma S_i + \zeta R_{l,t} + \eta' M_{j,t-1} + \beta' X_i + \alpha_j + \tau_t + \epsilon_{ij,t}, \quad (3.2)$$

[25] These characteristics are referred to as hedonics and include the name of the artist, her living status, the medium of the artwork, whether the artwork was part of a collection sale, and the auction house where the transaction took place. These are commonly accepted attributes determining the quality of artworks in the art economics literature (Ashenfelter & Graddy, 2011, 2003; Hodgson & Vorkink, 2004; Rosen, 1974; Velthuis, 2013)

[26] Even though the size of an artwork has a considerable explanatory power over price, the variable is excluded in the regressions due a high number of missing observations. The large drop of the sample size would lead to a misrepresentation of the true network.

[27] As we are using year-fixed effects, we do not adjust the price by the UK CPI.

where lnP indicates the log of the price of an artwork, i, bought by dealer j in a given year t. As before, all network effects are captured in N. The dealer's market exposure is represented in D. The object specific specialization difference between buyer and seller is represented by S. R is the seller's reputation, M represents the rival characteristics, and X denotes the artwork's characteristics. α_j and τ_t represent the dealer- and time fixed-effects. Lastly, $\epsilon_{ij,t}$ denotes the error term.

Table 3.6 shows the summary statistics for the control variables used in the OLS estimation. Unlike in Table 3.4, here we consider the dealers who actually bought artwork in a specific period. With a mean of under 61 years, the average market exposure is quite sizable. However, this number is likely to be driven by some large dealers. Further, on average, the buyer is less specialized than the seller at the level of individual artworks. However, the difference of 7.2% is of very small magnitude. Seller capacity is, on average, about £2,603 with large differences between the agents (standard deviation of £8,150). The average number of bidders, who won at least one lot in an auction sale is 11.238 while the average number of lots offered is 16.871. The rival's maximum capacity lies, on average, at £1,135, while the maximum market share, in terms of volume, is 2.8%. Both numbers have a considerably high standard deviation.

TABLE 3.6: Summary statistics of control variables for network effects on price

Variable	Mean	Sd
Price (in £)	446.397	786.017
Real price (in £)	400.546	731.791
Past number of direct buyer links with 10 year moving window	94.218	105.383
Past number of same-pair transactions	1.000	5.015
Hub centrality with 10 year moving window (weighted)	0.101	0.124
Degree centrality with 10 year moving window (weighted)	510.818	301.455
Buyer's market exposure (in years)	60.837	32.903
Past genre specialization buyer: buyer-seller	-0.072	0.236
Past capacity seller (£)	2,603.326	8,149.814
Number of bidders	11.238	7.324
Expected number of bidders	8.248	5.996
Average lot sequence in auction sale	16.871	16.723
Past rival's maximum capacity (in £)	1,135.040	4,766.622
Past rival's maximum share by volume	0.028	0.094

Seller capacity is in constant £1900.

The results of the bid regressions using a moving window of 10 years for buyer network formation are reported in Table 3.7. While columns 1-3 incorporate the past number of distinct buyer links, columns 4-6 use alternative measures of degree and hub centrality to capture the structure of a buyer's network. Columns 1, 2, 4 and 5 show the regression coefficients when the rival information is confined to measures

constructed from competitors within the same auction sale. In columns 3 and 6, we incorporate information on expected competitors based on the likelihood of making a link that depends on their history of link formation. Specifically, due to endogeneity concerns, the predicted number of competitors is obtained from the Bayesian estimation based on the model specification used in column 2 in Table 3.5. This specification employs homophily (sum of the standard deviations of the specialization differences across all genres) as a proxy for the distance between a buyer and seller.[28] As we use the logarithmic transformations of all variables, the coefficients can be interpreted as elasticities. Overall, the results indicate that in columns 1-3, the coefficient on the past number of distinct buyer networks is negative and statistically highly significant. The magnitude remains relatively stable around -0.181. The coefficients are slightly lower on degree centrality in columns 4-6. In line with our expectations, repeated transactions between the same buyer and seller result in lower prices. Hub centrality has a positive coefficient signifying the influence of a link in a network. This variable, weighing higher connections made to sellers who have had a large number of links to distinct buyers, is capturing the significance of a network by weighing each seller's own network of connections. It appears that links made to dealers who transact often with influential sellers are impacting prices at auctions. These dealers have a history of transactions to popular sellers that elevates their competitive profile at auction.

The buyer's market exposure is statistically and economically highly significant with coefficients between 0.186 and 0.196 across specifications. Dealers who have a long history of participation at auctions tend to bid more aggressively. Furthermore, the coefficient on capacity is close to zero and statistically insignificant. This can be explained by the large number of sellers as compared to buyers leading to limited relative number of prior trades. The relative difference in the object-specific genre specialization between buyer and seller has a rather low impact on price in terms of statistical significance. The larger the buyer's information leap over the seller in the traded object, the lower the price paid at auction. However, the coefficient has only weak significance in most specifications.

The auction and rival characteristics also exhibit an important influence on an artwork's price. Both the number of bidders and the lot sequence are positive and statistically highly significant. In line with the findings of Chanel and Gerard-Varet

[28] As a robustness check, we repeat all regressions in this section using the model specification where the absolute difference in genre specialization was included in the construction of the predicted network measures (columns 3 and 4 in Table 3.5). The results remain qualitatively the same and can be found in Table A3.2 in Appendix A.

TABLE 3.7: Network effects on prices

Variables	Log(price)					
	(1)	(2)	(3)	(4)	(5)	(6)
Log of past number of distinct networks	-0.175***	-0.181***	-0.182***			
by buyer with 10 year moving window	(0.021)	(0.021)	(0.021)			
Log of number of transactions by same	-0.074***	-0.075***	-0.070***	-0.082***	-0.084***	-0.079***
buyer and seller	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
Log of degree centrality with 10 year				-0.144***	-0.147***	-0.154***
moving window				(0.015)	(0.015)	(0.015)
Hub centrality with 10 year moving window				0.626***	0.627***	0.571***
				(0.149)	(0.150)	(0.149)
Log of buyer's market exposure (in years)	0.188***	0.186***	0.186***	0.192***	0.191***	0.196***
	(0.027)	(0.027)	(0.027)	(0.028)	(0.028)	(0.028)
Object specific specialization difference:	-0.066*	-0.032	-0.093**	-0.049	-0.014	-0.076**
buyer – seller	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)
Log of past capacity of seller	0.004	0.004	0.003	0.006*	0.006*	0.005
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Log number of bidders	0.041***	0.041***		0.050***	0.050***	
	(0.015)	(0.015)		(0.015)	(0.015)	
Log of expected number of bidders			0.117***			0.124***
			(0.013)			(0.013)
Log of lot sequence	0.157***	0.157***	0.111***	0.158***	0.158***	0.112***
	(0.009)	(0.010)	(0.010)	(0.009)	(0.010)	(0.010)
Log of rivals' average past number of		0.013			0.014	
distinct networks		(0.009)			(0.009)	
Log of rivals' past maximum capacity	0.028***		0.022***	0.029***		0.023***
	(0.004)		(0.004)	(0.004)		(0.004)
Rivals' past maximum share by volume	-0.028		0.076	-0.049		0.057
	(0.092)		(0.092)	(0.092)		(0.092)
Artist alive	0.165***	0.167***	0.156***	0.177***	0.180***	0.168***
	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)
Buyer effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Auction house effects	Yes	Yes	Yes	Yes	Yes	Yes
Artist effects	Yes	Yes	Yes	Yes	Yes	Yes
Medium effects	Yes	Yes	Yes	Yes	Yes	Yes
Collection effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,749	14,749	14,749	14,749	14,749	14,749
R-squared	0.401	0.399	0.405	0.403	0.401	0.406

Standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note that, expected numbers of bidders are calculated using estimates from Columns 1 and 2 of Table 5.

(1996) and Deltas and Kosmopoulou (2004), we show evidence that later lots are sold at higher prices. This could be an indication that bidders behave more aggressively as the auction sale comes to an end to avoid being left empty-handed but more importantly it is also consistent with behavior in a common or affiliated value environment. Given that the lot sequence is based on an alphabetical order as opposed to the value of the lots as it is commonplace today, this result is particularly meaningful. The magnitude of the coefficient remains high across all specifications. The coefficient on the rival's maximum capacity is positive and highly statistically significant. It appears that competition from established dealers drives up prices at auction. However, a rival's market power in terms of market share by volume is statistically insignificant. More importantly, the expected number of bidders, estimated from the link formation model, is large in magnitude and statistically significant, signifying that potential competitors in this market exert considerable pressure on the price.[29]

As the market in our sample is characterized by a small number of very active dealers and a large number of dealers who exhibit lower levels of activity, we are also interested in exploring whether network effects differ between these two groups. As referred to earlier in Table 3.1, Agnew, Colnaghi, and Vokins were historically the most important dealers of the time. These three dealers captured about 46% of the total number of acquisitions whose payments reached about 55% of all transacted value. Their average number of unique direct links reached 567 or 17-fold the average number of links for all other dealers. To illustrate the differences across groups, we performed an additional regression analysis, splitting our sample into two subsamples (see Table 3.8). While Panel A excludes the largest three dealers in terms of volume of transactions, Panel B examines bidding patterns for those three only. The results show that the effect of the number of direct buyer links triples in magnitude for the top three dealers relative to that of the remaining sample exhibiting a much stronger effect on price. Robust effects are also seen with respect to the measures of degree, hub centrality and same pair transactions for the top three dealers both in terms of magnitude and significance. This might indicate that ties are stronger and more impactful for these three market leaders who are at the center of the network of dealers, trading more often, and obtaining broad information about the market and the competitive landscape that informs their bids. Overall, this analysis shows

[29] In order to construct the variable expected number of bidders, we calculate the probability of a forming link at given time, for each auction participant, using the full sample. Then, we add the probabilities of all participants at a given auction to construct the expected number of bidders. This is similar to the approach taken by Hendricks, Pinkse, and Porter (2003).

that having an extensive network is the key to the determination of prices for large dealers.

In summary, the results in this section provide strong statistical support that the buyer's network characteristics matter for artwork prices at auction. First, our findings stress the importance of the number of direct links as an explanatory factor in the prices paid by buyers. Art dealers who have a large network are able to acquire more information about the market conditions resulting in a competitive advantage that allows further rapid expansion of their network. This allows the dealer to select the trade opportunities that yield the highest rent. At the same time, the relative importance of trading partners in a network can raise prices through reputational effects. Repeated interactions with the same seller make the trade cheaper as less additional information on the counterpart needs to be collected thus decreasing costs. The results with respect to the network measures also emphasize the importance of a persistent presence of the seller. A market whose supply side is too fragmented might prevent the formation of close ties between agents which in turn inhibits the accumulation of private information through trade relationships. Another effect results from the level of a buyer's specialization in a given genre. The informational leap gives the buyer market power and allows them to realize higher rents by paying lower prices at auction. This effect is, however, of low statistical power. Finally, more rivalry for artworks from established buyers tends to drive up hammer prices. In the next section, we will investigate whether the lower prices paid by dealers with a superior network position also translate into longevity in the market.

3.4.3 Market Exit

In this section, we explore whether a dealer's preferential position in a network also improves the chances to remain longer in the auction market. If a superior network indeed provides a dealer with a less noisy signal about the value of the artworks and results in higher profit margins, we expect dealers with a larger amount of direct links to stay longer in the market. The research on networks within the field of entrepreneurship shows that start-ups that receive support from a large and diverse social network are more successful. As a consequence, these firms are more likely to grow and survive in the market. A good network provides access to relevant information and resources and can substitute for human or financial capital

TABLE 3.8: Effect of top three dealers' networks on prices

Variables	Log(price)					
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Without top three dealers						
Log of past number of distinct networks	-0.112***	-0.119***	-0.113***			
by buyer with 10 year moving window	(0.025)	(0.026)	(0.025)			
Log of number of transactions by same	0.033	0.035	0.039	0.014	0.015	0.021
buyer and seller	(0.042)	(0.042)	(0.041)	(0.042)	(0.042)	(0.041)
Log of degree centrality with 10 year				-0.064***	-0.065***	-0.070***
moving window				(0.017)	(0.017)	(0.017)
Hub centrality with 10 year moving				0.760	0.734	0.648
window				(0.510)	(0.512)	(0.508)
Log number of bidders	Yes	Yes		Yes	Yes	
Log of expected number of bidders			Yes			Yes
All other controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,989	7,989	7,989	7,989	7,989	7,989
R^2	0.470	0.467	0.474	0.470	0.467	0.474
Panel B: Top three dealers only						
Log of past number of distinct networks	-0.389***	-0.395***	-0.407***			
by buyer with 10 year moving window	(0.045)	(0.045)	(0.045)			
Log of number of transactions by same	-0.118***	-0.119***	-0.115***	-0.106***	-0.107***	-0.104***
buyer and seller	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Log of degree centrality with 10 year				-0.491***	-0.497***	-0.506***
moving window				(0.035)	(0.035)	(0.035)
Hub centrality with 10 year moving				1.272***	1.286***	1.217***
window				(0.206)	(0.206)	(0.206)
Log number of bidders	Yes	Yes		Yes	Yes	
Log of expected number of bidders			Yes			Yes
All other controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,760	6,760	6,760	6,760	6,760	6,760
R^2	0.322	0.322	0.325	0.336	0.335	0.339

Standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

All models include controls for seller capacity, number of bidders, rivals' maximum capacity and share by volume, lot sequence, artist's living status. Additionally, all models include buyer, year, auction house, artist, medium, and collection effects as in Table 7. Note that, expected numbers of bidders are calculated using estimates from Columns 1 and 2 of Table 5. We define top three dealers as firms with total market share by volume and value to be in the top three. See Table 1 for identities of these top three dealers.

(Brüderl & Preisendörfer, 1998; Dubini & Aldrich, 1991; Hoang & Antoncic, 2003; Raz & Gloor, 2007). For instance, Brüderl and Preisendörfer (1998) showed, in their empirical study on Munich-based business founders, that a start-up was more likely to survive and grow if it had support from a personal network. Similarly, in a longitudinal study, Raz and Gloor (2007) presented empirical evidence, in the case of Israel-based software start-ups, that suggested that a larger informal communication network increased their likelihood of surviving an external shock.

To measure the effect of the network characteristics on the dealer's likelihood to exit the auction market, a simple probit model is employed. Here, all variables are collapsed on a yearly basis. The binary dependent variable, exit, takes the value of one if the dealer exits the auction market in a given period and zero otherwise. Following the approach of De Silva, Kosmopoulou, and Lamarche (2009), exit takes place upon the last period of appearance of the dealer in the sample. The last year in our sample is 1913. In order to track exits, we restrict entry by new dealers up until the last three years of the sample period. We consider a dealer who did not exit the market before 1910 as still active. A period of three years was selected as it should be a time period of sufficient length to assume that an agent has ceased activity as an art dealer. We cannot exclude the possibility that she replenished her inventory elsewhere. However, given that auctions in London constituted the most important marketplace for art during that period, we consider inactivity in this market for more than three years as an exit. The results are robust if we use larger cut-off points of five or ten years to determine exit.

Here, our network variable of interest in Panel A is the number of direct buyer links while in Panel B we include degree and hub centrality measures. As in previous analyses, we are limiting the lifetime of once-established links to 10 years. Furthermore, we introduce interaction terms between the network measures and the dealer's market exposure. Figure 3.2(b), for example, showed that the number of direct links for the top three dealers was increasing exponentially after a certain age, therefore, for some dealers it might be the case that the number of links starts to rise at a higher rate after some time in the market. The interaction term in Panel A accounts for this potential non-linear relationship between the number of links and a dealer's market exposure.

In addition to network measures, we also control for the dealer's average market share for the last three years in terms of value and volume. Market share allows us to account for a dealer's market power in the more recent past. We expect that a higher market share will result in a lower exit probability. As market share by value

and volume are highly correlated, they are considered separately in different model specifications. Furthermore, we control for market competition by considering the number of rival dealers in a given year. As exit will depend on profit opportunities, this variable captures how attractive it is to remain in the market given the level of rivalry. Lastly, we account for the genre specialization of the dealers with a dummy variable. The variable takes the value of one for the genre in which the dealer has the highest market share in terms of volume. As mentioned before, there are overall ten possible genre specializations.

To ensure that the results are not driven by the three largest dealers – Agnew, Colnaghi, and Vokins – who remained in the market for an exceptionally long time, we perform a robustness check by excluding the top three dealers from the sample. The empirical specification of the probit model has the following form:

$$Pr(Exit = 1|W_{j,t}) = \Phi(\lambda' W_{j,t}), \tag{3.3}$$

where the independent variables in $(W_{j,t})$ can be classified into three main groups $N_{j,t}$, $D_{j,t}$, and $M_{j,t}$. $N_{j,t}$ denotes the dealer j's network characteristics, $D_{j,t}$ represents the dealer j characteristics, and $M_{j,t}$ includes rival characteristics based on the proxy used to assess the competitive landscape. Φ is the cumulative normal distribution.

Table 3.9 shows the summary statistics for the control variables. The average market exposure is 34.28 years. The dealer's average market shares in terms of volume and value are in line with each other, both having a value of 2.4%. There appears to be a larger variation between dealers when market share is calculated in terms of value. The mean of the yearly number of rival dealers is 53.748. Lastly, the average network size of the dealer's rivals in an auction amounts to almost 25 links.

TABLE 3.9: Summary statistics of control variables for market exit

Variable	Mean	Sd
Average past number of direct buyer links with 10 year moving window (yearly)	9.442	23.498
Hub centrality with 10 year moving window (weighted)	0.009	0.030
Degree centrality with 10 year moving window (weighted)	108.267	171.664
Buyer's market exposure (in years)	34.280	27.856
Dealer's average share for the last three years (by volume)	0.024	0.052
Dealer's average share for the last three years (by value) (£)	0.024	0.074
Number of rival dealers	53.748	17.596
Number of rivals' networks	24.965	22.097

The results of the probit regression are reported in Table 3.10. Panel A presents results including network count measures and Panel B introduces network centrality

measures. Columns 1 and 2 present the results for the full dealer sample. Columns 3 and 4 show the result when the top three dealers are excluded from the probit regression. For all regression coefficients, we report the marginal effects. The results indicate that, independent of the selected dealer sample, the coefficients of direct buyer links, degree and hub centrality are not statistically significant. However, it appears that the relation between the number of direct buyer links and the dealer's age is to some extent non-linear. The interaction term is positive and statistically significant. This indicates that overexposure has negative impact on market presence as a dealer is accumulating experience. Splitting the sample in a different way, and considering the top 25 versus the remaining dealers, a high number of links which seems to be beneficial for small dealers becomes less relevant over time for business longevity with growing market experience.[30]

A dealer's market share has a very strong negative effect on exit probability. The coefficient is large in magnitude and statistical significance in all regression specifications. The market share in terms of volume plays a more important role than the market share in terms of value. As the latter can easily be driven up by a small number of large acquisitions, it may be more indicative of a dealer's financial capacity as opposed to her market power. The larger effect in market share by volume may speak to the value of diversification. Surprisingly, the number of rival dealers, which is defined as the total number of other dealers in the market in a given period, does not seem to affect the probability of exit. Rather, the size of the dealer's rivals' network has a consistently statistically significant positive effect on market exit. It appears that a larger network provides dealers with a competitive advantage, making it more difficult for other dealers to sustain market presence. The fiercer competitive landscape decreases the potential for profits and drives dealers out of the market.

Overall, our findings provide evidence that the buyer's market power in terms of market share by volume is a decisive factor in her ability to sustain market presence. Moreover, it is not the number of competitors that affect the likelihood of exit but how connected they are.

[30] These results are available upon request.

TABLE 3.10: Probability of exit

Variables	All dealers		Without top three dealers	
	(1)	(2)	(3)	(4)
Panel A: with network count measures				
Log of past number of direct buyer links	-0.003	-0.006	-0.004	-0.007*
with 10 year moving window	(0.003)	(0.004)	(0.003)	(0.004)
Log of buyer's market exposure (in years)	-0.004***	-0.005***	-0.005***	-0.006***
	(0.001)	(0.001)	(0.001)	(0.001)
Log of past number of direct buyer links with 10 year	0.002**	0.002**	0.002**	0.003**
moving window×Log of buyer's market exposure (in years)	(0.001)	(0.001)	(0.001)	(0.001)
Buyer's average share (by volume)	-0.274***		-0.299***	
for the past three years	(0.047)		(0.062)	
Buyer's average share (by value)		-0.153***		-0.138*
for the past three years		(0.056)		(0.071)
Log of average number of rival dealers' networks	0.005***	0.007***	0.006***	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)
Number of rival dealers	-0.003	-0.003	-0.003	-0.003
	(0.003)	(0.004)	(0.003)	(0.004)
Genre specialization	Yes	Yes	Yes	Yes
Observations	5,405	5,405	5,128	5,128
Log pseudolikelihood	-390.300	-397.300	-389.400	-395.400
Panel B: with network centrality measures				
Log of degree centrality with 10 year moving window	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Hub centrality with 10 year moving window	0.056	0.081	0.033	0.072
	(0.050)	(0.065)	(0.086)	(0.085)
Log of buyer's market exposure (in years)	-0.003**	-0.003***	-0.003**	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
Log of degree centrality with 10 year moving window	-0.000	-0.000	-0.000	-0.000
×Log of buyer's market exposure (in years)	(0.000)	(0.000)	(0.000)	(0.000)
Hub centrality with 10 year moving window	0.011	0.003	0.036	0.017
×Log of buyer's market exposure (in years)	(0.017)	(0.034)	(0.043)	(0.050)
Buyer's average share (by volume)	-0.291***		-0.317***	
for the past three years	(0.060)		(0.075)	
Buyer's average share (by value)		-0.158*		-0.152*
for the past three years		(0.083)		(0.087)
Log of average number of rival dealers' networks	0.006***	0.009***	0.007***	0.009***
	(0.002)	(0.002)	(0.002)	(0.002)
Number of rival dealers	-0.003	-0.004	-0.004	-0.005
	(0.003)	(0.004)	(0.004)	(0.005)
Genre specialization	Yes	Yes	Yes	Yes
Observations	5,405	5,405	5,128	5,128
Log pseudolikelihood	-396.400	-401.600	-395.300	-400.100

Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

We define top three dealers as firms with total market share by volume and value to be in the top three.

See Table 1 for identities of these top three dealers.

3.5 Concluding Remarks

This study is unique in the sense that we are able to observe the formation of a network throughout the emergence of a new market until relationships are too entangled to identify actual direct links between two agents. This provides us with a clean setting to analyze the effect of an agent's network position on economic outcomes. Nowadays market structures are oftentimes characterized by a high level of complexity and an opaque web of relationships leading to a reliance on probabilistic estimates of links in network analysis. Having access to a unique historical data set, which covers the formative period of the contemporary art market in the United Kingdom, gives us the opportunity to use the art market as a case study. We use the evolution of this market to investigate determinants of strategic link formation for art dealers which eventually affect the prices paid by different agents at auction. Art dealers were the most dominant buyer group at auction as auctions constituted their main source of artwork supply. They were interested in the resale value of an artwork and had larger and deeper links than other buyers making them a natural focal group of this analysis. Furthermore, this is the first empirical study that introduces network measures to auction data allowing us to cope with the complexity introduced by interdependence between different actors in the market. By taking into account the relative positions of buyers and sellers in the bipartite network, as well as the overall network structure, we can make accurate predictions about the effect of individual players on price.

Our key findings provide insight into what drives link-formation choices of art dealers, how a buyer's network influences the price of an artwork, and whether a preferential network position affects the dealer's likelihood to remain in the market. First, we provide empirical support to the theory that agents make profit-maximizing choices based on the market player's characteristics and the existing network structure. In particular, we find that network attributes, including the number of direct buyer links, the link-specific history, market exposure, as well as similarities in product specializations all drive the formation of new connections. These results are in line with Currarini et al. (2009), who find evidence for preferential attachment based on common attributes and with Iori et al. (2015), who show that repeated interaction leads to preferential link formation.

Second, the network structure can provide significant benefit to agents. A higher number of direct links results in lower prices paid by dealers. Through a larger

network, more information can be retrieved on artwork values and the competitive landscape, thus improving one's bargaining position. This is consistent with the empirical findings by Ozsoylev et al. (2014) who show that, in an investor network, central players perform better due to better access to information. In terms of dealer characteristics, the level of market exposure, the importance of past network connections, the number of repeated interactions with the same agent, as well as the depth of product specialization have an impact on prices paid. While it is an established fact in auction theory that bidders can benefit from superior information at auction (Milgrom & Weber, 1982; Hendricks & Porter, 1988), until now there is no empirical evidence on the impact of a network's characteristics and network's growth on prices.

Third, we examine if the position of an agent in a network has an important influence on longevity. For the smaller dealers, the larger number of direct links improves the probability to sustain market presence. This result is in line with the findings in the entrepreneurship literature, where evidence on the importance of formal and informal networks for the survival of start-ups was provided (Brüderl & Preisendörfer, 1998; Hoang & Antoncic, 2003; Raz & Gloor, 2007). It is also consistent with anecdotal evidence, where dealers report that their connections to other actors in the art market provide them with key information on market conditions including prices, client demand, new sources of supply, and changes in the competitive landscape. This information tends to be more valuable than public information such as auction sales outcomes.

Lastly, consistent with the structures prevalent in the financial industry (Allen & Gale, 2000; Babus, 2016; Furfine, 2003; Gai & Kapadia; Lux, 2015) as well as in academia (Goyal et al., 2006), our results show that the art market is characterized by a few central players who nurture the rest of the network. This network structure remains persistent over a full century. As outlined in the 2017 Tefaf report (Pownall, 2017), similar structures can still be observed in the art market today. A small number of art dealers dominate the industry in terms of sales, leading to preferential information sharing.

Exploiting large data sets can yield important insights about the interdependent decision making of linked individuals from which valuable policy implications can be derived. Within the context of the art market, driving forces of network formation and resulting structures among dealers may explain price developments for certain artists as well as record prices yielded at auctions.

Additionally, our findings have important policy and governance implications for industries in which high market concentrations prevail. Examples extend from the financial industry and research collaborations to energy providers and car manufacturers. Understanding the formation of and the motivations behind a network–cooperation, risk sharing, or competition–are important to understand industry dynamics.

3.6 Appendix

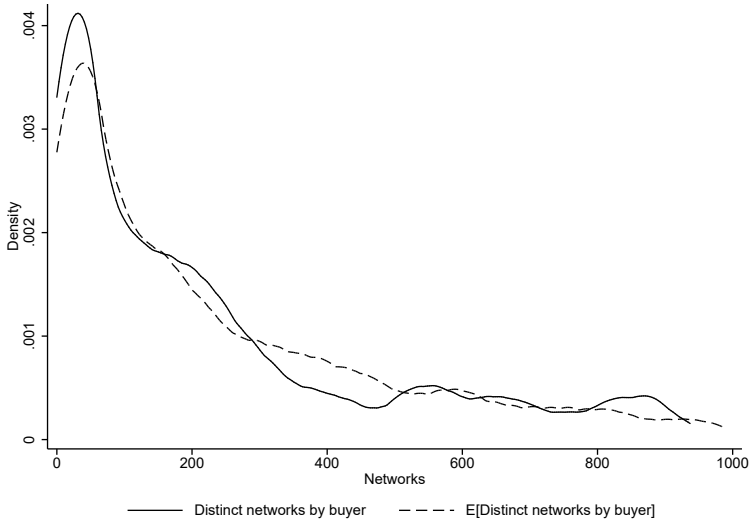


FIGURE A3.1: Predicted number of direct buyer links versus actual number of direct buyer links

TABLE A3.1: Overview of artwork characteristics

Variable	Definition/ unit
Personal characteristics of the artist	
Name	First and last name of the artist
Living status	Dummy indicating if artist was dead or alive at the date of sale
Genre	Indicates to which genre the artwork can be attributed to: animal, landscape, still life, history, religion, mythology, genre, portrait, marine, other
Age	Difference between birth year and date of sale
Physical characteristics of the artwork	
Size	Height times width in inches
Medium	Dummy indicating if artwork was a painting, sculpture, engraving, drawing or a copy
Transaction characteristics	
Sales price	Nominal sales price in Pounds, Sterling and Dimes
Sales date	Day, month, year when the transaction took place
Auction house name	Name of auction house that held the sale
Collection sale	Dummy indicating if artwork was part of a sale where an entire collection was sold (mostly the case for posthumous sales)
Seller name	First and last name of the seller
Buyer name	First and last name of the buyer

TABLE A3.2: Network effects on prices: alternate specification

Variables	Log(price)					
	All dealers		Without top three dealers		Top three dealers only	
	(1)	(2)	(3)	(4)	(5)	(6)
Log of past number of distinct networks	-0.176***		-0.109***		-0.397***	
by buyer with 10 year moving window	(0.021)		(0.025)		(0.045)	
Log of number of transactions by same	-0.069***	-0.077***	0.040	0.022	-0.115***	-0.103***
buyer and seller	(0.018)	(0.018)	(0.041)	(0.041)	(0.024)	(0.024)
Log of buyer's market exposure (in years)	0.182***	0.193***	0.102***	0.110***	0.786***	0.756***
	(0.027)	(0.028)	(0.031)	(0.031)	(0.113)	(0.113)
Log of degree centrality with 10 year		-0.151***		-0.070***		-0.502***
moving window		(0.015)		(0.017)		(0.035)
Hub centrality with 10 year moving		0.545***		0.635		1.199***
window		(0.149)		(0.508)		(0.206)
Object specific specialization difference:	-0.082**	-0.065*	-0.103**	-0.094**	-0.095	-0.083
buyer – seller	(0.038)	(0.038)	(0.043)	(0.043)	(0.085)	(0.084)
Log of past capacity of seller	0.003	0.004	0.002	0.003	0.008	0.009*
	(0.003)	(0.003)	(0.004)	(0.004)	(0.006)	(0.005)
Log of expected number of bidders	0.127***	0.135***	0.148***	0.153***	0.109***	0.120***
	(0.014)	(0.014)	(0.018)	(0.018)	(0.022)	(0.022)
Observations	14,749	14,749	7,989	7,989	6,760	6,760
R-squared	0.405	0.406	0.475	0.475	0.325	0.339

Standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
All models include controls for seller capacity, number of bidders, rivals' maximum capacity and share by volume, lot sequence, artist's living status. Additionally, all models include buyer, year, auction house, artist, medium, and collection effects as in Table 7. Note that, expected numbers of bidders are calculated using estimates from Columns 3 and 4 of Table 5.
We define top three dealers as firms with total market share by volume and value to be in the top three.
See Table 1 for identities of these top three dealers.

Chapter 4

Glass Ceilings in the Art Market?*

We provide strong empirical evidence of decreasing barriers for female artists in a market historically characterized by high gender inequality using an exclusive data set consisting of the population of fine art transactions for Western artists since the millennium. First, controlling for (hedonic) artwork characteristics, we find an average price premium of 4.4% for artworks by female artists at auction driven by female lots from older generations. This reflects larger structural barriers prevalent in the past resulting in a selection of more talented women to enter the profession. Second, while we still find that contemporary female artists are less likely to transition from the primary (gallery) into the secondary (auction) market than male artists we also show a larger increase in the number of female artists traded at auction as well as convergence in average prices between men and women. Lastly, we show that despite lower initial price levels of female lots, conditional on artwork characteristics, the top 50 female artists do not underperform the top 50 male artists in terms of returns. Overall, we show that as women are becoming more recognized they are breaking through the glass ceiling by moving more into the previously male dominated space at the top end of the art market. Our study has important implications for industries characterized by a superstar effect, information asymmetries and inertia towards underrepresented groups.

* This chapter is co-authored with Fabian Bocart (Former Chief Data Scientist at artnet Worldwide Corporation) and Rachel A.J. Pownall (Maastricht University)

4.1 Introduction

Market structures characterized by the superstar effect where a few individuals absorb the majority of rewards can reinforce the lack of mobility of underrepresented market participants. In these so-called “winner-take-all" industries lesser talent is an imperfect substitute for higher talent and the gap in compensation can be disproportional to the gap in skill (Rosen, 1981). Eventually, the size of rewards will depend more on rank than on talent. At the same time, consumers in these markets are often not able to perfectly evaluate the level of talent and future potential of an artist making meritocracy more difficult to achieve. As a result, higher quality standards might be applied to market participants for whom fewer track records are available and for whom it was historically more difficult to acquire legitimacy due to lower status characteristics.[2] In summary, the extremely large competition for top ranks in combination with information asymmetries in these industries might inhibit underrepresented groups from progressing. This may lead to a glass ceiling for them as consumers try to minimize risk and avoid uncertainty in their consumption decisions.

In this large-scale empirical study, we are interested in whether the superstar effect in combination with information asymmetries encountered in the art market translate into barriers for female artists at auction. In particular, we investigate auction outcomes for artworks created by female and male artists and analyze whether the prevailing market structure impacts artwork prices and materializes in a glass ceiling for female artists at the top of the market.

We have access to an exclusive auction data set representing nearly the whole population of global art auction transactions in the time period between 2000 and 2017. From this global database we consider only Western artists to facilitate an accurate identification of the gender of the artists. Overall, we have auction results of 110,938 male and 5,612 female artists (with 2.6 million and 105,844 lots respectively). Furthermore, the data cover several art genres and media types allowing us to segment and homogenize sub-samples resulting in improved comparability. This auction sample allows us to compare the performance of female artists in the secondary market to the performance of male artists. Our focus is on the output (the artistic

[2] Lower status characteristics might refer, for instance, to age, education race or gender.

product) instead of on the input of labor as is often common practice in gender performance differential studies. This approach has the advantage that our results are less likely to be driven by differences in the individual characteristics of the artists. These may include better negotiation and self-promotion skills due to relative overconfidence of men as documented in the literature (Huang & Kisgen, 2013). Artists can be considered entrepreneurs who take on a large human capital risk by pursuing an artistic career. Therefore, their incentives are not distorted and agency conflicts are immaterial in this setting. Furthermore, we also employ a primary (gallery) market data set to investigate the mobility between the primary and the secondary (auction) market for male and female artists. Access to the opaque dealer market data is extremely limited and has not been studied empirically within the art market literature. Lastly, to test for the presence of a glass ceiling specifically and to observe the upper tail of the price distribution where most of the rewards are concentrated, we perform a quantile regression analysis.

The superstar effect is very well illustrated in the art market. The distribution of rewards in this industry is highly skewed with the largest profits concentrated at the top. According to the latest Art Basel and UBS art market report (McAndrew, 2019) only 1% of artists accounted for 64% of auction sales in terms of value in 2017.

It is also documented that female artists are historically underrepresented in this industry. The eminent female art historian, Linda Nochlin, was among the first to question the notion of the male genius and to draw attention to the issue of gender discrimination in the art world in her 1971 landmark essay *"Why Have There Been No Great Women Artists?"* Later in 1984, the Guerrilla Girls started to create awareness for sexual discrimination by pointing out the underrepresentation of female artists in the New York based Museum of Modern Art's exhibition *International Survey of Painting and Sculpture* where only 10% of all works were by female artists ("The Guerrilla Girl's Complete Chronology", 2017). The share of female artists decreases gradually along the career ladder indicating impaired mobility. While women do not display less interest in pursuing an artistic career than men do (about 50% of all Master of Fine Arts (MFA) holders are female in the US), their share drops to 30% in commercial US galleries ("National Museum of Women in the Arts", 2017) and to 25% at art fairs (McAndrew, 2019). According to the "National Museum of Women in the Arts" (2017), nowadays, artworks by female artists represent only 3% to 5% of major permanent collections in the US and Europe. Furthermore, based on our

data, female artworks at auctions make up less than 4%.

Our data reveal evidence of historically high but recently decreasing barriers for female artists in the market for fine art. First, we find an average 4.4% price premium for female artworks at auction which is driven by female artists from older generations (mainly pre-1950s works of art). This is suggestive of higher historical institutional supply-side hurdles and is supportive of a selection mechanism whereby only the most talented female artists enter the profession. Similar dynamics have also recently been observed in a study involving a field experiment on a large online Q&A forum (Bohren, Imas, & Rosenberg) as well as for the case of the referee process in academic journals (Hengel), patent applications (Jensen, Kovács, & Sorenson, 2018) as well as investment advice (Botelho & Abraham, 2017; Egan, Matvos, & Seru, 2017). Second, we show that women are less likely to be sold in the secondary (auction) market, where artists traded who have a resale value. At the same time, we observe a steeper increase in the share of contemporary artworks by women traded at auction which sell at a lower price level (of 8.3%) compared to contemporary artworks by men. This provides evidence of lower barriers for female artists. Third, female artists are still not reaching the sales level of male artists. In particular, the top 0.03% of the market, where 40% of the sales value is concentrated, is entirely occupied by men.

We complement the literature on the influence of market structures characterized by intertia, the superstar effect as well as information asymmetries and their implication for the performance of underepresented groups in particular within the area of the cultural and creative industries. Previous findings within the art market stress high underrepresentation, relatively lower sales revenues of female artists, as well as hurdles experienced by women that impede their careers (Reis, 1995a, 1995b; Rengers, 2002; Throsby & Zednik, 2010; Cowen, 1996). However, with the exception of Adams, Kräussl, Navone, and Verwijmeren, rather small sample sizes impact the external validity and robustness of these results. As superstar markets are characterized by a skewed distribution of income, it is of particular importance to be able to analyze the tails of these distributions which calls for a critical sample size. For instance, using a small sample of fine art graduates from Yale University, a recent study by Cameron, Goetzmann, and Nozari (2017) provide empirical evidence of a higher bar for women from older generations. Consistent with our results, they show that while female artists experience more obstacles than men when

entering the market, their artworks sell at a premium conditional on being traded in the market. Another recent larger empirical study by Adams et al. studies the performance of female artists at auction and suggest demand-side driven discrimination of female artists. The authors document an average discount of 47.6% for female artworks before adjusting for the quality of the artworks which is line with an unconditional average discount of 16.8% and the documented discount for contemporary artists in our data. However, while the goal of their study is to find how price differences are moderated by the level of country-specific gender inequality, we provide nuanced empirical evidence of the manner in which female artists are becoming more represented and recognized in the market, and how female artists are taking a larger share of the contemporary art market. There is some statistical support from other industries subject to superstar economics showing that women encounter a glass ceiling when they climb up the career ladder. This was found to be the case for top athletes (Kahn, 1991), movie stars (Bielby & Bielby, 1996; Lincoln & Allen, 2004), top executives (Bertrand & Hallock, 2001) and researchers (Barbezat & Hughes, 2005; Probert, 2005). However, these studies use salaries to investigate reward differentials. This approach bears the risk of omitting individual characteristics such as negotiation skills which might explain the gap in salaries. Our focus on auction sales enables us to isolate any direct influence of the artist on prices.

Our results provide important insights on dynamics in entrenched market structures and the consequences for gender (in)equality. It appears that the competitive pressure for high ranks paired with uncertainty about the level of skill lead to higher quality standards for underrepresented market participants and impairs their mobility. We provide evidence of changing market dynamics and offer material input for a closer investigation of the underlying reasons of initial gender discrimination.[3] Establishing a comprehensive and detailed overview on the state of gender inequality in the art market beyond anecdotal evidence is the first step towards its mitigation. Parallel dynamics are likely to be present in other occupational areas characterized by the superstar effect such as high-end gastronomy, top sports, academia,

[3] One approach to disentangle the supply from the demand side would be to perform the analysis separately for common names where there is a clear association with one gender (e.g Mary) and ambiguous artist names (e.g. Kim). However, this is not a plausible assumption that auction houses or auction participants are uninformed about the identity of the artist. For instance, auction catalogs typically provide some information about the artist using pronouns which disclose the gender of the artist.

journalism as well as for leadership positions in general which are still largely dominated by homogeneous groups. Therefore, this study might find valuable application across a wider range of industries acting as a starting point for a founded and constructive discussion on gender equality.

The paper proceeds as follows: In section 2, we illustrate the institutional background of the art market. The data are described in section 3. Section 4 is dedicated to the empirical analysis and results. We finish with some concluding remarks in section 5.

4.2 Institutional Setting

Uncertainty with respect to the talent of an artist and the quality of his or her output are important obstacles to efficiency within the art market. Artworks are heterogeneous goods and have either short or no trading histories. Therefore, a lot of subjectivity in judgment is involved in assigning value to an artwork or evaluating the talent of an artist. Furthermore, there is a large reliance on experts such as art dealers, major private collectors, museums and art critics in resolving these uncertainties. They act as gatekeepers of quality an can exert a major influence on an artist's career. Therefore, young/ emerging artists typically seek reputable gallery (dealer) representation after the completion of their art degrees.[4] As opposed to museums or art critics, art dealers (or gallery owners) have a financial stake in the artists they represent. As intermediaries they pursue the goal of creating a market for their artists in exchange for a price commission. This makes the initial hiring decision of art galleries very crucial. While they charge a premium of 40%-70% to buyers for certifying artwork quality, they are themselves exposed to uncertainty with respect to the talent and future potential of an artist. The assessment criteria that make a good artist are rather ambiguous and therefore not fully understood. This does not imply that art has no fundamental value or that it is entirely constructed by the institutions in the art world. Assessing the value of art requires a lot of expertise in the arena of art history as well as good insights into market dynamics

[4] Not all artists are completing university art programs. According to "Is Getting an MFA Worth the Price?" (2016), out of the 500 most successful early-career artists 35% have no MFA degree and 12% are self-thought.

and collector tastes. While we do not empirically observe the hiring decision of an art gallery, is it important to understand the supply chain in the art market since (contemporary) artists who are represented by art galleries constitute a large part of the future artwork supply at auction.

The superstar effect prevalent in the art market implies that the largest part of the sales value/ revenue is concentrated among a small number of artists who are located at the top of the price distribution. In times of art market growth, concentration increases and a larger share of the art buyer's budget is allocated to the same players instead of investing in new artists (Pownall, 2017). In a "winner-take-all" market differences in prices are disproportional to the differences in the talent making rank a crucial factor. This also implies that small changes in expectations or tastes may have large effects on the market values of artists.

The auction market accounts for about 50% of the total sales value in the art market (McAndrew, 2019; Pownall, 2017) and constitutes the secondary market. A sign for the artist's market establishment is that his or her artworks appear at auction sales (the secondary/ resale market) trading for prices not below gallery level.[5] This suggests that these artworks have a resale value and are in demand by other buyers. The appearance of an artwork at auction signals professional recognition (Goetzmann, Jones, Maggioni, & Walden, 2016). Therefore, artists who reach this stage are regarded as relatively established with their quality being certified by the market. Similar to individual wages these prices represent the market value of an artist. An artist's track record within the secondary market is highly visible to the public as opposed to prices in the primary dealer market. Information on past auction results are frequently used by art collectors, experts, consultants and insurers as input to determine the value and future potential of an artist. Therefore, while prices fetched at auction do not directly accrue to the artists themselves they may have a large impact on their careers and also feed back into gallery prices (Galenson & Weinberg, 2000).

The sellers at auction are typically composed of private individuals who previously acquired artworks through the primary market (or through inheritance as a family

[5] There are also instance in which artists sell directly through auction houses (Damien Hirst being a very prominent example). However, this is considered a risky strategy since only little control can be exerted over prices. Price stability is of utmost importance in the art market as prices proxy the quality of an artwork and future potential of an artist (Velthuis, 2007).

bequest).[6] With the exception of liquidity sales (these are famously known as the three D's: death, disease and divorce), an artwork is usually put up for sale at auction if there is a belief that it has increased in value and that there is demand for this artist.

The buyers at auction sales are usually composed of private collectors, art dealers[7] and to a lesser extent institutional buyers such as museums. For private collectors, purchasing motives may be driven by aesthetic, status and investment considerations. Recently, art has received a lot of attention for its suitability as an financial asset class.[8] It is reasonable to assume that after a certain monetary threshold the ability of the artwork to act as a store of value is likely to be an important element in addition to consumption considerations.

If there is uncertainty with respect to the individual talent and future sales potential of an artist who has no market history, art galleries and collectors might use an observable salient group characteristic which is correlated with talent and future sales potential to proxy for the missing information. A reason why gender may be adopted as a lens to make inferences about talent and future value is due to the established archetype of the male artistic genius (Nochlin, 1971) as well as the historically lower status ascribed to women by society (Ridgeway, 2001). Furthermore, the distinctiveness of gender as an attribute provides a large amount of differentiation between groups with little within-group variation (Hilton & Von Hippel, 1996). If art dealers and collectors form their beliefs about group talent and future value in terms of past auction performance at the right tail of the skewed sales distribution, female artists will be subject to a disadvantage due to their historical underperformance. In a "winner-take-all" market art dealers as well as wealthy collectors might aim to maximize their chance to bet on the right artist. This probability will be higher with the purchase of an artwork by a male artists based on past auction results. Overall, this might result in an imperfect substitution between men and women which leads to an underrepresentation of female artists. Gallery sales figures are not publicly available. Nevertheless, there is evidence that the proportion

[6] Due to regulatory restrictions on de-accessioning practices, museums are typically precluded from selling at auction.

[7] There some anecdotal evidence that art dealers bid for the artists they represent at auction in order to stabilize prices. However, this is difficult to trance and unlikely to constitute the majority of sales.

[8] There is a rich literature investigating the risk and return profiles of art including among other Ashenfelter and Graddy (2003), Baumol (1986), Goetzmann (1993), Mei and Moses (2002), Pesando (1993), Renneboog and Spaenjers (2013).

between male and female artists represented by galleries is unbalanced (ranging at around 30%)[9] as opposed to the proportion among MFA graduates ("National Museum of Women in the Arts", 2017). Further, based on our data set, women at auction account for only 4% of the traded artists. Potential explanations are related to self-selection as a result of a higher bar in terms of quality standards in the primary market.[10] As the advantage of one group over another accumulates over time it comes more difficult to catch up. This might lead to inertia and a persistent underrepresentation of women especially in the top ranks of the art market. Assuming that talent is equally distributed among men and women, the underrepresentation might not prevail with perfect information since past auction performance would not matter. Similarity, if the art market was not a "winner-take-all" or superstar market a wrong bet would not be as costly and which potentially would result in a more segmented market.

4.3 Data

4.3.1 Sample

The data employed in this study were provided by Artnet AG (artnet thereafter). The Berlin-based company is an online platform offering trading as well as research and analytic services within the art market. The artnet Price Database dates back to the year 1989 and has over twelve million price quotation records.[11] Global art auction transactions recorded on artnet's Price Database are sourced from over 1,800 auction houses worldwide; each transactions is required to have an estimate minimum of 500 US Dollars or above to be included in the database. As a result, this data set is the most comprehensive archive of results to represent auction house transactions.

[9] In our gallery sample the share of women is 12.5%.

[10] For instance, Breen and Garcia-Penalosa (2002) show that the anticipation of lower revenues leads to a self-selection among women which is responsible for gender segregation in occupations.

[11] This includes decorative art (antiques, ceramics, furniture, jewelry, and watches) which us excluded from this analysis.

In this analysis, we focus on the fine art sector. The category includes photography, prints and multiples, works on paper, paintings, installations, design objects and sculptures totaling 6,140,774 auction transactions. We exclude installations from this study. The market for installations is slightly different from the market for other more traditional object types as installations are more difficult to maintain, store and exhibit for collectors. Furthermore, as Artnet gradually increased the comprehensiveness of its price database between 1989 and 2000, we restrict our sample period to the years 2000 (January) to 2017 (April) resulting in a very high degree of representation since the millennium.

The database provides information on transaction characteristics including the name of the auction house and its location, the date of the sale, the lot number, the price pre-sale estimate of the auction house and the hammer price in US Dollars before transaction costs. We deflate all prices using the US consumer price index (CPI) provided by the OECD using 2017 as our base year.[12] With respect to the artists' attributes, the database records name, date of birth, living status and nationality. At an artwork level, we have information on the title of the work, its size and object type. Additionally, we categorize all auction transactions into movements based on the birth year of the artist. Consistent with the classification in the Tefaf report (Pownall, 2017), we distinguish between Old Masters and Impressionists (1250-1874), Modern (1875-1910), Post War (after 1911 and deceased) and Contemporary (all living artists). The artworks where the artist's birth year was not available are subsumed under "other". We do not consider artists born before 1250. It is important to mention that while we have artists in our sample from different artistic movements and generations, we observe their sales only in the time period from 2000 until 2017. This implies that while opportunities for these artists differed across time, we do not expect the perceptions of buyers with regard to gender performance differences to vary too much during the period of the past 17 years.

Our variable of interest is the artist's gender. Since Artnet's price database does not indicate the gender of the artists, we identified female artists by matching them to a name list. In order to ensure accuracy and increase the homogeneity of the artists in our sample in terms of opportunities such as access to resources and education, we focus on Western artists who are based in Europe and North America (the US and Canada). Whenever there were two nationalities attributed to an artist, the name

[12] The employed consumer price index can be found under https://data.oecd.org/price/inflation-cpi.htm.

was included in the sample if either of the nationalities was European or North American (e.g. the male artist Zao Wou-Ki who is French-Chinese). We use two name lists available from the US Social Security Administration[13] and the German computer magazine Heise[14]. The former list contains North American baby names, while the latter provides a name dictionary with a focus on European names by country. In cases where the name was unisex (e.g. Jessy, Joan and Kim), we manually researched the identity of the artist. Instances where the artist consisted of more than one person (e.g. Christo and Jeanne-Claude) were dropped from the sample.

As a result, we were left with a sample size of 4,387,393 observations. We drop observations where information on the dimension (size) of the object is missing which is the case for 58,166 transactions. Lastly, we exclude bought-in lots from our main analysis.[15] Our final sample consists of 2,677,190 auction transactions. To the best of our knowledge, this represents the largest and most comprehensive art market auction transaction sample so far employed in such a study.

Additionally, we have access to primary market data provided by artnet. Primary market data identifies which artists are represented by which galleries and is highly confidential and therefore difficult to obtain. As a provider of art market services, artnet also provides an online platform for art galleries to sell their work. This data set will be applied to examine the presence of entry barriers into the secondary market for female artists. It contains the names of the galleries and the names of the artists they represent as well as the artist's year of birth over the time period from 2000 until 2017 on an aggregate basis. In total, there are 1,281 galleries in artnet's international gallery network representing 15,121 unique artists. Again, we focus on Western artists only. Furthermore, as we are interested in the transition from the primary to the secondary market we restrict our sample to the population of living (contemporary) artists. This leaves us with an overall sample of 4,754 artists.

The following subsection will introduce the properties of our data set and provide some first evidence for gender differentials within our sample based on univariate analysis.

[13] The list is available at https://www.ssa.gov/oact/babynames/limits.html.
[14] The list is available at ftp://ftp.heise.de/pub/ct/listings/0717-182.zip.
[15] In auctions, a buy-in takes place when an artwork is not sold as it fails to meet the seller's reserve price. The buy-in rate in our sample is 37.73% (1,622,019 observations) which is in line with the commonly observed buy-in rates in auction sales.

4.3.2 Descriptive Statistics

Table 4.1 illustrates the extent of the concentration within the secondary market for art based on our data for the whole sample period (2000 until 2017). It depicts for different shares of the market (in terms of US Dollar value) the percentage (number) of artists who account for it. First, the market is highly concentrated with only 2.2% of the artists accounting for 90% of the overall sales value. Second, artwork sales of female artists amount to only 3.4% of the total auction market ($121.4 billion). Third, whereas the female segment is smaller in size it is more concentrated than the male market. While 19.9% of male artists are responsible for 99% of the sales value, only 15.5% of all female artists occupy the same share within their segment. These numbers suggest that the art auction market resembles a superstar market where rewards are concentrated among a few individuals.[16] This appears to be amplified for the segment of female artists.

TABLE 4.1: Concentration in the auction market (2000-2017)

	Share of market value				
Share (number) of artists	50%	75%	90%	99%	Total value
All artists	0.07% (80)	0.43% (497)	2.18% (2,563)	19.67% (22,926)	$121.4bn
Male artists	0.07% (73)	0.41% (453)	2.16% (2,401)	19.89% (22,065)	$117.3bn
Female artists	0.27% (15)	0.89% (50)	2.41% (135)	15.54% (872)	$4.1bn

Table A4.1 in the Appendix shows the summary statistics for auction prices for men and women with detailed statistics by artistic movement, object type, region and living status. The last column presents the difference between mean male and female prices. Overall, 96.1% (2,572,346) of all artworks sold at auction can be attributed to male artists. Hence, the proportion of female artworks in terms of volume is slightly higher (3.9%) than their share in terms of value (3.4%) in our sample. Figure 4.1 shows how the total sales value and volume evolved for both genders over the sample period as well as over different generations. We chose these two dimensions since while attitudes toward gender might not have changed profoundly over the last 18 years, the market might perceive gender differently across artist generations due to the improvement of conditions for women pursuing an artistic career. As shown in Figures 4.1(a) and 4.1(c) sales volumes have clearly increased for men and women with a larger relative increase for women. While female artists

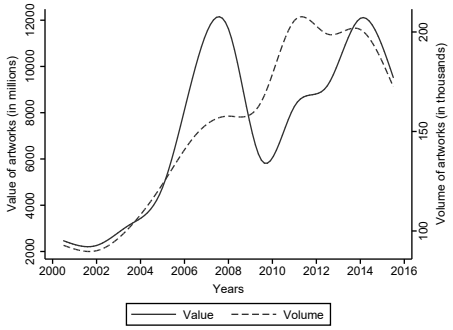
[16] Another attribute of the superstar effect in the sense of Rosen (1981) is that rewards are disproportional to talent. However, in this study we are unable to exactly determine the level of talent of each artist.

increased their overall sales volume by a multiple of 1.95 (from 3,714 artworks in 2000 to 7,247 artworks in 2016), male artists increased sales by a multiple of 1.68 (from 97,807 artworks in 2000 to 164,936 in 2016). Similarly, total sales values have increased for both genders despite a dip following the financial crisis. From the year 2000 until 2017, female artists increased sales value by a multiple of 6.0 while male artists only increased sales by a multiple of 2.8. Nevertheless, female artists remain a small fraction of the overall market in terms of volume and value (4.2% in terms of volume and 5.0% in terms of value in 2016). For both genders, sales numbers highly increased for artists born after 1875 as depicted in Figures 4.1(b) and 4.1(d). This is more pronounced for female artists and is likely to reflect a higher supply of contemporary artworks and indicates lower entry barriers for female artists born in later generations.

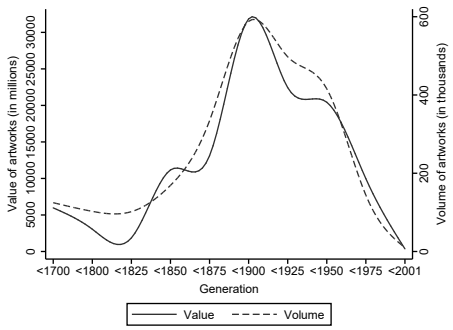
With respect to the number of artists, men clearly dominate the auction market occupying 95.2% of the market. While there are 110,938 male artists, there are only 5,612 female artists. The proportion of female artists is highest for Contemporary art (9.3% are female) and smallest for the Old Masters period (2.9% are female). Figure 4.2 shows the evolution of the number of male and female artists during the sample period and over generations. From Figures 4.2(a) and 4.2(c) which depict the number of distinct male and female artists in every year, we can observe that there is an increasing trend for both groups over the years. However, the trend is stronger for the female sub-group with an almost three-fold increase from 165 artists in 2000 to 456 artists in 2016. The number of male artists at auction per year less than doubled from 4,303 to 7,815 artists over the same time period. As a result, the male-to-female ratio improved by 40% over time from 0.03 in 2000 to 0.05 in 2017 (see Figure A4.2 in the Appendix). This trend is also reflected in Figure 4.2(d) which shows a steady increase in the number of female artists over the generations with a clear peak for the generation that was born between 1975 and 2000. The number of male artists remains rather stable for the generations born after the year 1875. The rising market entry by female artists points to a potential improvement in conditions and higher market acceptance making the artist profession more attractive for women.

An interesting observation is that while the average prices of female artworks are significantly below the average price for male artworks ($39,065 versus $45,614)[17], the median price is with $3,931 higher for women than for men ($3,649). This is

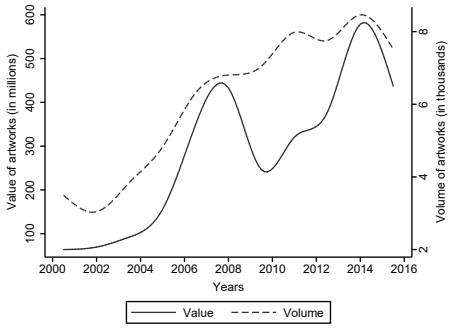
[17] This is equivalent to an average discount of 16.8% which is below the unconditional discount of 47.6% documented by Adams et al.



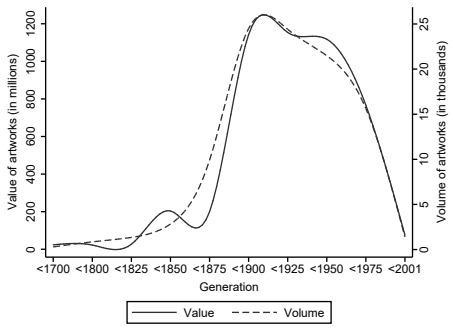
(a) Number and value of artworks by men by years



(b) Number and value of artworks by men by generation



(c) Number and value of artworks by women by years

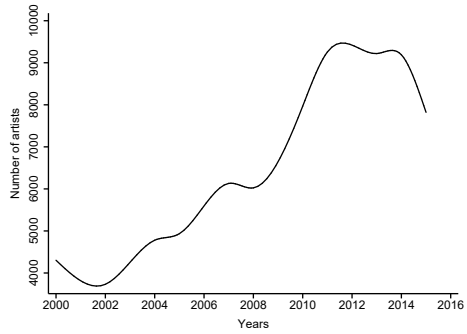


(d) Number and value of artworks by women by generation

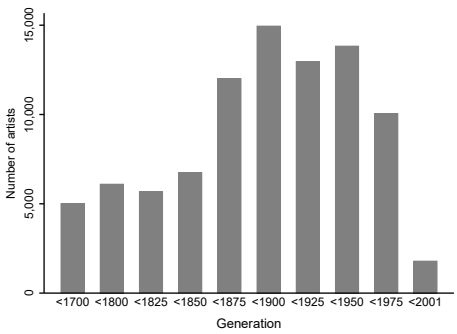
The year 2017 is omitted in Figures a) and c) as we only use the first four months of this year. Overall, there were 35,860 artworks by male and 1,787 artworks by female artists in this year. The value of these artworks is $1,521,769,000 and $53,611,000 respectively. Due to missing data on the year of birth not all artists could not be allocated to a generation. Figures b) and d) omit these artists. Overall, there are 89,888 artworks by male and 2,199 artworks by female artists in this omitted category. The value of these artworks is $761,310,000 and $7,780,000 respectively.

FIGURE 4.1: Evolution of sales by male and female artists

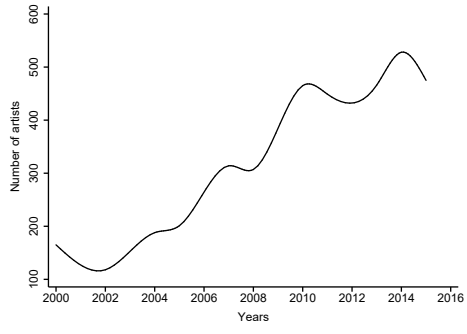
also reflected in Figure 4.3 which shows how these numbers have evolved over time and through generations of artists. In Figure 4.3(a) we can observe that mean artwork prices tend to be higher for men, whereas median prices (4.3(c)) appear to be higher for women after 2002 with a widening gap after 2011. The hedonic price indices based on the respective time (year) dummies for both genders in Figure A4.1 in the Appendix show that sales of female artists have overall outperformed male artists (4.1(a)). However, this seems to be driven by artists from older generations since the financial performance of contemporary female artist (4.1(b)) appears to be



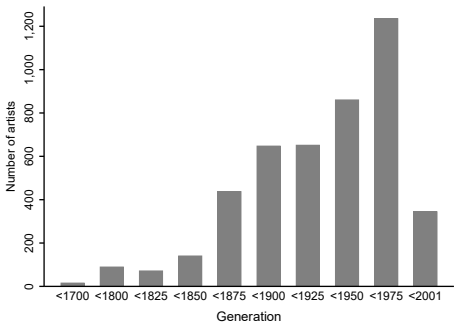
(a) Number of male artists by years



(b) Number of male artists by generation



(c) Number of female artists by years



(d) Number of female artists by generation

The year 2017 is omitted in Figures a) and c) as we only use the first four months of this year. Overall, there were 6,171 male and 167 female artists in 2017. Due to missing data on the year of birth not all artists could not be allocated to a generation. Figures b) and d) omit these artists. Overall, 21,748 male and 1,113 female artists could not be allocated to a generation.

FIGURE 4.2: Evolution of number of male and female artists

significantly worse than the performance of contemporary male artists.

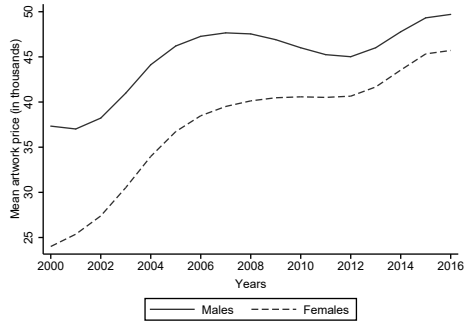
Paintings are with 42.3% the most frequent object type in our data set for both genders while Photographs are the least frequent object type. Mean artwork prices are significantly lower for women for Paintings and Works on Paper while median prices are only lower for Prints and Multiples.

In terms of national residency, it is noteworthy that mean artwork prices of female artists are slightly higher in North America ($58,929 versus $58,234) and significantly higher in Eastern Europe ($68,258 versus $40,758). Only in Western Europe median prices for female artists are lower than for male artists.

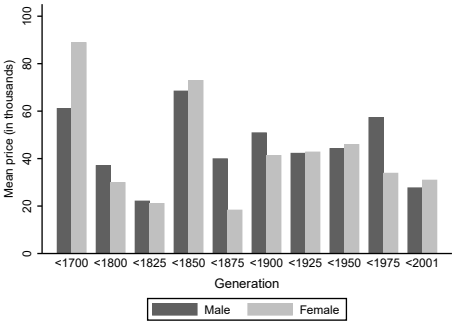
With respect to living status, the share of artworks by deceased artists is lower for the female sub-sample (64.9%) than for the male sub-sample (78.5%). Furthermore, artworks by both living and deceased female artists fetch significantly higher mean and median prices than artworks by male living and deceased artists.

Lastly, Tables A4.2 and A4.3 in the Appendix provide an overview of the top 25 male and female artists and reveal some first insights on the rank of female artists in the market. With a sales value of $393 million the highest selling female artists, Joan Mitchell, does not even reach the total sales value of any of the male artists in the top 25.

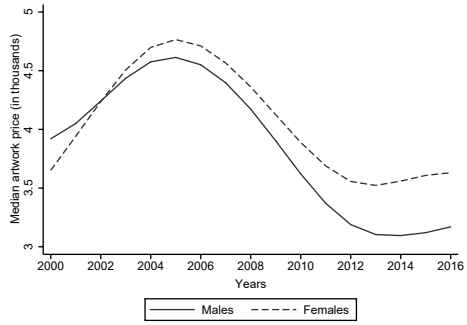
In summary, the univariate analysis reveals three important facts about gender differences in the secondary art market. First, with a share of less than 4% female artists are extremely underrepresented but relatively more concentrated in terms of sales value in the secondary art market. Second, although mean prices are less median prices appear to be higher for women. This might be indicative of a selection mechanism where a higher bar is applied to female artists admitting only the most talented ones. Third, it appears that those women, who do break through the initial barrier to the market, still lag behind top male artists in terms of sales value. In the following section, we will perform an in-depth multivariate analysis in order to investigate the performance of female artists in the secondary art market.



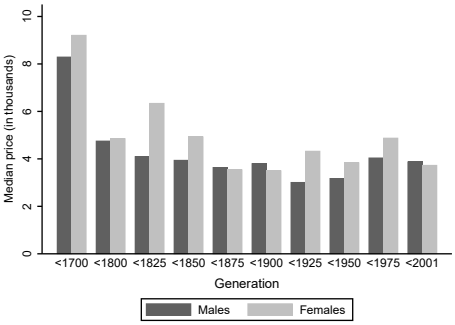
(a) Mean artwork prices by year



(b) Mean artwork prices by generation



(c) Median artwork prices by year



(d) Median artwork prices by generation

The year 2017 is omitted in Figures a) and c) as we only use the first four months of this year. Overall, the mean (median) value is $42,436 ($3,681) for artworks by male and $30,001 ($4,306) for artworks by female artists in this year. Due to missing data on the year of birth not all artists could not be allocated to a generation. Figures b) and d) omit these artists. Overall, the mean (median) value is $8,968 ($1,992) for artworks by male and $3,542 ($1,182) for artworks by female artists in this omitted category.

FIGURE 4.3: Evolution of mean and median artwork prices for men and women

4.4 Empirical Analysis

4.4.1 Auction Participation

Starting at the art gallery level, we want to investigate whether female artists are less likely to enter the secondary art market than men. As shown in the descriptive statistics, female artists are highly underrepresented in the secondary market with

a share of less than 4%. At the same time, it is reported that the number of female students pursuing MFA degrees is not below the number of men. This indicates that there appears to be a large drop out rate of women between these two career stages. However, it might be the case that not all students attending fine art schools are interested in pursuing professional careers as artists. Therefore, in order to make conclusions with respect to the mobility of female artists, we need to observe the share of women present in the primary market where less established and younger artists are represented by galleries.

If an artist is present in the primary data set, it means that this artist is represented by at least one gallery during the sample period. Having gallery representation is the first crucial step in an artist's career after the completion of an art education program. A gallery provides the artist with access to its network of buyers as well as marketing activities to improve his or her visibility in the art market. While galleries can represent emerging as well as more established artists, good representation is particularly important for new, unknown artists. Reasons for selling an artwork at auction can be liquidity related or in order for its owner to realize a financial return following a value appreciation. Hence, if an artist is not traded at auction it might be suggestive of an insufficient value appreciation and/ or demand to make it attractive enough for its owner to sell.

In order to determine how many male and female artists move from the gallery to the auction market, we check whether the artists in the contemporary primary market sample are also present in our main (auction) sample of living artists. Table 4.2 shows that out of 4,180 male artists, 96.9% (4,050 artists) can also be found in the secondary market sample. However, only 93% (534 artists) out of the 574 female artists made this transition. The difference in proportions is statistically significant at a 1% level. It is also notable that the share of women decreases from 13.7% in the primary market to 11.6% in the secondary market within this sample. This amounts to a drop of 15%. The result of this univariate analysis provides us with a first evidence that female artists progress slower to the secondary market. In order to analyze the mobility of women in a multivariate setting, we employ a probit model on the entire primary market sample with a binary dependent variable indicating whether an artist from the gallery sample is traded at auction. The model takes the following form:

$$Z_j = \alpha_1 + \delta_1 D_j + \lambda_1 A_j + \epsilon_{1j}, \tag{4.1}$$

where Z_j is a binary variable that takes the value 1 if an artist j participates at auction and 0 otherwise from the population of $N_a = 4754$ living artists in our sample. D_j denotes the discrimination coefficient which is a gender dummy taking the a value 1 whenever the respective artists is a woman. A_j is a 1×92 vector that denotes the artist characteristics including the artist's nationality[18], his or her year of birth as well as a dummy for every gallery an artist is represented by as a gallery's reputation is known to have a high impact on an artist's success.[19]

The result of the probit model is shown in Table 4.3. It provides evidence for a small but statistically significant barrier for female artists at the transition from the primary into the secondary market. The presented coefficients are the marginal effects at the mean. The coefficient on the female dummy indicates that female artists are 2.2% less likely to participate at auction compared to men. For example, a female artist might have interrupted her artistic career which would negatively impact the market demand for her existent artworks. This can also be the result of self-selection whereby female artists decide to cease their artistic endeavors in anticipation of less success. It could also be the case that galleries underinvest in female artists as they estimate their likelihood to succeed to be lower. An alternative explanation might be that buyers of female artworks differ from other other buyers with respect to their buying motive. These buyers could prefer to hold on to their purchases being less interested in realizing financial returns. Indeed, art dealers prefer selling to collectors who agree to not sell ("flip") the artwork after a short period of time at auction in order to avoid unforeseen price fluctuations. This is in particular important for emerging artists who do not have a price history. In some instances art dealers will offer to buy back the artwork in order to avoid that it is flipped at auction at a low price (Velthuis, 2007). If maintaining price stability is more crucial for female artists galleries might select different types of buyers for their female lots. However, in this

[18] Nationality is defined on country level and includes all countries in Europe and North America totaling to 53 countries. Due to collinearity concerns, 5 of these nationalities were included in the regression model.

[19] In order to avoid overparameterization, galleries that represented less than 100 artists were subsumed under the category 'others'. This resulted in 23 gallery dummies. Due to collinearity concerns, 9 of these galleries were included in the regression model.

case we should observe a price premium on female contemporary artworks conditional on them being traded at auction as a sale through auction should only take place if the risk of the hammer price being below the gallery price level can be ruled out.

TABLE 4.2: Summary statistics for men and women: primary market sample

Variables	Men			Women		
	N	mean	sd	N	mean	sd
Auction participation	4,180 (4,050)	0.969***	0.174	574 (534)	0.930***	0.255
Total sales value (in $)	4,050	3,381,389	41,400,000	534	1,536,746	8,015,190
Year of birth	4,180	1955	15.622	574	1958	14.990

The primary market sample consists of Western, contemporary artists only.
***The difference in proportions of the auction participation rates between men and women is statistically significant on a 1% significance level.
All prices are in constant 2017 $.

TABLE 4.3: Auction participation - Artist level regression results (primary market)

Variables	Auction participation
	Probit model
Female	-0.022***
	(0.006)
Year of birth	-0.001***
	(0.000)
Artist Nationality Effects	Yes
Gallery Effects	Yes
Observations	4,754

Standard errors in parentheses. p<0.01, ** p<0.05, * p<0.1.
The probit model shows the marginal effects at the mean.
The primary market sample consists of
Western, contemporary artists only.

Overall, the magnitude of the chance with which female artists are less likely to transit from the primary into the secondary market (-2.2%) appears to be low. However, it is worth keeping in mind that this estimate is on the lower bound given that we are only considering Western contemporary artists. It is also worth mentioning that artnet's gallery network does not capture the whole population of galleries. Our sample consists of more successful artists as being a member of an online gallery network requires resources smaller galleries might not have. As a result, it might be the case that the artists in our gallery sample represent the top of the market, experience a large value appreciation and have a larger chance to progress into the secondary market.

4.4.2 Performance at Auction

In the previous section we have found that based on our gallery sample female artists are less likely or slower to progress from the primary into the secondary market. We will now turn to our main (auction) sample to investigate the overall performance of female artists on artwork level at auction. The basic regression model has the following specification,

$$\log P_{it} = \alpha + \psi W_i + \beta X_i + \eta H_i + \tau_{t+}\epsilon_{it}, \quad i = 1, \ldots, N; \qquad t = 1, \ldots, T; \tag{4.2}$$

where $\log P_{it}$ indicates the log of the real price of an artwork, i, which is sold at a given time t. $N = 2,677,190$ artworks in our sample over $T = 72$ seasons between 2000 and 2017. W_i denotes the discrimination coefficient which is a gender dummy taking a value of 1 whenever the respective artists of a given artwork, i, is a woman. This regression specification estimates the differences between the actual sales price for an artwork of a female artist and the value of an artwork by a male artist with the same characteristics. All artwork characteristics are captured in X_i, a 1×276 vector that includes the object type (the base category is paintings), the auction house where it was sold and the size of the artwork.[20] H_i is a 1×5 vector that denotes the artist characteristics of a given artwork, i, including region of the artist's nationality (the base category is North America) [21] and a dummy for the living status of the artist at the time of the transaction (the base category is deceased). Due to collinearity between the artist names and the gender dummy, we exclude artist fixed effects from the regression in our main analysis. τ represents time fixed-effects for the years 2000 until 2017. ψ, β and η are time-independent parameters. α is a constant term. Lastly, ϵ_{it} denotes the error term.

Table 4.4 reports the regression results when estimating parameters using the OLS methodology. The highly statistically significant female dummy coefficient in our base regressions shows that artworks by female artists are on average 4.4% more

[20] In total, there are 1,522 auction houses in our data set. Due to collinearity concerns we subsumed auction houses below the 90th quantile in terms of number of transactions under "other". This resulted in 270 different categories.

[21] All countries are split into five regions: North America, Eastern Europe, Northern Europe, Southern Europe and Western Europe.

expensive than the artworks of male artists given the quality of the artworks. While this difference appears to be rather small, this depicts merely the average effect. It is also consistent with findings by Bertrand and Hallock (2001) who studied gender salary differentials for the case of top executives. This result implies that there is a premium on artworks created by women which is supportive of evidence for the presence of a selection mechanism whereby female artists that make it to the secondary art market are on average better than male artists. It could also be indicative of a potential supply squeeze. Due to the limited supply of high-quality female artworks, collectors are willing to pay a premium for these rare lots.

All other coefficients are in line with expectations. Sculptures are the most expensive objects, while prints and multiples display the highest discount relative to paintings. Artworks of artists from Southern Europe sell highest. This is not surprising given that many of the top artists such Picasso, Modigliani, Miro and Fontana originate from there. Lastly, there is a premium on deceased artists (due to a fixed and established market values). The R-squared of the regression is 0.42 which is within the usual range for hedonic models in the field of art market economics (Ashenfelter & Graddy). All coefficients remain unchanged independent of whether the nominal or the real artwork price is used as the dependent variable.

Male and female artists in different time periods were subject to different conditions especially with respect to access to education and the general acceptance of women as creators of cultural goods and part of the workforce. Assuming societal barriers as the only source of performance difference between men and women, our base regression results might pick up unobserved quality differences between the artworks produced due to unequal opportunities granted to women. For instance, less support for female artist in the Old Masters movement could have led to an even higher bar for women during this time period reinforcing a potential selection mechanism. In turn, this would imply that women who succeeded to pursue careers as professional artists had to be on average better than male artists resulting in a higher demand for these lots. As opportunities and beliefs held in society with respect to gender roles have shifted throughout time, the selection mechanism is expected to become less pronounced resulting in a convergence in the supplied quality between artworks produced by men and women in later time periods. As a result, any observed performance differences at auction between the genders are expected to be to a lesser extent due to factors related to differences in access to opportunities.

In order to test this hypothesis, we estimate the model specified in equation (4) for each artistic movement separately. The last four specifications in Table 4.4 present the results. Interestingly, the coefficient on the female dummy is positive and statistically highly significant for each movement with the exception of Contemporary art where we observe a negative and statistically significant coefficient. The Post War era yields the largest premium (14.9%) for female artworks. While it is difficult to imagine that opportunities were worse for female artists in the mid-20th century than in the mid-19th century, it could be the case that this era produced a small number of female artist considered large superstars (e.g. Agnes Martin, Helen Frankenthaler and Joan Mitchell) for whose lots competition among buyers is high. The discount on contemporary female lots is more likely to be driven by a gender bias present in the market given the improved opportunities for women pursuing an artistic career which is also manifested in a relatively higher proportion of women in this period (9.3%). However, it is also indicative of a lower bar and a larger demand for female art whereby also artworks of lesser quality enter the secondary market.[22]

Even though our data set contains artworks created by artists in different time periods, all sales of these works take place over a time period of about 18 years (2000 to 2017). While we do not expect large shifts in the market attitude towards female artists or strong differences in the quality of the artworks by men and women available in the market, we are interested in investigating the persistence of the difference in performance found in our baseline regression in Table 4.4 over time. Therefore, we split our data into four different time periods for which we run separate regressions. The results are shown in Table 4.5. For all four periods a premium for female lots persists ranging from 1.9% to 7.4%. The premium appears to be smaller for the years after 2010. However, this might be due an increased supply of artworks in the market in later years by female artists (see Figures 4.2(a) and 4.2(c)). Since we observed a discount on female Contemporary lots (Table 4.5), Table 4.6 separately reports the results for the sub-sample of Contemporary artworks for the four time periods. Interestingly, it appears that the discount on female lots intensifies throughout time. While the marginally statistically significant discount amounts to 3.5% in the period from 2000 until 2004, it increases to 12.6% for the years from 2015 until

[22] To further homogenize our sample, we also consider every cohort of artists separately and run regressions for each generation of artists whereby one generation is defined as a time period of 25 years. The results are presented in Table A4.4 in the Appendix. Consistent with the previous results, we observe a premium on female lots for the generations active before the year 1850 and a discount for more recent generations born after 1950.

TABLE 4.4: Artwork level OLS regression results

Variables	Log of real price					
	Real price	Nominal price	Old Masters	Modern	Post War	Contemporary
Female	0.044***	0.044***	0.100***	0.045***	0.149***	-0.083***
	(0.004)	(0.004)	(0.011)	(0.007)	(0.008)	(0.007)
Design	-0.219***	-0.219***	-0.012	-0.199***	-0.261***	-0.168***
	(0.003)	(0.003)	(0.009)	(0.006)	(0.006)	(0.009)
Photographs	-0.688***	-0.688***	-0.707***	-0.788***	-0.718***	-0.494***
	(0.004)	(0.004)	(0.014)	(0.007)	(0.008)	(0.007)
Prints & multiples	-0.918***	-0.918***	-0.897***	-1.017***	-0.962***	-0.804***
	(0.002)	(0.002)	(0.006)	(0.004)	(0.005)	(0.006)
Sculpture	0.330***	0.330***	0.322***	0.406***	0.341***	0.393***
	(0.003)	(0.003)	(0.008)	(0.007)	(0.007)	(0.007)
Works on paper	-0.409***	-0.409***	-0.379***	-0.383***	-0.371***	-0.325***
	(0.002)	(0.002)	(0.005)	(0.004)	(0.005)	(0.006)
Eastern Europe	0.014***	0.014***	0.441***	0.168***	-0.528***	-0.359***
	(0.005)	(0.005)	(0.010)	(0.007)	(0.011)	(0.012)
Northern Europe	-0.272***	-0.272***	-0.228***	-0.130***	-0.497***	-0.057***
	(0.003)	(0.003)	(0.008)	(0.006)	(0.006)	(0.007)
Southern Europe	0.149***	0.149***	0.107***	0.539***	-0.228***	-0.085***
	(0.003)	(0.003)	(0.010)	(0.006)	(0.007)	(0.008)
Western Europe	-0.043***	-0.043***	0.010	0.120***	-0.284***	-0.100***
	(0.003)	(0.003)	(0.006)	(0.005)	(0.005)	(0.006)
Alive	-0.381***	-0.381***			-0.370***	
	(0.002)	(0.002)			(0.004)	
Log of size	0.181***	0.181***	0.186***	0.144***	0.188***	0.240***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	2,677,190	2,677,190	539,186	854,843	556,518	418,504
R-squared	0.422	0.419	0.420	0.417	0.437	0.483
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes
Season Effects	Yes	Yes	Yes	Yes	Yes	Yes
Auction house Effects	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
The base category for the object type is paintings.
The base category for the region is North America.

2017. These results also reject the participation rate hypothesis which states that extreme performance outcomes are less likely for women for statistical reasons as they are fewer in number. It provides an intriguing explanation why women are excluded from top ranks in occupations with a high concentration of men. However, as our results show, increasing the ratio of women or lowering their barriers to entry does not defeat a gender gap in performance. This suggests that these additional female artists fall into the lower price quantiles lowering their average performance which could be interpreted as a sign of lower barriers for female artists.

TABLE 4.5: Artwork level OLS regression results – by time period

Variables	Log of real price			
	2000-2004	2005-2009	2010-2014	2015-2017
Female	0.074***	0.069***	0.019***	0.039***
	(0.009)	(0.007)	(0.006)	(0.013)
Design	-0.425***	-0.207***	-0.200***	-0.186***
	(0.021)	(0.007)	(0.005)	(0.011)
Photographs	-0.945***	-0.722***	-0.563***	-0.570***
	(0.009)	(0.007)	(0.006)	(0.014)
Prints & multiples	-1.175***	-1.074***	-0.736***	-0.661***
	(0.005)	(0.004)	(0.004)	(0.009)
Sculpture	0.406***	0.444***	0.289***	0.190***
	(0.008)	(0.007)	(0.005)	(0.011)
Works on paper	-0.439***	-0.448***	-0.378***	-0.346***
	(0.005)	(0.004)	(0.004)	(0.008)
Eastern Europe	-0.016	0.140***	0.000	-0.138***
	(0.012)	(0.008)	(0.007)	(0.015)
Northern Europe	-0.260***	-0.264***	-0.247***	-0.273***
	(0.007)	(0.006)	(0.005)	(0.011)
Southern Europe	0.242***	0.188***	0.095***	0.083***
	(0.007)	(0.006)	(0.005)	(0.011)
Western Europe	0.012**	-0.049***	-0.048***	-0.084***
	(0.006)	(0.005)	(0.004)	(0.009)
Alive	-0.487***	-0.397***	-0.357***	-0.279***
	(0.005)	(0.004)	(0.003)	(0.007)
Log of size	0.201***	0.204***	0.167***	0.147***
	(0.001)	(0.001)	(0.001)	(0.002)
Observations	496,923	756,668	1,026,029	209,830
R-squared	0.452	0.443	0.424	0.402
Year Effects	Yes	Yes	Yes	Yes
Season Effects	Yes	Yes	Yes	Yes
Auction house Effects	Yes	Yes	Yes	Yes

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
The base category for the object type is paintings.
The base category for the region is North America.

A frequent reason underlying the gender gap is found to be the woman's child-rearing responsibility (Reis, 1995a, 1995b). In order to more closely investigate this

TABLE 4.6: Artwork level OLS regression results – by time period (contemporary sample)

Variables	Log of real price			
	2000-2004	2005-2009	2010-2014	2015-2017
Female	-0.035*	-0.040***	-0.093***	-0.126***
	(0.020)	(0.014)	(0.011)	(0.022)
Design	-0.504***	-0.135***	-0.126***	-0.194***
	(0.061)	(0.019)	(0.013)	(0.028)
Photographs	-0.583***	-0.514***	-0.435***	-0.520***
	(0.018)	(0.013)	(0.010)	(0.023)
Prints & multiples	-1.061***	-0.993***	-0.659***	-0.654***
	(0.015)	(0.011)	(0.009)	(0.018)
Sculpture	0.488***	0.471***	0.399***	0.271***
	(0.021)	(0.015)	(0.011)	(0.022)
Works on paper	-0.249***	-0.313***	-0.309***	-0.375***
	(0.017)	(0.012)	(0.009)	(0.018)
Eastern Europe	-0.286***	-0.221***	-0.384***	-0.489***
	(0.040)	(0.023)	(0.017)	(0.033)
Northern Europe	-0.091***	0.056***	-0.093***	-0.102***
	(0.019)	(0.014)	(0.010)	(0.021)
Southern Europe	0.050**	0.033**	-0.211***	-0.120***
	(0.024)	(0.016)	(0.012)	(0.025)
Western Europe	0.034**	-0.055***	-0.165***	-0.141***
	(0.017)	(0.012)	(0.009)	(0.019)
Log of size	0.257***	0.265***	0.234***	0.205***
	(0.004)	(0.003)	(0.002)	(0.004)
Observations	44,731	106,980	185,573	43,267
R-squared	0.538	0.496	0.498	0.443
Year Effects	Yes	Yes	Yes	Yes
Season Effects	Yes	Yes	Yes	Yes
Auction house Effects	Yes	Yes	Yes	Yes

Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
The base category for the object type is paintings.
The base category for the region is North America.

potential explanation for a difference in performance we estimate the model specified in equation (4) for the sample of contemporary artists and include a binary variable which is equal to one if the artists is 40 years old or above at the time of the transaction. We also interact this variable with our female dummy. Indeed, Table A4.5 in the Appendix shows that being above 40 years old has a positive effect on price and that this effect is stronger for women than for men. Motherhood and the risk of a career break might be a potential concern for collectors.

Another possible explanation for the difference in performance of female and male artists might be due to a lower productivity of women. A certain supply of artworks needs to circulate in the market in order to satisfy demand in case of a price appreciation. While we do not have an overview over all artworks ever created by every artists in our sample, we compared the amount of artworks sold by each artist per year.[23] Table 4.7 shows that the mean annual sales volume is a lot higher for male artists (105 versus 38). However, this appears to be driven by a number of male artists who have an extremely large trading volume (e.g. Picasso) since median male and female yearly sales volumes are very close to each other (14 versus 16). Furthermore, in terms of trading frequency female artists appear to be traded slightly more actively than male artists with an average of 165 days (versus 177 days for men) in between two consecutive sales.

TABLE 4.7: Frequency of trading at auction

Variables	Men				Women			
	mean	median	sd	max	mean	median	sd	max
Average number of sales (per year)	105	14	329	2,995	38	16	55	398
Average time between consecutive sales (in days)*	177	42	402	6,245	165	33	398	5,951

*Excludes artists who had only one transaction (amounting to 31.6% of male and 41.1% of female artists.

A better way to control for the unobserved quality characteristics of the artworks which are not explicitly captured by our hedonic variables, would be to modify the dependent variable (the artwork price) by dividing it by the mid-point of the auction house pre-sale estimate.[24] This way, we would analyze whether gender can explain the auction house's estimation error which is equal to the deviation of the final hammer price from the auction house price estimate. However, this assumes

[23] These are typically listed in a catalogue raisonné which would need to be obtained for every artist on our sample.

[24] Before an auction takes place, auction houses typically publish a catalogue listing all lots that will be for sale with their own estimated value of these lots.

that auction house estimates are unbiased measures of quality. We believe that this is unlikely given that auction house experts incorporate buyer preferences and tastes in their valuations of the artworks. In addition, there are over 1,500 auction houses in our sample with diverging valuation procedures. The summary statistics in Table A4.6 in the Appendix show that the auction house estimation error is on average higher for male artworks (2.43 versus 1.78). Proportionally, the share of undervalued artworks are slightly higher for women than for men (and vice versa). For robustness, we performed a regression using the model specification in equation (4) with the nominal price scaled by the auction house pre-sale estimate as the dependent variable. The results of the OLS regression can be found in Table A4.7 in the Appendix. The female dummy coefficient together with most of the other coefficients on our hedonic variables becomes statistically insignificant. This means that auction houses do not systematically over- or underestimate the artworks in relation to the final hammer price and potentially account for a gender bias among buyers.

Even though Nochlin (1971) argues that topics are more correlated within artistic periods as opposed to within gender, other potential explanatory variables that could be correlated with the female dummy are certain colors or themes. For instance, it could be the case that female artists are more likely to focus on family themes in their artworks. These topics might in turn be valued higher or lower by the market. Furthermore, the artist's identity is known to be the strongest predictor of artwork prices capturing important not directly observable quality characteristics such as an artist's reputation. However, given that gender is a time-invariant characteristic of an artist, a gender dummy cannot be included together with artist fixed-effects in the same regression model. In order to incorporate the information contained in the artist's identity we repeat the regression model specified in equation (4) with artist fixed-effects instead of the gender dummy.[25] We then test for differences in the means of the distribution of male and female artist fixed-effect coefficients. Figure 4.4 shows the density distribution of the male and female artist coefficient. The graph clearly highlights the dominance of the female distribution of the fixed-effect coefficients. The two-sample Kolmogorov-Smirnov test for equality of distribution

[25] Due to computational limitations we only allocate individual artist dummies to artists for which there are at least 45 sales transactions. This corresponds to the 25th percentile in the sales volume distribution on artist level. All other artists are subsumed under two IDs (one for male and one for female artists). This results in 9,584 distinct male and 366 distinct female artists.

(unreported) provides statistically significant evidence that the male artist's coefficient distribution is smaller than the female artist's coefficient distribution.[26]

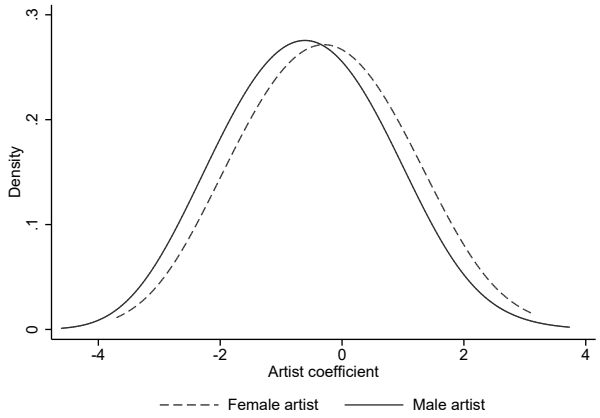


FIGURE 4.4: Density distribution of the artist fixed-effect coefficient for male and female artists

Overall, the analysis in this section showed that there is an average premium on female artworks which might be the consequence of a higher bar and a limited supply of high-quality female lots. This effect is in particular driven by artworks of older generations where different possibilities for men and women prevailed. At the same time, we observe an increasing discount over time for Contemporary female lots which suggests lower barriers for women in recent time periods. Given the underrepresentation of female artists and the superstar effect in the art market, our conjecture is that the premium observed for older generations of artists is driven by a small number of female artists whose artworks demand very large prices. These top artists could be causing a supply squeeze as in a "winner-take-all" market demand will be concentrated around these few individuals. Further, a potentially skewed distribution of sales is not taken into account by OLS estimation which focuses on the average effect. Therefore, the next section will take a closer look at the distribution of sales for male and female artists.

[26] The results of this test are available upon request.

4.4.3 Distribution of Rewards

The analysis so far showed that the share of female artists decreased as they moved from the primary into the secondary market. The shortage of supply of high quality female artworks at auction is reflected in their outperformance in terms of auction prices. We hypothesize that this average effect results from a supply squeeze for the most popular female artists who attract the highest demand. These women constitute the superstars in the “winner-take-all" market and drive the observed average premium. Results on artwork level are distorted if a large amount of artworks is sold by a small amount of female artists located on the top of the price distribution.

Table 4.8 depicts the distribution of lots of male and female artists. Overall, we can see that a smaller number of female artists accounts for a relatively larger amount of lots in terms of volume and value than it is case for male lots. For instance, 95% of the female lots sold at auction stem from 36.7% of female artists accounting for 99.5% of the overall value of female lots. For the male sample, 95% of all lots are covered by 40.0% of the male artists who absorb 99.0% in terms of artwork value. Given the difference in the concentration between the male and the female market, the artwork level OLS is likely to be not informative about the true performance of female artists at auction.

TABLE 4.8: Concentration of lots for male and female artists

Share of lots	Men		Women	
	Share of artists	Share of value	Share of artists	Share of value
25%	0.30% (336)	51.69%	0.37% (21)	23.62%
50%	2.09% (2,316)	78.40%	1.66% (93)	65.65%
75%	8.87 % (9,838)	93.39%	6.56% (368)	93.36%
90%	23.96% (26,585)	97.99%	20.31% (1,140)	98.77%
95%	39.95% (43,318)	98.99%	36.72% (2,061)	99.54%
	110,938	117,335,262,644	5,612	4,095,761,313

All prices are in constant 2017 $.

As an additional robustness check and in order to account for sales of extraordinary magnitude, we split our sample into a sub-sample including only mega transactions (defined as artworks that yielded above $1 million at auction) and a second sub-sample which excludes these large transactions. The regression results for the baseline OLS model can be found in Table A4.8 in the Appendix. It seems that the observed discount for female artworks is driven by a number of male superstars

who are responsible for a large number of high priced artworks. In unreported results we also performed a Wilcoxon-Mann-Whitney test based on the average auction price for male and female artists. This non-parametric test does not rely on a normal distribution of the dependent variable. The result suggests that there is a statistically significant difference between the underlying distributions of the average price of male and female artists. The sum of the female ranks was lower while the sum of the male ranks was higher than expected. Thus the male group had higher rank. However, the difference in the distribution of average prices is not statistically significantly different between the two groups for the sub-sample of contemporary artists.[27]

Further, we are investigating the concentration within the female segment of the market. Table 4.9 shows the percentages of male and female artists at every quantile of the sales value distribution on artist level. As defined in the section above, the sales value equals the sum of the value of all sold lots throughout the sample period per artist. The most interesting observation is that the female sub-market is more concentrated at the top (top 10%) and less concentrated at the bottom (bottom 50%) than the male sub-market. The latter effect becomes more amplified the further we move down the sales value distribution. While an expected share of 10.1% (5,650) of the male artists can be found in the top 10% of the sales value distribution, only 7.5% (178) of the female artists are located there. At the 50th quantile of the sales value distribution, only a total of 38.9% of the female artists can be found as opposed to an expected share of 50.6%. Moving further down the sales value distribution, 9.7% of all male and as many as 15.9% of the female artists are situated at the bottom 10% of the sales value distribution. Overall, this implies that female artists are more likely be found at the bottom in the sales distribution than men. The superstar effect wherein a small number of individuals absorbs all industry rewards (Rosen, 1981) applies even more to the female sub-group than to the male segment.

4.4.4 The Superstar Effect

If being traded in the secondary market is not sufficient to signal quality and legitimacy for female artists, we expect that this should materialize in a glass ceiling on

[27] The results of these tests are available upon request.

TABLE 4.9: Quantiles by total sales value for men and women

		Men		Women	
Quantile	Total sales value ($)	N artists	Cumulative	N artists	Cumulative
>99.97%		0.03% (40)	0.03%	0.00% (0)	0.00%
<99.97%	452,388,320	0.01%(17)	0.05%	0.02% (1)	0.02%
<99.96%	351,808,064	0.04% (43)	0.08%	0.05% (3)	0.07%
<99.1%	176,461,520	0.90% (994)	0.98%	1.19% (67)	1.27%
<99%	9,461,848	4.05% (4,490)	5.03%	3.06% (172)	4.33%
<95%	982,622	5.09% (5,650)	10.12%	3.17% (178)	7.50%
<90%	312,493	15.24% (16,908)	25.36%	10.23% (574)	17.73%
<75%	50,209	25.19% (27,949)	50.56%	21.19% (1,189)	38.92%
<50%	8,604	24.92% (27,644)	75.48%	26.60% (1,493)	65.52%
<25%	2,089	14.82% (16,442)	90.30%	18.55% (1,041)	84.07%
<10%	814	4.90% (5,435)	95.20%	6.99% (392)	91.05%
<5%	545	4.80% (5,326)	100.00%	8.95% (502)	100.00%
Total sales value	121,431,023,957				

the top of the market where the largest rewards are concentrated.

Table 4.9 does not only exemplify the concentration of sales within the female subsegment, but also provides first critical evidence for a barrier for female artists at the top of the market. In the 99.97th quantile of the sales value distribution no single female artist can found. This quantile corresponds to a market share of 40% in terms of value which entirely accrues to a core of 40 top male artists. As the most expensive female artist, Joan Mitchell, can be found in the 99.96th quantile. With $393 million in total sales, she is ranked 43rd in the list of top artists.

Furthermore, Table 4.10 shows for different quantiles of the sales value distribution the respective brackets for male and female artists as well as the number of artists per bracket. The key takeaway is that the sales value is significantly lower for female artists than for male artists in every quantile with the exception of 99th quantile where the sales value bracket is $9.3 million for male artists and $12,.4 million for female artists. However, at the very top, namely at the 99.91th quantile, the sales value per artist for men elevates again above the sales value level of women. Moving from $9.3 million in the 99th quantile to $176.8 million in the 99.1th quantile, represents a sizable jump. At this sales level 99 male artists and a mere of 5 female artists can be encountered. While the overall 1:20 male-to-female ratio is preserved at this quantile, the increase in sales values is disproportional. It represents the part of the distribution where the superstars of the art market are located who absorb the largest chunk of the rewards. Lastly, we compare the distribution of maximum (record) artwork prices achieved by male and female artists. Figure 4.5 highlights how in particular at the top of the price distribution men overshoot women. This

univariate artist level analysis shows that in order to reach the sales level of male artists, a woman needs to be at the top of the distribution. At the same time, she is precluded from entering the league of the superstars of the art market which appears to be reserved for the male population of artists.

TABLE 4.10: Group-specific quantiles for men and women

	Men		Women	
Quantile	Total sales value ($)	N artists	Total sales value ($)	N artists
>99.91%		99		5
<99.91%	176,750,048	1,010	135,153,952	51
<99%	9,342,266	4,437	12,382,016	224
<95%	992,138	5,547	724,759	281
<90%	318,364	16,641	168,534	842
<75%	51,854	27,735	23,281	1,403
<50%	8,801	27,734	4,557	1,403
<25%	2,147	16,640	1,288	841
<10%	831	5,546	581	281
<5%	554	5,549	403	281
Total sales value	117,335,262,644		4,095,761,313	

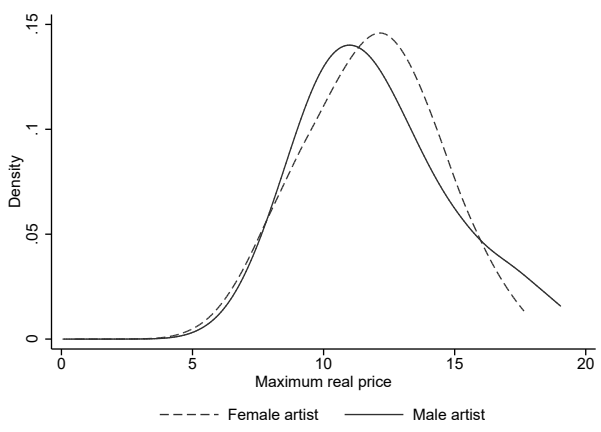


FIGURE 4.5: Distribution of maximum prices achieved at auction for male and female artists

In the following step, we aim to investigate whether taking into account the skewed distribution of prices in the art market will open up a more granular view on gender differences in the art market. Capitalizing on our comprehensive data set that allows us to dig into the tails of the price distribution, we estimate parameters of equation (4) with a quantile regression technique as laid out by Koenker and Bassett Jr (1978). Quantile regression models consider every price segment separately focusing on parts of the distribution other than the conditional expectation. Table 4.11

provides an overview of the number of male and female artworks located in every price quantile. Only 67 artworks by women lie above the 99.9th quantile yielding prices above $4.4 million. Table 4.12 presents the regression results and offers a very clear perspective on gender effects in our sample which are in line with the findings from the univariate analysis. For illustration, the female dummy coefficient is plotted in Figure 4.6. At the 25th quantile, we observe a premium on female artworks which steadily increases from 4.5% to 6.7% in the 95th quantile. A discount of 4.1% emerges for artworks by female artists at the 99th quantile and amplifies to 19.9% at the 99.9th quantile, which represents the very top of the secondary art market. This is supportive evidence for the presence of a glass ceiling that precludes women from participating in the high-end of the art market. We have repeated the same regression for the sub-sample contemporary artists. The coefficients presented in Table 4.13 mirror the results for the full sample. The discount on female lots becomes more pronounced along the price distribution. At the top of the distribution there is premium of 3.7% for female lots. This could be regarded as consistent with a supply squeeze for a small number of female superstars and an amplified superstar effect among female artists.

TABLE 4.11: Quantiles for artwork prices for men and women

Quantile	Price ($)	No. of male artworks	No. of female artworks
>99.9%		2,607	67
<99.9%	4,382,047	23,099	998
<99%	606,033	102,447	4,641
<95%	103,541	512,642	22,582
<75%	12,808	643,428	26,084
<50%	3,930	643,252	26,016
<25%	1,512	644,871	24,456

TABLE 4.12: Quantile regression results

Variables	Log of real price					
	q25	q50	q75	q95	q99	q99.9
Female	0.045***	0.049***	0.054***	0.067***	-0.041**	-0.199***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.040)	(0.000)
Auction House Effects	Yes	Yes	Yes	Yes	Yes	Yes
Region Effects	Yes	Yes	Yes	Yes	Yes	Yes
Alive Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Size Effects	Yes	Yes	Yes	Yes	Yes	Yes
Artist Effects	No	No	No	No	No	No
Observations	2,677,190	2,677,190	2,677,190	2,677,190	2,677,190	2,677,190

P-values based on bootstrapped standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

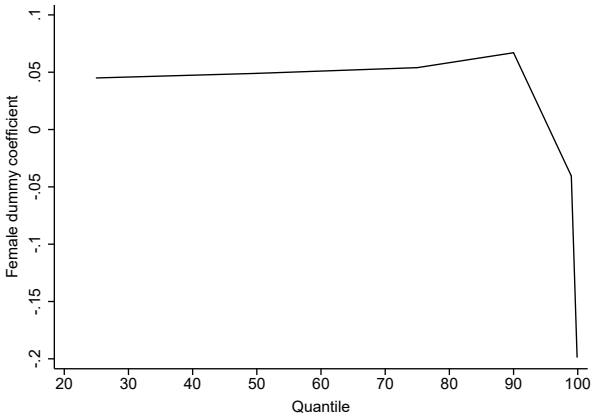


FIGURE 4.6: Coefficient on female dummy in quantile regression

TABLE 4.13: Quantile regression results - Contemporary artists sample

Variables	Log of real price					
	q25	q50	q75	q95	q99	q99.9
Female	-0.042**	-0.062***	-0.090***	-0.094***	-0.120***	0.037
	(0.040)	(0.001)	(0.002)	(0.001)	(0.001)	(0.140)
Auction House Effects	Yes	Yes	Yes	Yes	Yes	Yes
Region Effects	Yes	Yes	Yes	Yes	Yes	Yes
Alive Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Size Effects	Yes	Yes	Yes	Yes	Yes	Yes
Artist Effects	No	No	No	No	No	No
Observations	418,504	418,504	418,504	418,504	418,504	418,504

P-values based on bootstrapped standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Overall, the preceding analysis showed that at the very top of the market the idea of the male artistic genius still prevails. The “winner-take-all" effect in the art market appears to create a structure which precludes female artists from reaching the top of the market.

4.5 Concluding Remarks

This is among the first large-scale studies to provide a convincing empirical illustration of how a market structure characterized by the superstar effect and uncertainty about talent reflects on the mobility and performance of an underrepresented group. Using a sample of data that is only fractionally smaller than the true population enables us to accurately describe and analyze gender performance differences in the secondary market for fine art. The analysis goes beyond establishing the average effect of being a woman on the price of artworks. Instead, we closely look into the upper tail of the sales distribution where most of the rewards are concentrated.

First, we show that female artists are still highly underrepresented in the primary (gallery) as well as in the secondary (auction) market. While the share of women in art schools pursuing MFA degrees is reported to be equal to the share of men, we encounter a proportion of only 13.7% in our primary art market sample of contemporary artists which decreases to 11.6% in the secondary market. Overall, across movements and generations, female artists make up a share of less than 4% in terms of number of artists as well as number of lots. This could be interpreted as supporting evidence for higher quality standards for female artists at the gallery hiring stage. Further, the probit model results show that women are 2.2% less likely to progress into the secondary market. This could be due to a slower process for women in establishing themselves as artists in the market.

In line with a higher bar explanation, we observe an average price premium of 4.4% on artwork level for female artists which is driven by artists of older generations where opportunities were less equal presumably allowing only the best and most persistent women to pursue an artistic career. These findings are consistent with the most recent working paper by Cameron et al. (2017) who find a premium for female artworks traded at auction within a sample of Yale graduates. A higher

bar for women was also found in recent studies within the area of academia where journal papers abstracts by women had to be better written than the abstracts of male authors (Hengel) and science where patent application by women were found to be subject to higher scrutiny (Jensen et al., 2018). Furthermore, Bohren et al. found that women are subject to higher standards in an online Q&A platform when no task history certifying their reputation is available. At the same time, our results show that the share of contemporary female artists has increased and that they are subject to a price discount at auction which is consistent with the findings by Adams et al. This might be indicative of lower entry barriers for women and decreasing information asymmetries in the art market over the past two generations.

Second, we provide empirical evidence that the “winner-take-all" phenomenon (superstar effect) which is a characteristic of the art market is more prevalent within the group of female artists than within the male segment. The observed average price premium for female artworks turns into a 10% price discount after correcting for the number of lots per artist. This discount is driven by Post War and contemporary artists and implies that the observed price premium is due to a small number of female artists who account for a large share of expensive lots. Additionally, we find that the top end of the market is more concentrated in the female sub-sample than in the male sub-sample. The women located at the top of the sales distribution appear to be responsible for the price premium and potentially cause a supply squeeze for their limited amount of lots. Furthermore, relatively more female than male artists are located in the lower tail of the value distribution. In every quantile of the distribution, the total sales value for men is higher than the one for women with exception of the 99th quantile. This implies that unless a female artist reaches the top, her sales will remain below the sales level of a male artist in the secondary art market. This has also been shown for the case of women in top executive positions and for women in higher salary quantiles in general (Bertrand & Hallock, 2001; Garcia, Hernández, & Lopez-Nicolas, 2001; Kuhn, 1987).

Third, we reveal that the top end of the art market is still dominated by a core number of male artists. In terms of total sales values, the 99.97th quantile which corresponds to 40% of the market by value is entirely occupied by male artists where no single women can be found. This is supported by the quantile regression results which show that within the 99.9th quantile of the price distribution a discount of 20% for female artworks emerges. This result is in line with empirical findings in

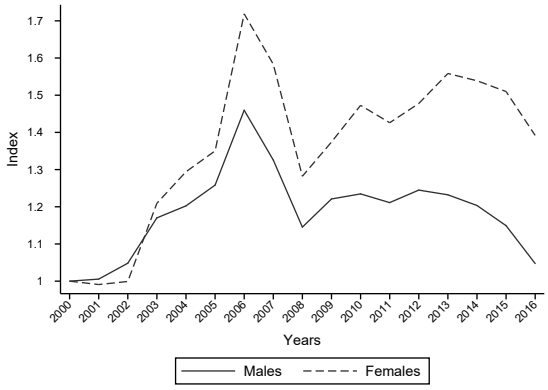
other industries where the superstar effect prevails including the market for top athletes (Kahn, 1991), movie stars (Bielby & Bielby, 1996; Lincoln & Allen, 2004), high-level executives (Bertrand & Hallock, 2001) and researchers (Barbezat & Hughes, 2005; Probert, 2005) and might be the result of the given market structure which prevents the mobility of historically underrepresented groups. For the case of contemporary artists we observe an increasing discount as we move through the price quantiles. This could be regarded as evidence for a lower mobility for female artists to the top. It appears that being traded in the primary or secondary market is not sufficient for a female artist to signal quality and establish legitimization.

Overall, our results suggest that gender still plays an important role in the art market. While the art industry has grown substantially over time with increasing rewards for artists located at the top of the market as documented by the recent Art Basel and UBS Art Market Report (McAndrew, 2019), these rewards are still concentrated among a core that purely consist of male artists. This can induce self-selection mechanism for female artists. The anticipation of lower sales might discourage women from pursuing professional artistic careers leading them to drop out of the market. Only female artists with lower opportunity costs and greatest talent may be willing to remain in the market. While this might be efficient, there is no explanation why the same filter is not applied to the population of male artists. On the other hand, we show that the number of artworks by women traded in the secondary market has increased.

Our study provides important lessons for gender differentials in labor market outcomes within markets characterized by the superstar effect and information asymmetries. Our results suggest that an inertia towards existing market structures can hamper the mobility of historically underrepresented groups. These results can be extended to other professions where rewards increase disproportionately with talent and where quality or skill is difficult to assess. However, while in other occupational areas (e.g. orchestra auditions) blinding the identity of the individuals has mitigated gender inequality, this is less feasible in the art market. Part of an artwork's value consists from its historical value which is difficult to detach from an artists' identity. Therefore, to establish gender equality, it is important that institutions and intermediaries in the art world deviate from the current paradigm and promote market transparency. Recent trends such as a growing number of women among high-net-worth-individuals increasing the share of female art buyers, as well

media attention and interest in female artists by major museums might contribute to an organic alleviation of the status-quo. As a result, the next generation of art dealers and buyers might become more confident about the quality and future potential of artworks created by women so that less reliance on historical group statistics will be necessary.

4.6 Appendix



(a) Index by genders - Full sample

(b) Index by genders - Contemporary sample

FIGURE A4.1: Price index by gender

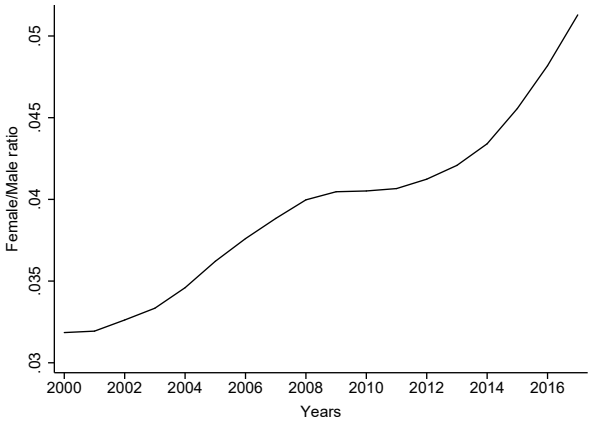


FIGURE A4.2: Evolution female-to-male ratio

TABLE A4.1: Summary statistics for men and women

	Men					Women					
Price	N	N artist	mean	median	sd	N	N artists	mean	median	sd	Δ in means
Overall	2,572,346	110,938	45,614	3,648	686,070	104,844	5,612	39,065	3,931	330,635	16.8%***
Buy-in rate*			0.378	0.376	0.027			0.361	0.361	0.034	4.7%
Movement											
Contemporary	388,070	19,917	38,025	3,146	432,129	30,434	2,031	28,502	4,011	170,396	33.4%***
Postwar	532,238	34,173	41,047	3,090	635,913	24,280	1,863	54,262	4,121	405,305	-24.4%***
Modern	819,923	21,281	51,358	3,542	860,069	34,920	961	41,332	3,701	409,739	19.5%***
Old Masters & Impressionists	525,405	19,806	48,503	3,776	678,067	13,781	595	29,921	3,928	223,868	62.1%***
Other	306,710	15,761	38,641	5,743	494,310	1,429	162	34,316	5,418	135,044	12.6%
Object type**											
Design	212,709	9,250	12,848	3,269	67,873	11,141	521	19,934	4,009	17,703	-35.5%***
Sculptures	169,704	15,306	70,600	5,032	852,476	8,132	807	88,341	11,419	483,140	-20.1%***
Paintings	1,132,403	78,184	75,343.8	4,903.5	951,020.9	33,064	3,663	72,025	5,142	486,108	4.6%***
Works on paper	453,729	36,161	24,543	3,090	315,271	16,477	1,646	18,470	3,797	93,931	32.9%***
Prints and multiples	477,203	15,050	2,117	2,241	172,222	19,371	711	6,630	1,895	100,688	-68.1%***
Photographs	126,598	6,822	15,477	3,572	76,292	16,659	603	20,475	5,125	107,243	-24.4%***
Region											
North America	545,239	24,641	58,234	3,946	803,389	34,751	1,727	58,929	4,525	467,225	-11.8%***
Northern Europe	463,192	19,162	29,560	3,033	593,016	25,195	1,310	27,827	3,625	263,459	6.2%
Western Europe	1,099,021	44,143	43,114	3,571	594,711	35,243	1,673	24,473	3,394	140,217	76.2%***
Southern Europe	337,164	14,049	57,251	4,246	912,561	4,040	329	25,012	5,695	111,384	128.9%***
Eastern Europe	127,730	8,943	40,758	4,247	453,220	5,615	573	68,258	4,258	491,061	-40.3%***
Living status at time of sale											
Deceased	2,018,743	65,760	49,159	3,893	748,360	68,033	2,263	44,659	3,941	390,600	10.1%***
Alive**	553,603	47,175	32,686	2,864	380,340	36,811	3,454	28,728	3,909	170,957	13.8%***

All prices are in constant 2017 $.
*The buy-in rate is the share of lots of all lots offered per artist that is not sold at auction.
In total, 156,761 male lots and 59,258 female lots were bought in.
**Multiple attributions for a single artist are possible.
***The difference in mean prices between men and women is statistically significant on a 1% significance level.

TABLE A4.2: Top 25 male artists by value of sales

Rank	Artist	Origin	Total sales value in $ (market share)	Total sales volume (market share)	Buy-in rate
1	Pablo Picasso	Southern Europe	5,853,551,616 (4.99%)	37,386 (1.45%)	0.247
2	Andy Warhol	North America	4,931,258,880 (4.20%)	19,028 (0.74%)	0.310
3	Claude Monet	Western Europe	2,509,770,496 (2.14%)	493 (0.02%)	0.197
4	Gerhard Richter	Western Europe	2,128,574,336 (1.81%)	3,587 (0.14%)	0.255
5	Francis Bacon	Northern Europe	2,071,435,648 (1.77%)	1,372 (0.05%)	0.235
6	Alberto Giacometti	Western Europe	1,661,223,808(1.42%)	1,991 (0.08%)	0.309
7	Jean-Michel Basquiat	North America	1,604,688,384 (1.37%)	1,308 (0.05%)	0.288
8	Mark Rothko	North America	1,589,495,040 (1.35%)	142 (0.01%)	0.184
9	Henri Matisse	Western Europe	1,384,500,224 (1.18%)	5,157 (0.20%)	0.302
10	Roy Lichtenstein	North America	1,365,195,904 (1.16%)	6,429 (0.02%)	0.247
11	Amedeo Modigliani	Southern Europe	1,282,909,952 (1.09%)	502 (0.58%)	0.344
12	Marc Chagall	Western Europe	1,246,740,480 (1.06%)	14,957 (0.57%)	0.294
13	Joan Miró	Southern Europe	1,195,891,584 (1.02%)	14,781 (0.21%)	0.285
14	Willem De Kooning	North America	1,144,317,696 (0.98%)	1,272 (0.06%)	0.272
15	Lucio Fontana	Southern Europe	1,098,615,296(0.94%)	2,772 (0.11%)	0.266
16	Alexander Calder	North America	1,088,666,752 (0.93%)	5,479 (0.05%)	0.238
17	Pierre-Auguste Renoir	Western Europe	1,046,396,352 (0.89%)	3,766 (0.15%)	0.309
18	Zao Wou-Ki	Western Europe	1,015,000,512 (0.87%)	4,045 (0.15%)	0.206
19	Fernand Léger	Western Europe	1,005,042,112 (0.86%)	2,978 (0.16%)	0.354
20	Cy Twombly	North America	850,141,376 (0.72%)	881 (0.06%)	0.765
21	Jeff Koons	North America	848,892,096 (0.72%)	1,646 (0.12%)	0.296
22	Paul Cézanne	Western Europe	791,902,080 (0.67%)	697 (0.05%)	0.299
23	Edgar Degas	Western Europe	771,783,232 (0.66%)	1,274 (0.17%)	0.295
24	René Magritte	Western Europe	734,759,296 (0.63%)	1,519 (0.03%)	0.235
25	Damien Hirst	Northern Europe	705,134,592 (0.60%)	3,940 (0.03%)	0.406

All prices are in constant 2017 $.

TABLE A4.3: Top 25 female artists by value of sales

Rank	Artist	Origin	Total sales value in $ (market share)	Total sales volume (market share)	Buy-in rate
1	Joan Mitchell	North America	392,962,816 (9.59%)	641 (0.61%)	0.213
2	Georgia O'Keeffe	North America	211,702,064 (5.17%)	117 (0.11%)	0.204
3	Louise Bourgeois	North America	197,968,512 (4.83%)	649 (0.62%)	0.289
4	Agnes Martin	North America	193,711,040 (4.73%)	296 (0.28%)	0.249
5	Cindy Sherman	North America	140,606,176 (3.43%)	1,269 (1.21%)	0.268
6	Barbara Hepworth	Northern Europe	135,153,952 (3.30%)	616 (0.59%)	0.146
7	Tamara De Lempicka	Eastern Europe	127,470,128 (3.11%)	313 (0.30%)	0.357
8	Natalia S. Goncharova	Eastern Europe	127,109,512 (3.10%)	731 (0.70%)	0.463
9	Mary Cassatt	North America	88,247,688 (2.15%)	832 (0.79%)	0.296
10	Helen Frankenthaler	North America	79,406,904 (1.94%)	1,100 (1.05%)	0.253
11	Bridget Riley	Northern Europe	78,610,368 (1.92%)	818 (0.78%)	0.189
12	Berthe Morisot	Western Europe	76,978,256 (1.88%)	258 (0.25%)	0.340
13	Eileen Gray	Northern Europe	75,399,800 (1.84%)	184 (0.18%)	0.326
14	Gabriele Münter	Western Europe	67,722,952 (1.65%)	449 (0.43%)	0.231
15	Niki De Saint Phalle	Western Europe	67,633,304 (1.65%)	1,849 (1.76%)	0.361
16	Maria H. V. Da Silva	Western Europe	62,461,532 (1.53%)	683 (0.65%)	0.320
17	Elisabeth Frink	Western Europe	56,816,528 (1.39%)	1,212 (1.16%)	0.186
18	Camille Claudel	Western Europe	47,351,292 (1.16%)	115 (0.11%)	0.275
19	Julie Mehretu	North America	39,050,448 (0.95%)	117 (0.11%)	0.328
20	Marie Laurencin	Western Europe	37,916,940 (10.93%)	1,633 (1.56%)	0.452
21	Germaine Richier	Western Europe	36,489,668 (0.89%)	207 (0.20%)	0.310
22	Charlotte Perriand	North America	36,297,372 (0.89%)	1,270 (1.21%)	0.367
23	Sonia Delaunay	Western Europe	35,823,440 (0.87%)	2,414 (0.23%)	0.412
24	Zinaida E. Serebryakova	Eastern Europe	46,413,028 (0.87%)	130 (0.12%)	0.272
25	Elizabeth Peyton	North America	34,532,152 (0.84%)	305 (0.29%)	0.343

All prices are in constant 2017 $.

TABLE A4.4: Artwork level OLS regression results - by generation

Variables	Log of real price									
	<1700	<1800	<1825	<1850	<1875	<1900	<1925	<1950	<1975	<2001
Female	0.358***	0.058	0.125***	0.340***	0.008	-0.008	0.124***	0.080***	-0.105***	-0.097***
	(0.069)	(0.041)	(0.031)	(0.024)	(0.013)	(0.008)	(0.008)	(0.008)	(0.011)	(0.033)
Design	-0.668***	-0.292***	0.045	0.049***	-0.012	-0.171***	-0.248***	-0.312***	-0.068***	0.180***
	(0.092)	(0.048)	(0.041)	(0.017)	(0.011)	(0.007)	(0.007)	(0.009)	(0.016)	(0.055)
Photographs	-0.708*	-0.469***	-0.231***	-0.775***	-0.689***	-0.787***	-0.658***	-0.756***	-0.406***	-0.461***
	(0.371)	(0.105)	(0.020)	(0.026)	(0.017)	(0.010)	(0.008)	(0.008)	(0.010)	(0.037)
Prints and multiples	-1.267***	-1.441***	-1.154***	-0.999***	-0.851***	-1.003***	-1.010***	-1.025***	-0.742***	-0.738***
	(0.013)	(0.012)	(0.019)	(0.014)	(0.008)	(0.005)	(0.005)	(0.005)	(0.010)	(0.042)
Sculpture	0.225***	0.061***	0.118***	0.352***	0.354***	0.400***	0.452***	0.314***	0.483***	0.103**
	(0.026)	(0.019)	(0.017)	(0.014)	(0.011)	(0.008)	(0.008)	(0.007)	(0.012)	(0.042)
Works on paper	-0.601***	-0.467***	-0.402***	-0.475***	-0.348***	-0.390***	-0.355***	-0.367***	-0.248***	-0.326***
	(0.013)	(0.009)	(0.010)	(0.009)	(0.006)	(0.005)	(0.005)	(0.006)	(0.010)	(0.038)
Eastern Europe	0.392*	0.119**	0.567***	0.513***	0.427***	0.134***	-0.182***	-0.499***	-0.431***	-0.399***
	(0.201)	(0.049)	(0.031)	(0.020)	(0.012)	(0.009)	(0.010)	(0.012)	(0.019)	(0.046)
Northern Europe	0.060	-0.537***	-0.659***	-0.209***	-0.224***	-0.145***	-0.221***	-0.476***	0.058***	-0.197***
	(0.189)	(0.020)	(0.018)	(0.013)	(0.010)	(0.008)	(0.007)	(0.007)	(0.010)	(0.039)
Southern Europe	0.491***	-0.085***	-0.183***	0.174***	0.089***	0.607***	0.027***	-0.294***	-0.168***	-0.300***
	(0.188)	(0.021)	(0.027)	(0.018)	(0.013)	(0.007)	(0.007)	(0.008)	(0.014)	(0.059)
Western Europe	0.500***	-0.299***	-0.327***	0.055***	-0.008	0.081***	-0.022***	-0.335***	-0.212***	-0.322***
	(0.188)	(0.020)	(0.017)	(0.011)	(0.008)	(0.006)	(0.006)	(0.006)	(0.010)	(0.038)
Alive							-0.079***	-0.322***	-0.659***	
							(0.005)	(0.004)	(0.013)	
Log of size	0.133***	0.224***	0.229***	0.206***	0.182***	0.147***	0.182***	0.222***	0.287***	0.220***
	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.008)
Observations	125,023	103,448	103,135	171,749	343,970	612,586	521,910	437,473	159,572	11,237
R-squared	0.455	0.440	0.415	0.445	0.413	0.419	0.412	0.481	0.533	0.589
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Season Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Auction house Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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

The base category for the object type is paintings. The base category for the region is North America.

TABLE A4.5: Artwork level regression results – child-rearing

Variables	Log of real price
Female	-0.140***
	(0.025)
Above 40	0.153***
	(0.009)
Female x Above 40	0.067**
	(0.026)
Design	-0.172***
	(0.009)
Photographs	-0.497***
	(0.007)
Prints & multiples	-0.808***
	(0.006)
Sculpture	0.391***
	(0.007)
Works on paper	-0.327***
	(0.006)
Eastern Europe	-0.347***
	(0.012)
Northern Europe	-0.053***
	(0.007)
Southern Europe	-0.086***
	(0.008)
Western Europe	-0.099***
	(0.006)
Log of size	0.241***
	(0.001)
Observations	418,504
R-squared	0.483
Year Effects	Yes
Season Effects	Yes
Auction house Effects	Yes

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
This sample includes contemporary artists only.
The above 40 is a dummy variable that equals one if the artist is above 40 years old at the time of the transaction.
The base category for the object type is paintings.
The base category for the region is North America.

TABLE A4.6: Summary statistics- Auction house estimation error

	mean	median	sd	no. undervalued artworks	no. overvalued artworks
Male artworks	2.43	1.03	328.7	1,229,644 (47.8%)	1,068,275 (41.5%)
Female artworks	1.78	1.05	126.7	52,931 (50.5%)	42,444 (40.5%)

The estimation error is defined as the artwork sales price divided by the mid-point of the auction house pre-sale price estimate.

TABLE A4.7: Artwork level OLS regression results - price scaled by estimate

Variables	Ratio nominal price to action house pre-sale estimate				
	Pooled	Old Masters	Modern	Post War	Contemporary
Female	-0.667	-0.085	0.458	-1.777	-2.268
	(1.070)	(2.116)	(1.932)	(2.453)	(2.764)
Design	2.915***	-0.353	4.617***	5.109***	-4.058
	(0.907)	(1.670)	(1.597)	(1.956)	(3.531)
Photographs	0.043	-0.151	0.794	-0.783	-0.505
	(1.036)	(2.573)	(2.081)	(2.373)	(2.538)
Prints & multiples	0.905	-0.348	2.055*	0.157	-0.278
	(0.654)	(1.278)	(1.203)	(1.572)	(2.262)
Sculpture Sculpture	0.952	0.229	1.787	-1.092	1.279
	(0.935)	(1.610)	(1.963)	(2.051)	(2.755)
Works on paper	0.212	-0.160	0.616	-0.473	-0.600
	(0.609)	(0.917)	(1.111)	(1.601)	(2.285)
Eastern Europe	1.383	-0.131	2.823	-0.712	-0.697
	(1.235)	(1.891)	(2.037)	(3.311)	(4.501)
Northern Europe	0.084	0.448	-4.825***	1.680	3.668
	(0.841)	(1.408)	(1.753)	(1.919)	(2.641)
Southern Europe	0.055	0.040	-0.875	-1.158	-0.712
	(0.880)	(1.939)	(1.637)	(2.068)	(3.093)
Western Europe	0.439	0.011	0.887	-0.724	-1.083
	(0.686)	(1.185)	(1.329)	(1.613)	(2.345)
Alive	1.060**			-1.356	
	(0.529)			(1.162)	
Log of size	-0.232	0.086	0.035	-1.200***	-0.335
	(0.148)	(0.265)	(0.289)	(0.350)	(0.507)
Observations	2,434,732	479,566	772,853	515,204	392,850
R-squared	0.001	0.000	0.003	0.001	0.004
Year Effects	Yes	Yes	Yes	Yes	Yes
Season Effects	Yes	Yes	Yes	Yes	Yes
Auction house Effects	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
The base category for the object type is paintings.
The base category for the region is North America.

TABLE A4.8: Artwork level OLS regression results – mega transactions

Variables	Log of real price			
	All	All	Contemporary	Contemporary
	Only mega transactions	Excl. mega transactions	Only mega transactions	Excl. mega transactions
Female	-0.184***	0.046***	-0.179**	-0.053***
	(0.033)	(0.004)	(0.073)	(0.007
Design	-0.317***	-0.192***	-0.316	-0.146***
	(0.068)	(0.003)	(0.250)	(0.009)
Photographs	-0.333***	-0.627***	-0.361***	-0.445***
	(0.074)	(0.004)	(0.075)	(0.006)
Prints & multiples	-0.265***	-0.869***	-0.350***	-0.759***
	(0.060)	(0.002)	(0.131)	(0.006)
Sculpture	-0.028	0.318***	0.050	0.385***
	(0.022)	(0.003)	(0.041)	(0.007)
Works on paper	-0.229***	-0.381***	-0.315***	-0.300***
	(0.025)	(0.002)	(0.081)	(0.006)
Eastern Europe	0.004	0.021***	0.058	-0.337***
	(0.034)	(0.004)	(0.146)	(0.011)
Northern Europe	0.076***	-0.256***	-0.101**	-0.052***
	(0.025)	(0.003)	(0.045)	(0.007)
Southern Europe	0.136***	0.142***	-0.268***	-0.078***
	(0.022)	(0.003)	(0.064)	(0.008)
Western Europe	-0.281***	-0.368***	0.197***	-0.104***
	(0.019)	(0.002)	(0.041)	(0.006)
Alive	-0.487***	-0.397***		
	(0.005)	(0.004)		
Log of size	0.084***	0.169***	0.096***	0.228***
	(0.005)	(0.001)	(0.012)	(0.001)
Observations	15,881	2,661,309	2,270	416,234
R-squared	0.095	0.410	0.138	0.472
Year Effects	Yes	Yes	Yes	Yes
Season Effects	Yes	Yes	Yes	Yes
Auction house Effects	Yes	Yes	Yes	Yes

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Mega transactions are defined as transaction above $1,000,000 in real 2017 USD.
The base category for the object type is paintings.
The base category for the region is North America.

Chapter 5

Conclusion

This dissertation used the art market, an industry characterized by a high level of product heterogeneity, as a testing ground to investigate how intermediaries exploit information asymmetries to extract profits and generate a persistent competitive advantage. Furthermore, it provided insights into the extent to which uncertainty with respect to the quality of artworks limits the mobility of historically underrepresented market participants who are subject to larger information asymmetries due to their group belonging based on their gender. Focusing on the interaction between information asymmetries, prices and the behavior of agents, the thesis contributes to a deeper understanding of the sources and impact of informational advantage in markets that are subject to uncertainty about the quality of a good, the value of experts and the extent of inequality for underrepresented groups in these industries.

To briefly summarize, chapter 2 focused on expertise as a source of informational advantage. It studied the evolution of the art dealer profession over a time period of over a century, during the emergence of the modern art market in 19^{th} century in London. It was shown that entry into the market coincided primarily with the intensity of the current trading activity of dealers and was deterred by increased competition. Furthermore, access to buyer and seller identities made it possible to observe the individual acquisition strategies that were used at auction to replenish dealer inventories. It was shown that dealers who accumulated a larger amount of expertise paid higher prices at auction controlling for artwork characteristics. The fact that these dealers could sustain a longer market presence lends support to the conjecture their expertise helped them form more precise signals on the value of the

artworks. It appears that the size of the premium paid at auction can be regarded as a proxy for the value they created as experts by lowering information costs for their clients. Chapter 3 focused on the informational advantage that arises from a network and took a closer look at the position of art dealers within the nexus of other buyers and sellers. Using Bayesian methods and network measures, it was found that an art dealer's likelihood to link to a seller increased with the size and depth of his network as well as with a higher degree of homophily between the agents. In addition, it was shown that a larger and deeper network exacerbated informational asymmetries across buyers, leading to higher profits due to lower prices, and facilitated longer market presence.

Overall, these two studies shed some light on how intermediaries who are active in a market characterized by uncertainty are able to exploit their informational advantage to extract larger profits. A limitation of these studies is the absence of a perfect proxy for artwork quality. While a large number of artwork and transaction characteristics commonly used in the art economics literature which explain a large amount of variation in prices was controlled for, the possibility that unobserved quality attributes lead to differences in the prices paid by different dealers cannot be excluded. One way to control for quality would be to use auction house pre-sale estimates that are commonly printed in auction catalogues prior to sales, but these were only institutionalized in the 1970s. Furthermore, data on the resale prices paid in the private dealer market is not available. As a result, the size of the profits dealers were able to extract from their auction acquisitions could not be quantified. To further advance art market research it would be crucial to gain more insights into the private businesses of art dealers which account for about 63% of sales within the art market (Pownall, 2017). However, this would require art market intermediaries to shift away from current practices that shield sales data from the public towards more transparency. Another interesting avenue for future research would be to investigate whether the influence of experts decreases with a larger amount of public information and more possibilities for cost-efficient self-representation for artists that came about with the emergence of social media.

Chapter 4, shifted the focus from art market intermediaries to the producers of art and tested whether the belonging to an underrepresented group can constitute a disadvantage when information asymmetries are present. In particular, the chapter analyzed whether there is a difference between the performance of female and male

artists in terms of prices achieved at auction. For this analysis, the entire population of fine art auction transactions for Western artists for the period between 2000 and 2017 was employed. It was documented that female artists were highly underrepresented at auction with a share of less than 5% in terms of sales value and volume with an increasing trend for younger generations of female artists. However, it was still found that art dealers tended to represent a higher proportion of male artists compared to female artists, despite an equal distribution of men and women graduating with fine arts degrees. Furthermore, it was shown that conditional on gallery representation, female artists were less likely to progress onto the auction market, which represents the secondary market, and is a sign of market recognition. The study provided evidence of an average price premium for artworks by deceased female artists and a price discount on artworks by contemporary female artists, suggesting that uncertainty about artwork quality might be driving the results. Lastly, it was shown that there was no single female artist traded at the superstar league of the market where 40% of revenues are still concentrated.

These results provided a snapshot of the current state of the art market with respect to gender equality, and can be used as an important input by regulators and art market institutions to design initiatives that help restore gender balance in the industry. One limitation of the study is that demand and supply explanations for the observed differences in performance for female and male artists cannot be disentangled. While the imbalance in artist representation in the primary market suggested that intermediaries might be partially responsible for female artists' lack of exposure to collectors and discriminate against women at the hiring stage, the discount for contemporary female lots at auction pointed to a demand side explanation. It is therefore important for future research to disentangle these two narratives. It is crucial to detect the leak in the pipeline where the attrition of women from the profession occurs and whether there is indeed a systematic bias among intermediaries or collectors. Moreover, analyzing purchasing patterns of different buyer types (whose identities remain undisclosed in both the private market and at auction) is also valuable for gaining insights on whether preferences are driving the difference in performance.

To conclude, the main findings of this thesis stress the importance of experts in settings of high uncertainty. Building up expertise yields considerable power and enables intermediaries to have more accurate price estimates and a higher chance of

survival in the market. Furthermore, a large and deep network with other market participants facilitates preferential access to information, improving conditions of exchange in the form of lower prices and a sustained market presence. Market structures that emerge from such dynamics result in a small number of very powerful intermediaries and persist over long periods of time. Additionally, with respect to the mobility of underrepresented groups, the thesis showed important divergences between the dominant group and the minority group. This suggests that industries characterized by large information asymmetries and high competition for ranks and profits, disadvantage groups who have historically been excluded from the market and for whom information is more costly to acquire.

"Die Wahrheit ist eben kein Kristall, den man in die Tasche stecken kann, sondern eine unendliche Flüssigkeit, in die man hineinfällt."

Robert Musil, *The Man Without Qualities*

Chapter 6

Research Impact

For academic research to be valuable it must produce results that can be translated into implications that are relevant for the economy and society at large. In this section, I will highlight the general implications of my findings and provide suggestions for implementable measures.

The art market and the creative sector as a whole are growing economic sectors. According to the Tefaf Art Market report (Pownall, 2017), the art market reached a global size of $45 billion in 2016. This is an increase of 1.7% compared to the previous year. Furthermore, in 2017 it exhibited the largest investment growth among luxury goods. Currently, the asset allocation of Ultra-High-Net-Worth-Individuals (UHNWI) to collectibles is $1.62 trillion with an increasing trend (Bailey, 2018). Moreover, in the United States, art and cultural production contributed a total of $764 billion to the nation's economy in 2015. This represents a share of 4.2% of its GDP ("Americans for the Arts", 2017). In the European Union, employment in the cultural industry amounted to a share of 3.8% in 2017 ("Eurostat", 2017). In the Dutch local economy, it reached a share of 17% for the city of Maastricht and 13% for the Netherlands as a whole with a growing trend since 2009 (Pownall, Duivenvoorden, & Gertsberg, 2018). These statistics highlight the growing popularity of art among investors and the general importance of the cultural and creative industries for the economy. Demystifying the art market is important in order to stabilize and justify investment strategies of individual investors and governments.

However, when putting these numbers into perspective and comparing the art market to other alternative investment assets such as the real estate market ($8.5 trillion in 2017) (Bert Teuben, 2018) or to the market capitalization of a company like Google ($841 billion) ("Yahoo Finance"), shows that it is relatively small. Art is still regarded more of a passion investment and dries up when the economy slows (Sullivan, 2019). Similarly, while the production of cultural output has substantial positive externalities, government funding for the cultural and creative sector is oftentimes the first budget to be cut when austerity measures are implemented as it was now the case three years in a row in the United States (McGlone, 2019).

This thesis provides valuable and novel insights on the institutional structures and dynamics that are at work in the art market and that are potentially responsible for a market structure which impedes an acceleration of growth and efficiency.

The results illustrated in chapter 2 stressed the immense power of expertise. The richness and depth of the data employed is unique given the extent of the time period covered, and the availability of buyer and seller identities at auction, which typically remain undisclosed. It constitutes the first study to observe and analyze acquisition strategies of professional buyers in the art market. It was found that the art dealers who managed to accumulate a substantial amount of expertise were able to form more accurate value estimates and pay higher prices for artworks at auction, controlling for quality. Furthermore, the aggregation of high market shares and knowledge helped these dealers sustain a longer market presence. The data also provided evidence that three main dealers dominated the art market over the time period studied. The institutions in the art market and their role have largely remained the same until today. The findings of the study imply that in the art market, knowledge is very costly to obtain, and that information does not flow freely. Instead, it appears to be concentrated among a small number of large players such as top auction houses, prominent dealers and renowned museums. Their advantage over other players accumulates over time making it very costly for new players to enter and navigate the market. While this might be very beneficial for incumbents due to the higher profits it entails, such interlocked structures hamper the development of the industry as a whole. Therefore, one implication of these studies is that it should be an imperative for policy makers to attempt to reduce barriers to entry within the art market. This could be achieved by providing studios, workshops, meeting or practice rooms to local artists and entrepreneurs at affordable

prices. Creative work can often not be executed in private living spaces and specialized rental space can be very expensive particularly in gentrified locations where creative activity is clustered.

Chapter 3 examined in more depth on the network structure within the art dealer industry and the advt ages from access to propitiatory information. The findings highlight the importance of large and dense networks. Players located at the center of the network have preferential access to information, resulting in a better bargaining position due to more outside options as well as a longer market presence. Closely related to the findings in the previous chapter, these results suggest that information in the art market does not flow freely and is not equally distributed among buyers and sellers. Therefore, more efficiency could be achieved by breaking up existing network structures and dissolving small elitist circles. This could increase competition and dissipate profits. In particular, tacit as opposed to explicit information can be valuable in settings of high uncertainty. However, this is more likely to be shared within very close networks characterized by high-levels of trust. These relations need a long time to develop. It is important to prevent dynamics whereby isolated peninsulas based on status emerge. For instance, on a local level, international organizations such as Tefaf in Maastricht could be integrated into the city's cultural infrastructure and collaboration on a year-round basis should be encouraged. This might foster more trust and increase network diversity.

Chapter 4 shifted the focus from art dealers or intermediaries to the artists themselves. The results of this study have particularly important implications due the acuteness of the topic and the comprehensiveness of the data employed. The data set in the analysis comprises the full population of auction records for Western artist from 2000 until 2017, which had never been used for empirical research before. A current snapshot of the whole art market with respect to gender imbalances in terms of their performance at auction is provided. The results show that female artists represent a share of no more than 5% based on value and volume of sales. This share doubles for the group of contemporary artists. Overall, strong evidence for a systematic exclusion of women from the art market, which appears to have improved over time is provided. Given that women account for a 50% share of graduates from fine arts programs ("National Museum of Women in the Arts", 2017), it is shown that the attrition of women from the artist profession starts at a stage of gallery representation, where art dealers represent a disproportionately higher number of male

artists. Therefore, this study provides a small but rare and valuable glimpse of the practices of the primary art market.

The issue of gender inequality has recently received a lot of attention across various industries. The results of this dissertation contribute to a higher awareness about the prevalence of gender inequality in the art market. This work quantifies the size of the gap for different generations of artists and across various price segments. For policy makers who want to stimulate the industry with investments, it is crucial that the beneficiaries are not those who already have an advantage. For instance, municipalities could guarantee sales in galleries up to a certain amount for emerging underrepresented artist groups, to encourage art dealers to experiment more and increase the diversity of the artists they represent. Art dealers are profit-oriented businesses. In a setting of high uncertainty they may increase risk-aversion and overrepresent male artists as it might appear to be the safer choice based on past sales history. However, increasing the diversity of one's portfolio may reduce risk due to the benefits from diversification. The results of this study show that price discounts are most prevalent for contemporary female artists as opposed to already established deceased female artists. In order to reduce gender imbalances it might help to increase exposure to female art, in order to lower perceived higher information asymmetries for women.

Taken together, the studies presented in this dissertation provide answers to a variety of pressing question that are relevant for various stakeholders including investors interested in alternative assets, emerging artists, cultural entrepreneurs and policy makers on municipal and national levels within the area of the art market and the cultural and creative industries as a whole. Furthermore, this research can also provide useful insights for other industries that are subject to large information asymmetries, interlocked market structures and inequality.

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Biography

Marina Gertsberg was born in Charkow, Ukraine. She earned her BSc in International Business with a major in Finance from Maastricht University, the Netherlands. During her undergraduate studies, Marina spent a semester abroad at Universidad de Buenos Aires in Buenos Aires, Argentina. Before resuming with her graduate studies, Marina gained practical experience in Financial Consulting and Investment Banking. In 2014, she graduated with a MSc degree in International Business with specializations in Finance and Strategy & Innovation from Maastricht University. After graduation, Marina worked for one and a half years as a Management Consultant at Capgemini Consulting.

In 2015, Marina joined the Finance Department of Maastricht University as a PhD Candidate. During her doctoral studies, she was a research fellow at artnet New York. Marina conducted part of her research while attending Yale School of Management as a visiting assistant researcher. The main results of her research are presented in this dissertation.

Her work was presented at various universities and international conferences, among them Yale University, New York University, University of Sydney, Monash School of Business, Bucknell University, The Annual Meeting of the American Finance Association, The CEPR Summer Symposium, The Annual Meeting of the Financial Management Association, The Annual Meeting of the International Industrial Organization Association, The Annual Meeting of the European Association for Research in Industrial Economics, The Annual Meeting of the Computational and Financial Econometric Society, The Annual Meeting of the Cultural Economics Association and The Annual Meeting of the Southern Economic Association.

As of October 2019, Marina will join the Finance and Banking Department of Monash School of Business as Assistant Professor.

"Should we have stayed home and thought of here?"

Elizabeth Bishop